

PROPOSAL
CRP AND FLAGSHIP NARRATIVES

Livestock Agri-food Systems

CGIAR Research Program

Presented by the International Livestock Research Institute (ILRI) with :
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Science for a food secure future



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Proposal
Livestock Agri-Food Systems CGIAR Research Program
OVERALL AND FLAGSHIP NARRATIVES

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1.0 CRP Narrative

1.0.1 Rationale and scope

The Livestock Agri-Food Systems CGIAR Research Program (the Livestock CRP) will seize opportunities presented by rapid increases in demand for animal-source food in developing countries. The current suppliers of these foods are mostly millions of smallholder farmers, pastoralists and agro-pastoralists, together with the value chain actors who trade, process and deliver products to consumers. The program will provide research-based solutions to drive their transition to sustainable, resilient livelihoods and to productive small-scale enterprises that will help feed future generations. This will open up new business and income-earning opportunities in auxiliary services and subsectors. It will also improve local and global food and nutritional security and reduce poverty among poor households who keep livestock or contribute to livestock commodity systems, and enhance the environmental benefits these evolving smallholder-based systems can offer.

This transition is a significant opportunity to create a well-nourished, equitable and environmentally healthy world.

Why livestock in developing countries?

Demand for meat, milk and eggs is increasing rapidly and almost all the increase is in developing countries (see Figure 1.1; Robinson and Pozzi, 2011).

Over half a billion small-scale producers, the majority of them women, currently meet most of the demand for most animal commodities (Otte *et al.*, 2012).

90% of animal products are produced and consumed in the same country or region and at least 70% of livestock products are sold in informal markets (Roesel and Grace, 2014).

Such demographics of demand and supply open new, unprecedented opportunities:

- For small-scale producers and other livestock sector actors to play central roles in food and nutritional security;
- To transform livelihoods and rural economies in developing countries; and
- To make animal agriculture more environmentally sustainable.

The right enabling technologies, policies, markets and institutions will enable livestock systems to evolve to meet demand in economically viable, sustainable, equitable and healthy ways that reduce poverty and hunger.

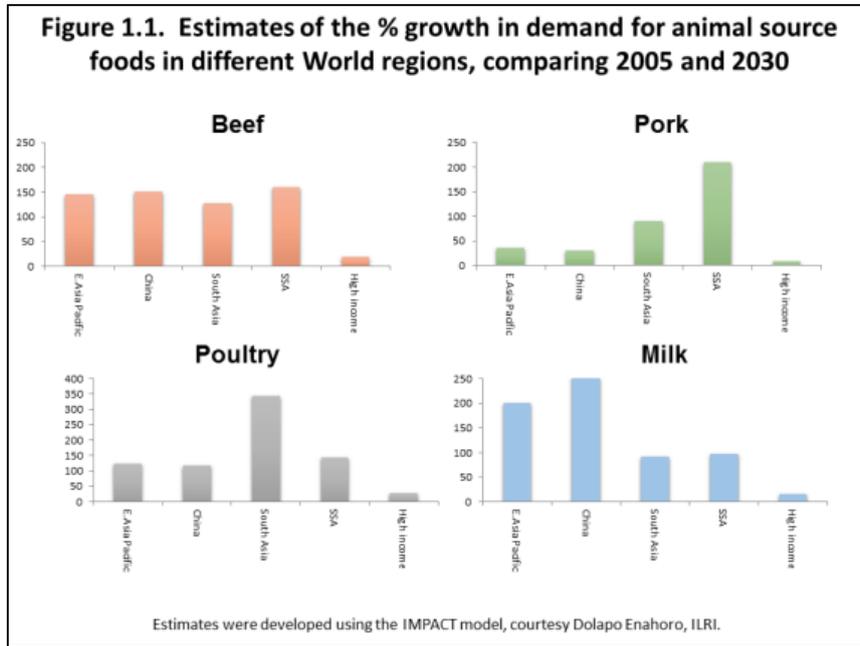
Paradoxically, compared to crop agriculture, and considering livestock is as much as 40% of agricultural GDP in many developing countries (see: World Bank, 2016; Behnke and Metaferia, 2011 for countries in the horn of Africa; [in India](#) it was over 25% in 2013) investment in the livestock sector by governments and development agencies is low, below 10% of total investment in agriculture (Pradère, 2014).

Why research on livestock in developing countries?

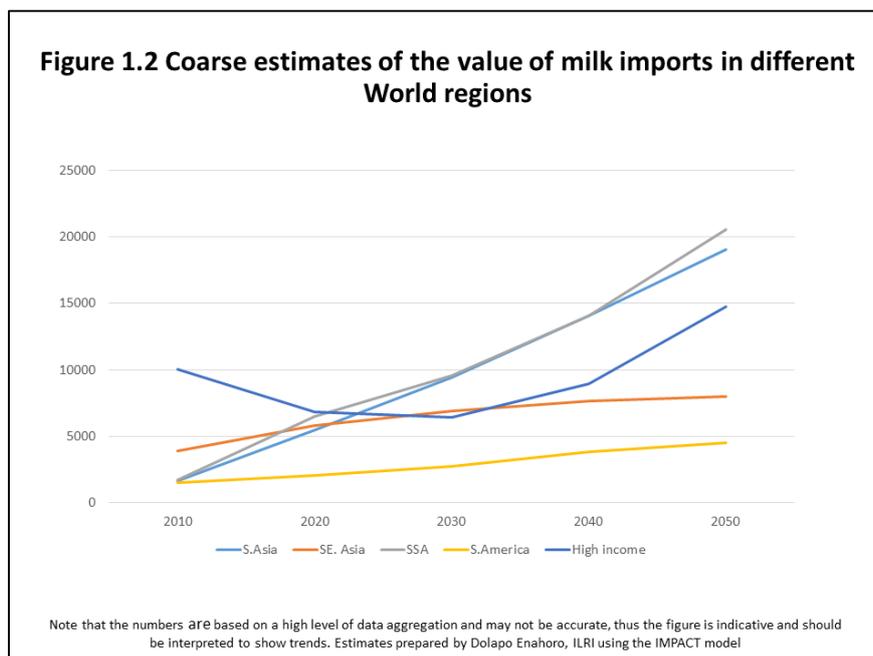
Livestock is the world's fastest-growing highest-value agricultural sub-sector (the top four livestock commodities are worth over USD 600 billion—FAOSTAT). It already accounts for about 40% of agricultural GDP globally (Pradère 2014), often much more in many developing countries.

A key trend is the fast-growing demand for animal-source food in consumer food baskets in the developing world as incomes rise. This is set to continue in coming decades, and will be pervasive across all livestock commodities and all developing countries (Figure 1.1). By 2050 milk consumption is likely to triple in east Africa, while the consumption of monogastric foods (pork and poultry meat and eggs) will increase at least four-fold depending on sub-region (Herrero *et al.* 2014). To date, the limited growth response of livestock production in developing countries is mainly due to the increasing

numbers of animals reared by small-scale producers rather than improvements in productivity. This trend is not sustainable because of the pressure it places on natural resources.



There has also been some expansion of industrial systems, especially for monogastric species. Overall, however, the supply response has not kept up with demand, meaning imports of livestock products have begun to rise in many developing countries. Africa’s total food import bill (some of which was intra-regional trade) in 2013 was USD 44 billion, one-fifth of which was livestock products (FAO 2014a). Such imports, initially anyway, can meet the increased per capita demand among middle- and higher-income urban populations, but it is unlikely to impact positively on the diets of lower-income and rural populations, especially women and children relying on local production. Moreover, meeting future demand by importing large quantities of animal-source food could present new and unwelcome challenges through high import bills, the economic sacrifices they impose, and the environmental and other costs of transport. Without major crop and livestock yield increases and resource-use



efficiencies for Africa and Asia in particular, import bills for animal-source food are predicted to rise significantly (Figure 1.2).

Looking ahead, three simplified scenarios (Box 1.1) describe how livestock supply and demand might evolve. Although a mosaic of the three scenarios is likely to emerge¹ and scenarios 1 and 2 are part of the context, the Livestock CRP will focus on the third, for three reasons. First, smallholders are currently a significant source of livestock products and that share can grow if they are able to integrate into markets, intensify production and transition to livestock as a business activity. Figure 1.3 shows that the lives of smallholders (often among the poorest people in rural areas) and livestock are often inter-twined in developing countries. Second, transforming these systems can meet growing demand; and help achieve several of the Sustainable Development Goals (SDGs). Third, applying its capacity to address the smallholder sector is fundamental to the focus of the CGIAR to achieve the SLOs.

Box 1.1. Hypothetical responses to growing demand for milk, meat and eggs in developing countries

Scenario #1: Meet demand by continuing to increase imports and responding to business opportunities. This relies on large-scale industrial enterprises, mostly located in developed countries, which would then export animal-source food to the developing world. Increasing imports of meat, milk and eggs mean high demands on foreign exchange, negative impacts on the sector's employment opportunities, and increased environmental footprint.

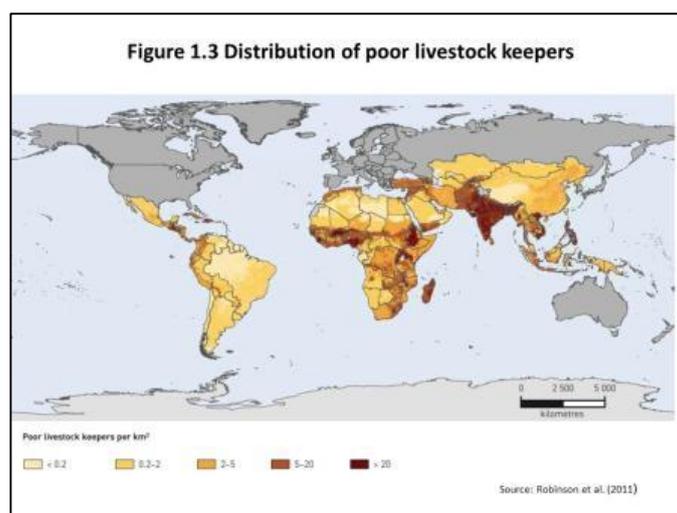
Scenario #2: Meet demand by importing industrial production know-how. Large-scale industrial units would be established in developing countries to produce in these 'milk- and meat-hungry' regions.

Scenarios #1 and #2 are likely to continue to varying degrees depending on different drivers and could have negative repercussions for national economies, urban poverty, small-scale producers and other small businesses, and the environment. They will continue to evolve and provide an important part of the livestock sector landscape.

Scenario #3: Meet livestock demand by transforming smallholder and pastoral livestock systems. Included here are increasing medium-scale commercial production, processing and trading opportunities which may be pursued by smallholders, but not reaching industrial scale.
Source: Smith, 2014

An assessment of future livestock demand scenarios in Africa indicates that most of the supply is likely to come from smallholder and agro/pastoral production systems for the foreseeable future in Africa (Herrero *et al.*, 2014) and Asia (Hemme *et al.*, 2015). Even in economies that are changing rapidly, such as Vietnam, 95% of pork comes from small- to medium-sized producers and even with optimistic investment, industrial systems are unlikely to play a significant role in meeting demand for several decades (Lapar *et al.*, 2012). Recent ISPC studies (Haan, 2013; ISPC, 2014) anticipate the dominance of the smallholder sector for several decades to come. The smallholder sector therefore offers the most compelling target for livestock research to achieve transformative impact in supporting the transition to vibrant agrifood enterprises and businesses for some and to a smooth transition out of agriculture for many, while using livestock-based strategies to improve and stabilize the livelihoods of others

¹ Indeed, it is already doing so in some cases: outcomes differ by commodity and region.



The role of livestock in meeting several SDG targets is recognized by national and regional policymakers. A livestock development strategy has been developed by the African Union Commission as part of the Comprehensive Africa Agriculture Development Programme (CAADP) agenda, setting the scene for investment in the sector (AUC, 2014). The Dairy Asia initiative articulates key roles for smallholders in the rapidly evolving dairy sector, noting the importance of livestock to address under nutrition (FAO, 2015). A recent high-level policy dialogue on investment in agricultural research in Asia and the Pacific concluded that 'Agriculture needs to focus on smallholder farmers'. In Vietnam the government has confirmed its policy to improve the efficiency of the smallholder sector for pig, buffalo, cattle and poultry production between 2015 and 2020 (Government of Vietnam, 2014). The Global Agenda for Sustainable Livestock brings together hundreds of actors from the global livestock sector, and through consultations over many years has identified three areas of focus which relate to livestock and the SDGs. ILRI's assessment is consistent with these areas. A synthesis from these various initiatives in relation to smallholders in developing countries is presented below.

Livestock and equitable livelihoods. Livestock make multiple contributions to the economic and social wellbeing of people in the developing world, providing highly nutritious foods, an income stream, assets against which to borrow, the primary source of organic fertilizer, energy for cultivation or transport, and a host of social functions (Moll *et al.*, 2007). Animals are a key asset in mitigating risk, especially in pastoral areas. In 2010 there were 752 million livestock keepers² living on less than USD 2 per day (Otte *et al.*, 2012), so increasing livestock productivity and resilience provide a unique opportunity to lift people out of poverty. Investing in women's ability to raise animals has significant livelihood potential, not least because women are far more likely to own animals than land. Many more people derive indirect benefits from livestock through, for example, trading, input supply, marketing and processing—and their incomes could also rise if the sector were to become more productive, creating additional jobs and business opportunities throughout the sector.

Many developing and emerging economies are addressing the role of the livestock sector in economic growth, and view livestock as potent instruments for **inclusive, sustainable growth**. Supporting intensification by enhancing equitable market participation offers opportunities that involve women and young people is an important strategy to enable smallholders and other poor producers to professionalize their livestock enterprises, develop small-scale businesses and respond to increasing demand with concurrent livelihood benefits, thus supporting inclusive growth. This must be

² 'Livestock keepers' includes all individuals, groups and others who keep or produce livestock for different purposes, including pastoralists.

underpinned by better livestock productivity through improved feeding, veterinary care and breeding to increase the supply, help keep animal products affordable and improve efficiency. All three areas are currently binding constraints in many parts of the developing world.

Food security and balanced, healthy diets. A transitioning smallholder sector presents opportunities for livestock to contribute to better nutrition and to address other dimensions of the animal-human health interface. Ensuring appropriate drug use will mitigate the emergence of antimicrobial resistance and will thus be important for human as well as animal health. Management practices that reduce food safety risks continue to be important as the sector grows.

The potential of animal-source food to enhance nutritional security of the poor is an opportunity not to miss as demand grows. Meat, milk and eggs in appropriate quantities contribute to healthy diets, reduce stunting, improve cognitive development and enhance inter-uterine growth (Lagrange, 2015; Gupta, 2016). Although empirical studies on the relationship between increased production and productivity and greater consumption of animal-source food are scarce, those that have been undertaken show both direct and indirect benefits of increased animal productivity for better household nutrition (Jodlowski *et al.*, 2016; Mergos and Slade, 1987).

Livestock and sustainable ecosystems. Small-scale systems are also strategic from an environmental perspective, not least because smallholder systems dominate where most animals are found, and are usually inefficient (Herrero *et al.*, 2013), and are thus strong candidates for efforts to ensure that animal agriculture is environmentally sound. Improving production efficiency in such systems could result in a 30% reduction in greenhouse gas emissions (Gerber *et al.*, 2013). Similarly, there are opportunities for integrated solutions that promote better waste and water management and conservation of biodiversity.

Small-scale production will not persist everywhere; there is much variation across countries and regions and across livestock commodities. As productivity rises in the sector a proportion of small-scale units are likely to become less competitive and a shift to larger-scale commercial production will likely result over time. Poultry, for example, may lend themselves to large-scale industrial units to meet urban demand, whereas dairy enterprises often remain competitive at the family farm scale (Sharma *et al.*, 2003). This tipping point has been or is being reached in some contexts, but is still very much the exception rather than the rule, and will remain so for several decades.

Considering the dynamic environments that set the context in which smallholders and others engaged in the livestock sector operate, the program's research was framed from three stylized trajectories for the livestock sector globally (see Box 1.2).

Box 1.2. Stylized trajectories for the livestock sector in developing countries

Rapid inclusive growth systems develop sustainable food systems that deliver animal-source nutrients to the poor while facilitating a structural transition in the livestock sector. Mostly, the transition is from many small-scale producers keeping livestock in low-productive systems to fewer households raising more productive animals in more efficient and intensive systems linked to markets. Such systems are likely to grow fastest in the near future. Mostly, this growth will occur in mixed crop–livestock systems, but some strong growth will also be in rangelands where appropriate market connections and sustainable productivity increases can be facilitated.

High growth with externalities will occur (and in some cases already exist) where dynamic markets, investment capital, infrastructure and skilled human resources lead to a rapid pace of change that often damages the environment and exposes communities to public health risks. This scenario, which could also be considered as one extreme of rapid growth, at times limits participation of the poorest livestock keepers and other value chain actors. It thus demands incentives, technologies, policies, strategies and innovations that mitigate such risks.

Fragile growth systems are those where rapid, market-focused growth is unlikely. Where productivity is severely limited by harsh climates and scarce resources, or by weak institutions, poor infrastructure and limited market access, emphasis will be to enhance the contribution of livestock to the resilience of people, communities and the environment. Livestock-based livelihoods will be important to feed families and communities, and will be supported by the protection of assets and the conservation of natural resources. Opportunities to diversify will be pursued, also institutional innovations that buffer producers from shocks and reward them for protecting natural resources.

There can be movement in the trajectories over time. Moving from a fragile growth to a rapid inclusive growth trajectory can occur as access to markets improves and smallholders manage their livestock as commercial enterprises. Moving towards more fragile growth can occur when market pressures increase competition and intensify the system in ways that are not sustainable. The trajectories can also apply to distinct geographical areas, such as pastoralist zones and highland areas in the Horn of Africa. They can also be co-located within the same region or community and even in different years on the same farm.

Source: Modified from Smith *et al.*, 2013b.

The descriptions summarize and distinguish the principal sets of challenges that research must address. They were conceptualized at a high-level dialogue on the livestock sector and subsequently endorsed and refined by stakeholders during a series of regional consultations convened by ILRI in 2012 as part of the ILRI strategy development process.³ Each trajectory, with its set of challenges, spanning livelihood, food security, human health and nutrition, and the environment, can be associated with a different set of research objectives and approaches, contributing to SLOs.

1. The **rapid inclusive growth trajectory**, supports sustainable intensification as part of the development of efficient and effective agri-food systems that enhance the livelihoods and nutritional security of poor consumers, producers and others. The focus is on technical, institutional and policy innovations that increase productivity while mitigating adverse environmental impact, improving participation in markets and access to safe animal-source food for consumers. This has been the focus of the Livestock and Fish CRP.
2. The **high growth with externalities trajectory**, has been the focus of work on appropriate public health strategies for evolving small-scale livestock systems and the formal and informal markets associated with them (Roesel and Grace, 2015). CGIAR has addressed this primarily in A4NH with work on environmental issues, mainly on water quality and manure management, undertaken by WLE and CCAFS.
3. The **fragile growth trajectory**, addressed by current system CRPs researches the innovations needed to increase the resilience of livelihood systems that rely on livestock. These include technologies that protect and enhance livestock assets, such as vaccination strategies appropriate for backyard or pastoralist systems, or institutional innovations that secure the assets of the vulnerable, such as index-based livestock insurance schemes. Technical and institutional options for managing interactions with the environment are important in terms of both adapting to environmental change and promoting the sustainable management of ecosystem services (e.g. carbon sequestration) and land management.

³ Consultations covered a range of public-sector, non-governmental and private-sector stakeholders in West, southern and eastern Africa and in South and Southeast Asia. The [original consultation](#) was convened by the World Bank, FAO, OIE, Bill and Melinda Gates Foundation and ILRI. See also: Smith *et al.*, 2013b.

The Livestock CRP will focus on the first and third trajectories to organize and prioritize its livestock research for development across a spectrum of situations and opportunities facing the small-scale livestock sector in the developing world. The CRP consolidates much of CGIAR's livestock research, bringing together work from the Livestock and Fish CRP and the systems CRPs. Some externalities, in the second trajectory, will be better addressed through global integrating CRPs, e.g. public health in A4NH with an interface with Livestock CRP risk reduction work in the other two trajectories. Similar alliances are planned with the CCAFS and LDC CRPs.

The two trajectories offer a means to focus research on two sets of challenges—one related to supporting inclusive sustainable intensification and addressing nutrition and poverty through increased market participation, production, input services and better targeting of innovations, and the other to enhance the role of livestock in strengthening resilience, protecting livelihoods and improving nutrition (Table 1.1). Research outputs will often be relevant to both sets of challenges but will require different institutional mechanisms and partners. A vaccine for a neglected animal disease, for example, might be delivered commercially in a rapid inclusive growth setting but would need greater public sector intervention in a fragile growth setting.

Table 1.1. Examples of research activities, solutions and outcomes contributing to SLOs for the two priority trajectories.

Trajectory	SLO 1. Reduced poverty	SLO 2. Improved food and nutrition security for health	SLO 3. Improved natural resource systems and ecosystem services
Rapid, inclusive growth	<p>Combined with strategies to increase access to and participation in markets, increased livestock productivity raises incomes and creates employment (directly in production and indirectly in auxiliary sectors).</p> <p>Research results improve market performance to enable access to inputs, technology and growing output markets. Research also addresses marketing risks arising from poor access to markets and the perishability of livestock produce, and producers' responsiveness to the requirements of commercial livestock markets.</p> <p>Employment opportunities through development of small and medium enterprises, including those benefiting women and youth are explored.</p> <p>Increased productivity results from research on:</p> <ul style="list-style-type: none"> Improving the provision of livestock for genetically superior traits emanating from informed breeding programs that utilize the functional genome diversity found in indigenous and exotic breeds. Herd health and technical disease solutions with delivery mechanisms combined with other interventions such as including the private sector, how farmers, community animal health workers, private and public vets can engage often facilitated by innovative hub-type arrangements. 	<p>Much of the work on institutions, new market opportunities and productivity outlined under SLO 1 will also stabilise incomes, some of which will be used to purchase more nutritious foods thereby improving diets. Beyond this, specific research enhances access to animal source foods, for poor consumers, targeting women and children. Research ensures livestock products are available and accessible – including being affordable- to poor consumers.</p> <p>Animal source foods need not only to be available and accessible but also safe. Research on livestock health identifies new disease threats as systems intensify, as well as providing herd health solutions that mitigate against AMR.</p>	<p>Research targets increasing resource use efficiency and decreasing pressure on ecosystems, from innovations, policies and incentives that enhance environmental benefits and mitigate damage in systems that are becoming more commercial and intensive to meet the growing demand for livestock products.</p> <p>Institutional (including governance) and technical solutions harness positive environmental effects, such as contributions to biodiversity, soil fertility and carbon sequestration.</p> <p>Increased productivity resulting from research yielding improved breeds and their reliable delivery, prevention of losses due to diseases and improved feeds and forages contribute to resource-use efficiency with positive environmental implications.</p>

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	<ul style="list-style-type: none"> Increasing the quantity and quality of feed biomass, to smooth seasonal variability in production. Exploring opportunities for private-sector engagement feed production and processing, especially for small and medium-sized enterprises that will also result in income and employment opportunities, especially for young people and women. 		
<p>Fragile growth</p>	<p>Institutions and incentives that support robust livelihood options, often preventing ‘falling into poverty’ and research explores integrated approaches in system sites that increase resilience. Securing livestock assets is key in this regard, including options such as livestock insurance.</p> <p>Research addresses system optimization while exploring interventions to reduce risks to shocks. Integrated solutions ensure resilience and identify opportunities for greater livestock-mediated livelihood options, which may include payment for environmental stewardship.</p> <p>Research on livestock genetics, health and feeds also contributes to improved and, importantly, stable productivity in the face of varying climatic and other conditions and addresses:</p> <ul style="list-style-type: none"> Utilising and retaining functional genomic diversity to ensure resilience and the ability to continue adapting to new environmental challenges. 	<p>Constant access to animal source food for those in fragile environments requires not only stable production (as for SLO1) but concurrent efforts to ensure access to safe and appropriate quantities meat, milk and eggs at reasonable prices.</p> <p>Research enables integrated approaches focused on improving resilience and nutrition, with a strong gender and equity dimension.</p> <p>Assessments identify the animal health threats due to the emergence of new diseases because of climate change and the changing distribution of vectors.</p>	<p>Global environmental changes, including climate change, other pressures and changes in land use, exert pressure on the natural resource base and ecosystem services, putting livestock production and related livelihoods at risk. Primary challenges are: high variability of climates and environments, the loss of key ecosystem services, weak institutions for managing natural resources, undeveloped infrastructure and a lack of suitable policy to foster the development of better management.</p> <p>Research addresses opportunities to: build resilience to environmental shocks, increase livestock productivity by enhancing sustainable rangeland management and to support policies, institutions and incentive schemes that enhance environmental management.</p> <p>Research improves the utilization of rangeland feed resources, together with rangeland conservation and rehabilitation measures which often reverse land degradation and increase water-use efficiency.</p>

	<p>Delivery mechanisms for improved genetics are important.</p> <ul style="list-style-type: none">• Technical and herd health solutions for livestock health that includes products less reliant on a cold chain. Appropriate delivery supported by the public sector will enhance resilience by preventing the loss of livestock assets (e.g. Veterinary field laboratories). Use of telecommunications for recording diagnostic test results may contribute to mitigating disease and enhancing resilience.• Forage research that enhances resilience by reducing spatial, seasonal and inter-annual variations in biomass availability, which may cause significant losses of animals.		
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The Livestock CRP proposes to focus on the range of livestock research for development opportunities by grounding its research in focus systems and value chains. This will ensure that it is appropriately demand-driven and relevant, and demonstrates how it goes to scale and translates into impact. This includes improving productivity of smallholder livestock systems, with increasing emphasis on their associated agri-food systems, thus addressing both livelihood dimensions ('by' the poor) as well as rural and urban consumers ('for' the poor)—as endorsed by the recent independent external review of the Livestock and Fish CRP.

The CRP relates its production-consumption link to the definition, dating back to the World Food Summit in 1996, that food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. It thus considers the following testable hypotheses:

- Abundance of animal-source food from greater productivity will lead to greater availability of food, and with improved supply at lower prices.
- Improved access to animal source food for many rural producers means they will have the opportunity to consume more of such nutritious foods.

To create a well-nourished, equitable and environmentally healthy world through livestock research for development will require an adequate supply of animal source foods to rural and urban consumers, generating sufficient income to producers, (the vast majority of whom are currently smallholders), while securing the natural resource base.

Functioning markets with a vibrant private sector providing input services and value added, reliable supply of livestock commodities based on robust productivity operating in an enabling public policy environment are all pre-requisites for this to happen.

This framework drives the broad prioritisation of research the CRP will undertake. The exact balance and prioritization of activities and entry points across these three areas (markets, productivity, enabling environment) will depend on the specific constraints in the context of the livestock species, value chain, country etc. and are expected to change over time.

These three elements have been the subject of decades of livestock research by partners in the CRP as well as other research organizations, national systems and universities worldwide. The development impacts of such research have been questioned, thus the CRP needed to re-evaluate and prioritise such 'traditional' research areas. Such an analysis, drawing from the development and implementation of the Livestock and Fish CRP, various reviews and assessments of the CRP, a number of research for development projects and the ex-ante impact assessment study conducted as part of the present CRP among others, concluded that the three elements are interdependent and must be addressed together to achieve impact. They require 'packaging' of business-ready technical solutions with market and policy dimensions and critical attention to gender as integrated interventions to achieve scale.

Where large-scale transformational change in smallholder systems has been achieved, such as Operation Flood in India, smallholder dairy in Kenya, small-scale poultry in Bangladesh, small-scale pig production in SE Asia and initiatives of the public and private sector in Latin America to increase forage production, such an integrated approach has been key (Candler and Kumar, 1998; Costales *et al.*, 2007; Kaitibie *et al.*, 2010; Fakhru Islam S M and M A Jabbar, 2005). The program's theory of change (described below) therefore assumes this type of integrated approach with balanced attention to the three entry points is essential to achieve impact at scale.

Research on productivity drivers remains important because of the fundamental need to increase and stabilise over time the productivity of animal source agri-food systems. Underpinning gender-responsive technical research on livestock genetics, health and nutrition needs to deliver both short and longer term solutions to present and future biophysical and climatic challenges, and to address delivery pathways (ISPC, 2014).

When identifying priorities, it has therefore been important to ensure a balance of research on technologies for the three main drivers of productivity (genetics, health, nutrition), systems analysis to promote adoption and for prioritisation, and environmental dimensions, with a balance of discovery versus downstream work. While current priorities for livestock research have emerged from and been repeatedly endorsed or refined through multiple consultative processes, the need for a more objective, evidence-based and analytical approach is well recognized.

Globally, work is being undertaken to develop and apply an appropriate framework to guide prioritization for livestock research in line with the conceptually powerful crop yield gap analysis approach. This work focuses on the contribution of the three productivity drivers and is confirming (i) their inherent interdependency, meaning that addressing one alone can be expected to provide only limited incremental improvements in productivity, and (ii) that animal genetics, followed by health, provides the most significant potential gains for sub-Saharan Africa and South Asia, that they need good livestock nutrition for the benefits to be borne out and that environmental pressures must be factored in (Staal *et al.*, 2009).

Why should CGIAR invest in this?

This CRP's research will address the grand challenges outlined in the SRF (see Annex 3.10.1). Research to support the role of livestock in inclusive sustainable intensification and in enhancing resilience is consistent with the CGIAR mission. Indeed, CGIAR is uniquely positioned to lead global livestock research for development, having both the mandate to focus on the poor and the breadth of capacity to view the challenges and frame solutions within a systems perspective. It can also convene a range of partners working up- and down- stream from research through to development to deliver livestock based solutions.

The CRP is a good investment: it will generate a high rate of return to investment, estimated at USD 9 for every USD 1 invested which compares well with previous CGIAR economic impact reviews (Raitzer and Kelley, 2008). This results from an ex-ante impact assessment exercise conducted by ILRI in February 2016 (Annex 3.10.2). The exercise identified 21 research streams across the five flagships of the proposed CRP. It evaluated their contribution according to multiple criteria consistent with the SRF, including expected economic impact, contribution to poverty alleviation, environmental impact, inclusiveness, internationality of the problem, and contribution to capacity development. At least one research area in each flagship was ranked among the top third using a weight index of the criteria, indicating each flagship is a good target for investment in its own right. Also importantly, the assessment finds the proposed research to represent a healthy portfolio with a balance of higher and lower risk investments reflecting a mix of longer-term discovery science and shorter-term adaptive research and delivery. Details are in Annex 3.10.2.

1.0.2 Goals, objectives and targets

The goal of the Livestock CRP is to create a well-nourished, equitable and environmentally healthy world through livestock research for development.

The CRP recognizes that for livestock research for development to enhance the performance of livestock systems, five interacting areas need addressing: the genetic potential of the animals kept, their nutrition, their health, their interaction with the environment, and a range of surrounding socio-economic conditions. The latter is a broad topic that spans market opportunities and services, the part played by gender in allocating labour and sharing benefits, opportunities to improve livestock-based livelihoods, secure assets and enhance access to affordable and safe animal-source food, as well as the policies and institutions that shape producers' incentives.

Most of these areas have always been the basic components of livestock research, with two areas strengthened in the current program. The intersection of livestock with the environment—recognizing that the performance of livestock systems is threatened if interactions with the environment are not addressed alongside ensuring that the opportunity to mitigate environmental damage through livestock is not missed. Climate change is increasing the urgency of work in this area. The second is to recognize that if food and nutritional security 'for' the poor are to be addressed, the traditional supply perspective of agricultural research needs to be complemented by increased consideration of the consumer-demand side, and specifically of how livestock agri-food systems can better serve food and nutritional security.

Based on these five areas, to reach the ambitious goal, the program's objectives are to:

- Ensure that appropriate livestock breeds are readily available, affordable and widely used by poor women and men livestock keepers.
- Improve livestock health and health service delivery.
- Increase livestock nutrition by identifying, testing and delivering superior feed and forage strategies and options.
- Reduce the environmental footprint of livestock production across both rapid and fragile growth trajectories, while ensuring that livestock systems in target countries are able to adapt to global environmental changes.
- Maximize livestock-mediated livelihoods and resilience to risk among smallholder and pastoral producers and their communities, whilst enhancing availability and access to animal-source food for rural and urban consumers.

These objectives will be pursued through gender-focused research, integrated with capacity development and communication activities framed by the two priority trajectories—rapid inclusive growth and fragile growth. Each goal is the objective of one of the five flagships with the corresponding flagship outcomes relating directly to the sub-IDOs. They respond directly or indirectly to the intermediate development outcomes (IDOs) and, beyond these, to the three SLOs described in the SRF: reduced poverty, improved food security for nutrition and health, and improved natural resource systems and ecosystem services.

The SLOs are development outcomes that depend on the actions of many players, spanning public and private sector and ranging from producers and communities through to governments, development agencies, and the research community at national, regional and global scales. The outcome targets below (Table 1.2) represent the best estimates of the contribution the CRP and its partners can make to the achievement of the SLOs, by 2022. It also recognises that some contributions are in terms of

simple headcounts, e.g. technology adoption for SRF 1.1, while others focus more on the CRP contribution to reducing the levels or gaps, e.g. poverty reduction for SRF 1.2; productivity increases for SRF 2.1.

A mixed-method approach to estimations was used to obtain the 2022 outcome targets for the CRP at flagship level and as contributions to SLOs (PIM Table A). The methodology relies on expert-knowledge and literature-based estimates of expected form and quantity of change (e.g. % productivity increase) combined with quantitative assessment of target populations to be reached by 2022, using geographical adoption domains and beneficiary groups (Annex 3.10.3). The assessment includes all Livestock CRP priority countries and other locations where flagships will work in the next six years (Section 1.0.7). The exercise was carried out in parallel with the ex-ante impact assessment exercise (Annex 3.10.2) and aimed to capture synergies in specific key parameters for adoption domains and rates. The 2022 outcome targets rely on many partnerships and how they are expected to be achieved is the essence of the program's theory of change (ToC, see Section 1.0.3). Further, the CRP also recognises the importance of its specific targets for cross-cutting sub-IDOs, in particular gender, and how these will also contribute to achieving sub-IDO targets. It also highlights the importance of mobilization of large-scale development-focused projects that take technologies to scale, with current evidence and projects indicating this is realistic.

For each flagship outcome the geographical reach (livestock production system, Robinson *et al.*, 2011), the population type (e.g. poor people, rural population, livestock keepers etc.) and an estimate of levels of reach (e.g. 10%, actual number from current bilateral projects etc.) were used to provide the overall target. Some of the key assumptions were: where flagships work within the same target population it assumes beneficiaries are the same, i.e. no double-counting; include potential spill-over effect from direct beneficiaries to indirect, taken as 1:2 for technology adoption and 1:3 for livelihood opportunities outcomes, respectively; when aggregating to SLO level, account for overlap of target population between sub-IDOs that contribute to the same SRF target.

Average yield gains for SLO 2.1 incorporate the variation and differences in predicted productivity gains across species, production systems and intervention type. There currently remains potential for reasonably large productivity gains, through a combination of animal breeding, feeding and health for livestock species in the developing world, in particular for large and small ruminants. In translating income increases to estimated numbers of people exiting poverty as a result of this (SLO 1.2) the CRP considered current levels of poverty (headcount and gap) and the distribution of these across livestock keepers, the relative importance of each species to household incomes in a given production system and the target increases provided for the relevant sub-IDOs contributing to SLO 1.2.

More details on the methodology for calculation, assumptions, and data sources are in Annex 3.10.3.

Table 1.2. Summary of CRP livestock outcome targets contributing to elements of the SRF

SLO Targets 2022 / 2030	Alignment of Livestock CRP to SDGs	IDO / Cross-cutting IDO	Sub-IDO / Cross-cutting IDO	Livestock contribution indicators	Livestock Target 2022	Relative financial contribution (%) Using total budget minus CRP management
SLO 1: Reduced Poverty						
SRF 1.2 - 30 / 100 million people, of which 50% are female, assisted to exit poverty	Contributes to Goals: 1 – End poverty, 3 – Ensure healthy lives, 5 – Achieve gender equality, 8 – Promote economic growth and work for all 10 – Reduce inequality within and among countries	Increased resilience of the poor to climate change and other shocks	Increased household capacity to cope with shocks	No. people in rural livestock keeping households with increased resilience (3 countries)	44,666	2.1
		Enhanced smallholder market access	Reduced market barriers	No. people in livestock keeping households increasing their supply of livestock to the market by 15%, on average (7 countries)	68,887	5.1
		Increased incomes and employment	Increased livelihood opportunities	No. households with 15-50% increase, on average in total household income from livestock-related activities, including 25% increase, on average, in proportion controlled by women (9 countries)	1,867,135	13.0
			More efficient use of inputs	No. poor households efficiently using inputs through optimized feeding strategies, including rations and processing (11 countries)	2,147,329	5.9
		Total contribution to SRF 1.2 (only showing those 'lifted' out of poverty)				4,128,000 people
SRF 1.1 - 100 / 350 million more farm households have adopted improved varieties, breeds or trees, and/or improved management practices	Increased productivity	Closed yield gaps through improved agronomic and animal husbandry practices	No. households realizing productivity increase through improved feeding options & strategies, integrated herd health packages and/or genetically improved livestock (12 countries)	4,050,000	16.6	
		Enhanced genetic gain	No. livestock keeping households realizing increase in genetic gain through use of genetically improved livestock (5 countries)	840,000	3.6	

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			Increased conservation and use of genetic resources	No. livestock keeping households changing their practices based on adoption of policy & institutional arrangements by policy-makers and/or national research partners (4 countries)	1,629,000	4.5
Total contribution to SRF 1.1					6,519,000 households	24.7
SLO 2: Improved food and nutrition security for health						
SRF 2.1 - Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5%/year / <2.0 to 2.5%/year	Contributes to Goals: 1 – End poverty, 2 – End hunger 3 – Ensure healthy lives, 5 – Achieve gender equality, 6 – Ensure availability of water and sanitation	Increased productivity	Closed yield gaps through improved agronomic and animal husbandry practices	% increase in productivity through use of integrated herd health packages	Genetics: 5% (small ruminants), 20-25% (pig, cattle, chicken) ; Health: 3-10% (depending on species and country) ; Feed & Forages: 30%	
			Enhanced genetic gain	% increase in genetic merit	6-12% (small ruminants); 25-50% (pigs); 50-100% (cattle and chickens)	
			Increased conservation and use of genetic resources	See above	See above	See above
SRF 2.2 - 30 / 150 million more people, of which 50% are female, meeting minimum dietary energy requirements	10 – Reduce inequality within and among countries	Improved diets for poor and vulnerable people	Increased access to diverse nutrient-rich foods	No. poor people with increased access to more affordable, safe and nutrient rich animal-source foods (4 countries)	3,347,000	1.3
		Improved food safety	Reduced biological and chemical hazards in the food system	No. people in livestock keeping households experiencing 15% reduction in prevalence of zoonotic pathogens and applying rational use of antibiotics in the livestock food system (7 countries)	3,970,000	2.3
		Improved human and animal health through better agricultural practices	Reduced livestock and fish disease risks associated with intensification and climate change	No. people in livestock keeping households experiencing 20% reduction in morbidity and mortality of livestock and 25% reduction in disease control costs through early diagnosis of disease (10 countries)	4,256,000	10.6
		Total contribution to SRF 2.2				11,573,000 people

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SRF 3: Improved natural resources systems and ecosystems services						
SRF 3.3 - 55 / 190 million ha degraded land area restored	Contributes to Goals: 5 – Achieve gender equality, 13 – Take action to combat climate change 15 – Protect and promote sustainable use of terrestrial ecosystems	Natural capital enhanced and protected especially from climate change	Land, water and forest degradation (including deforestation) minimized and reversed	Area of land (ha) impacted by reduction in land and water degradation, no. direct & indirect beneficiaries (people) impacted (8 countries)	2,796,000	1.8
		Enhanced benefits from ecosystem goods and services	More productive and equitable management of natural resources	Area of land (ha) under more productive and equitable management of natural resources, and no. beneficiaries (people) (9 countries)	5,172,000	1.9
			Agricultural systems diversified and intensified in ways that protect soils and water	Area of land (ha) representing diversified and intensified livestock production systems in ways that protect soils and water, and no. beneficiaries (people) (9 countries)	2,546,000	1.9
		More sustainably managed agro-ecosystems	Increased resilience of agro-ecosystems and communities, especially those including smallholders	Area of land (ha) representing 10 % increase in agro-ecosystem resilience, no. beneficiaries (people) impacted (6 countries)	3,172,000	1.6
		Total contribution to SRF 3.3				13,686,000 ha
SRF 3.2 - Reduce agriculturally-related greenhouse gas emissions by 0.2 / 0.8 Gt CO ₂ -e yr ⁻¹ (5% / 15%) compared with business-as-usual scenario.		Reduced net greenhouse gas emissions from agriculture, forests and other forms of land use (also cross-cutting sub-IDO for Climate Change)	% reduction in GHG emission intensities from agro-ecosystems (Gt CO ₂ -e yr ⁻¹), no. indirect beneficiaries impacted (7 countries)	0.08 Gt CO ₂ -e yr ⁻¹ (2%)	2.2	
Cross-cutting: Gender and Youth	Equity and inclusion achieved	Gender-equitable control of productive assets and resources	No. women experiencing gender equity relative to their level of effort (i.e. labour) at household level in the use of, and control of income generated by, livestock related productive assets and resources (4 countries)	288,000	0.7	

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		Technologies that reduce women's labour and energy expenditure developed and disseminated	No. women with reduced labour and energy expenditure (5-10%) (12 countries)	8,651,000	10.8
		Improved capacity of women and young people to participate in decision-making	No. women and young people with Improved capacity to participate in livestock related decision-making (5 countries)	1,950,000	2.5
Total contribution to Cross-cutting IDO on Gender and Youth				10,889,000 people	14.0
Cross-cutting: Policies and Institutions	Enabling environment improved	Conducive agricultural policy environment	No. livestock keepers and other value chain actors reached by laws, rules and regulations that include pro-poor livestock mediated development (4 countries)	4,087,000	3.9
Cross-cutting: Capacity development	National partners and beneficiaries enabled	Enhanced institutional capacity of partner research organisations	No. organisations involved in CRP institutional capacity development	200 organisations	0.8
		Enhanced individual capacity in partner research organisations through training and exchange	No. people in partner organisations with enhanced individual capacity	2,500 people	3.1
		Increased capacity for innovation in partner research organisations	No. organisation with increased capacity to innovate	200 organisations	1.6
		Increased capacity for innovation in partner development organisations and in poor and vulnerable communities	No. organisations and poor people with increased capacity for innovation	150 organisations and 150,000 people	2.4

1.0.3 Impact pathway and theory of change

The CRP's theory of change (ToC) describes how increases in livestock productivity underpinned by technological interventions in livestock genetics, health and feeds combined with integrated solutions and enabling conditions (markets, policies, incentives) lead to SLOs (Figure 1.4a). Anchored in the research areas described above, it focuses on opportunities presented by small-scale production systems for a well-nourished, equitable, resilient, and environmentally healthy world over the coming decades.

The ToC is structured around the 'three spheres' concept, an outcome mapping tool developed by the International Development Research Centre (IDRC) (Ofir and Schwandt, 2012) that describes how the program is likely to affect change processes. The first sphere, of **control**, includes everything for which the CRP takes full responsibility and includes all outputs and engagement with partners and stakeholders. The sphere of **influence**, refers to the reaction the program expects to see as a result of its activities: how its 'close' stakeholders and others—next users—apply and/or respond to the program's outputs to achieve near-term or local development outcomes. The sphere of **interest**, includes the long-lasting changes to which the program contributes with a wide range of other actors. Here the program achieves widespread impact on the lives and livelihoods of its ultimate beneficiaries, thereby contributing to the IDOs and, through them, to the SLOs.

The program develops and deploys research-based solutions that will drive the transition of smallholder producers, value chain actors, consumers, pastoralists and agro pastoralists from near subsistence to productive small-scale enterprises and/or resilient livelihoods. It will enable livestock keepers to choose their destination—to contribute to the growth of the sector by becoming a profitable and professional small to medium-sized livestock business, to exit from agriculture with greater security than they would have had without the program's impact on their productivity and income, or to stay in the sector and enjoy livestock-based livelihoods that are more secure and sustainable but are unlikely to become more profitable (Dorward *et al.*, 2009).

Research outputs will derive from the five areas of research described above and in the flagship narratives. All five rely on enabling actions embodied in the cross-cutting themes of gender, youth and capacity development, in order to achieve impact at scale. The gender ToC is described below. The research solutions developed will reflect, and in some cases cut across, sets of challenges associated with the rapid inclusive growth and the fragile growth trajectories. The first set, associated with inclusive growth, will support sustainable intensification and address nutrition and poverty through increased input supplies, productivity and income, together with the generation of ancillary business opportunities. The second set, associated with fragile growth, will focus on enhancing the role of livestock in strengthening household and ecosystem resilience, protecting livelihoods and improving nutrition in poor households.

Being intentional about engagement with partners in all three spheres will result in **international public goods (IPGs)** in two respects. The first is through engagement and co-creation of technological and methodological breakthroughs through biophysical and social science research which are adopted and adapted globally. These range from new methodologies in vaccinology, to gender-based approaches to define entry points in pastoral systems. A second type of IPG will arise from the program's integrated work in focus systems and value chains, resulting in approaches widely applicable to livestock systems transformation beyond the program's work on the ground.

The research will also generate **local public goods** grounded in focus systems and value chains in priority countries (section 1.0.6). Work at these sites will demonstrate that research outputs can a) support inclusive, sustainable intensification of small-scale livestock enterprises and/or enhanced resilience of livestock livelihoods, as well as increase availability of animal-source food for the poor b)

be adapted to address national, regional and global priorities, individually or as integrated packages, and c) generate the expected benefits and be taken up by next users—national research organizations, national extension systems, international research organizations and development partners in the priority countries for broader impact.

Simplifying the complexity of different livestock commodities and systems of production, four domains describe in generic terms the next users of research outputs and the sorts of changes in behaviour and capacity targeted. More details are presented in individual flagship narratives (numbering the domains is for ease of reference, not reflecting priorities or sequence). All domains will operate in both trajectories, but the specific changes will differ.

1. In national and international research and development systems, technology and evidence are used because they provide solutions to specific problems. For example, through co-creation of solutions, national research organizations further test vaccines for their efficacy, while feed interventions address feed deficits. Combinations of interventions that transform livelihoods or promote resilience are applied and start to influence agendas. National partners adopt new methods and approaches for identifying solutions, while improving their infrastructure and the platforms that support their livestock research (e.g. through the individual and institutional capacity development initiatives of the BecA-ILRI hub and Mazingira Centre). Women's roles in productive and sustainable management of livestock enterprises and natural resources is integrated into solutions for rapid inclusive and fragile growth trajectories.
2. Consumers, markets and enterprises, private-sector actors use innovative gender-sensitive business models, for example to multiply and deliver improved genetic materials, feeds and forages and animal health inputs and services. Development partners work with private-sector companies to co-create small- or medium-sized enterprises some of which will target young people. Links between producer organizations, service providers and professional organizations improve through strong functional partnerships enabling market demand to influence producers who are able to respond to available opportunities.
3. Production systems, individual producers and communities make greater use of innovations and start to deploy enhanced skills and knowledge to improve the health and sustainability of their livestock enterprises and livelihoods, including access to animal-source food. They enjoy increased access to pro-poor, inclusive, sustainable and resilient options for managing livestock enterprises as a business or as sustainable assets that enhance ecosystem services in the rapid and fragile growth trajectories respectively.
4. Changes in policies and investments emerge, accelerating impact beyond program target beneficiaries and sites. Business enterprises use new planning and management models and governments engage with these to deliver services and products more efficiently. Improved policies and institutional arrangements increase equitable technology uptake and impact. Large-scale enterprises invest with governments and regional institutions to promote the use of inclusive and sustainable technology packages. Governments introduce incentives, underpinned by appropriate policy and institutional reforms, needed to persuade livestock keepers and other actors to take better care of the environment. Appropriate national and regional policy instruments and institutional arrangements improve competitiveness, inclusiveness and value addition in the rapidly growing trajectory, and enhance resilience of both people and the environment in fragile trajectories.

The research and (near) development outcomes will result in research influencing the selected sub-IDs (section 1.0.2), based on a number of assumptions (Figure 1.4b) and through specific actions, including enhancing opportunities for women and young people, increasing the capacity of next users

(and the CRP partners themselves) and innovative communications tools. Each flagship's ToC provides more detail.

Together with strategies to improve smallholder access to markets, increased livestock productivity raises incomes and creates employment, thereby contributing to reduced poverty (SLO1). While the number of farms may decline as people leave the sector, new income-earning and employment opportunities will arise in auxiliary sectors—such as supply of inputs, veterinary or processing services. Many of these opportunities will appeal to women and young people. However, a caveat also applies: policymakers must create a level playing field, preventing the sector from being hijacked by large-scale producers, and fostering advantages such as increased access to service and input provision. Opportunities for private sector investment in the growing smallholder sector will emerge if it remains competitive and exhibits adequate potential for profitability. Increased productivity, together with appropriate institutions and incentives also enhances resilience and thus reduces poverty (and the likelihood of falling into poverty) in fragile systems.

For both trajectories, a principal IDO is increased productivity, leading in turn to increased and more constant availability of animal-source food. To ensure availability to poor consumers, this needs to be combined with work on livelihoods and access to animal-source food, along with targeting women and children, thus contributing to improved diets and to improved food and nutrition security (SLO2). A key assumption underlying the achievement of this outcome is that the prices of livestock products, which are high-value foods for which demand is rising, will become and remain affordable for poor consumers. This is not generally the case at present, because limited increases in supply from imports and improved domestic production have not yet led to sufficient price reductions.

By increasing resource-use efficiency and reducing pressure on ecosystems, and by giving explicit attention to innovations, policies and incentives that enhance environmental benefits and curb environmental damage, the program will contribute to improved natural resource systems and ecosystem services (SLO3). This outcome will only be achieved if innovations are environmentally and economically sustainable and individual end-users apply new practices, technologies and other innovations responsibly, limiting externalities. Past research emphasis on productivity gains has not generally led to improved resource conservation—for example in rangeland management—it will be imperative to accompany such gains with incentives such as payments for ecosystem services or other mechanisms, together with fair but effectively enforced regulatory systems.

Cause and effect in livestock research and development is a complex matter, with many trade-offs between different objectives, many feedback loops and potentially, the risk of some unintended consequences. While there is reasonable certainty that some parts of this ToC will be borne out by the results, other parts may not. For instance, livestock products are one of only two commodity groups (the other is beta-carotene containing foods) for which the links between increased consumption and improved nutritional status are relatively well established. In contrast, the links between increased production and increased consumption are clearly a good deal more complex, with a risk that poor consumers may still lose out despite declining prices. This will require work with other partners, in the nutrition and welfare sectors, to make sure this outcome is avoided.

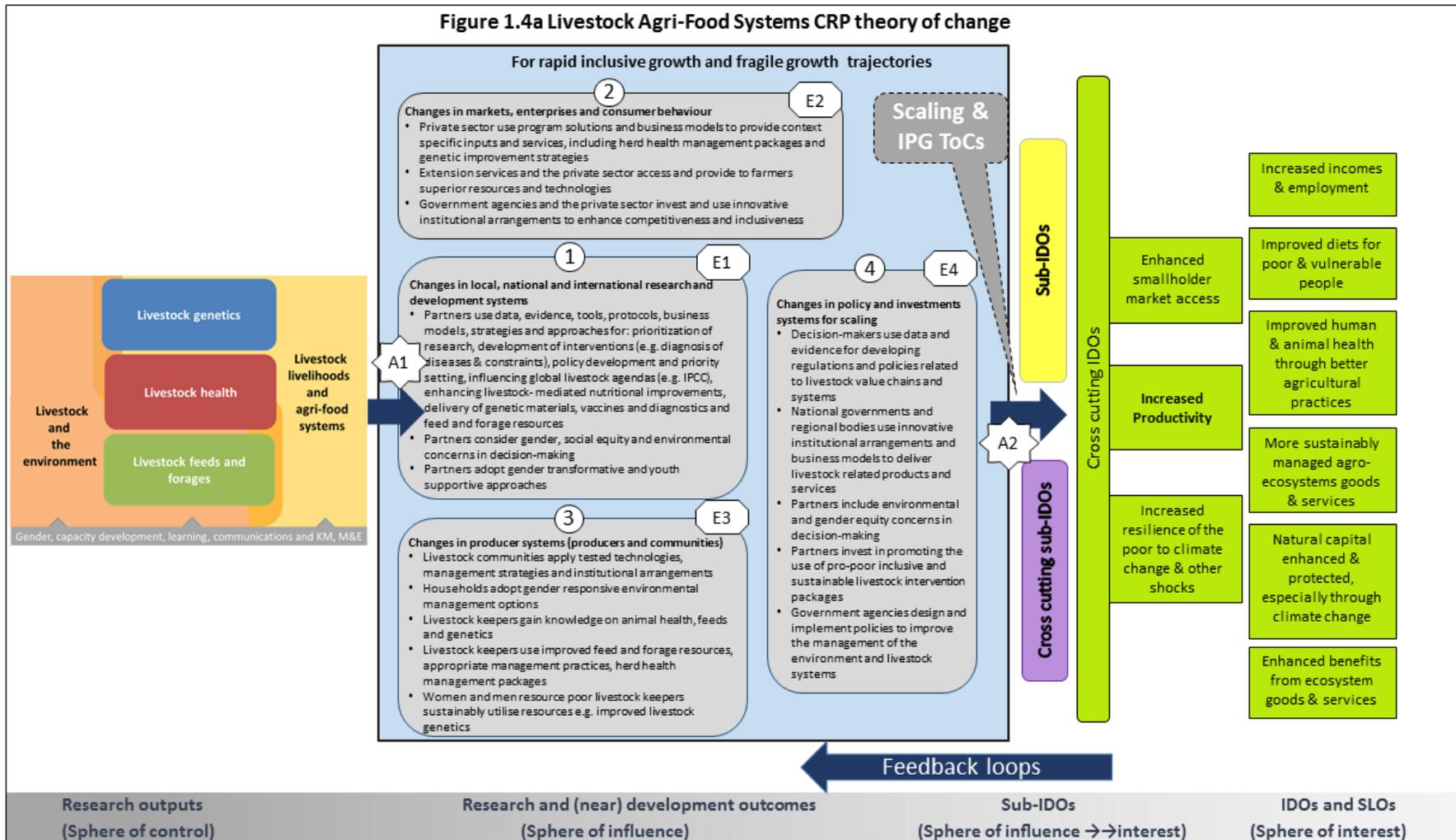


Figure 1.4b Livestock Agri-Food Systems CRP theory of change assumptions, enabling actions and change domains

A1 Assumptions		E1 Enabling Actions		
A1	1) Research and development partners support partnership development	E1	1) Design and delivery of innovative learning materials and approaches	
	2) Delivery systems and regulations are efficient and support effective and efficient delivery of innovations to partners		2) R4D actions informed by capacity needs assessments and intervention strategy design	
	3) Information platforms exist and support co-development of research outputs		3) Consideration of gender and youth issues in strategy assessments and setting	
	4) Partners are committed to promoting innovations to end users		4) Consideration of needs and preferences of women and men livestock keepers in development technologies	
	5) End users have adequate and robust safety nets to encourage change in behaviour		5) Consideration of gender and youth issues on policy and institutional arrangements	
	6) Strong and appropriate linkages between “next users” and “end users” exist		6) Enhance research and development partners’ capacity to innovate	
	7) End users have sufficient access to productive resources		7) Conduct a range of strategic organizational development activities with partners	
	8) Supportive services (e.g. market structures) exist and are accessible to end users;		8) Develop CRPs and Centres’ partnering capacities	
	9) Research and development partners are able, supportive and willing to invest in appropriate innovations & institutional arrangements		9) Consideration of environment issues in strategy assessments and development	
	10) Next users appropriately transfer innovations to end users		E2	1) Consideration of gender and youth issues on policy and institutional arrangements
	11) End users are willing to adopt tested innovations			2) Design and delivery of innovative learning materials and approaches
A2	1) Smallholder livestock sector exhibits adequate benefits to attract private sector investment	E3	3) Enhance development partners’ capacity to innovate	
	2) Smallholders remain competitive in the livestock sector		4) Develop CRPs and Centres’ partnering capacities	
	3) Research and development partners are able, supportive and willing to invest in innovative scaling strategies		E4	1) Consideration of gender and youth issues in strategy assessments and setting
	4) Innovations are socially and economically sustainable			2) Design and delivery of innovative learning materials and approaches
	5) End users appropriately apply innovations;	3) Enhance research and development partners’ capacity to innovate		
	6) Innovations are transferable beyond program geographical coverage;	E4	4) Conduct a range of strategic organizational development activities with partners	
	7) There is sufficient demand for livestock & livestock products		1) Build the capacity of extension and animal health workers to use the tools, advice and train livestock producers	
3 Domains of change				
1	Changes in local, national and international research and development systems	2	Changes in markets, enterprises and consumer behavior	
3	Changes in producer systems (producers and communities)	4	Changes in policy and investment systems for scaling	

1.0.4 Gender

The program's strategy for **gender-integrated research** and **strategic gender research** is described below and in Annex 3.3.

Gender in the Livestock CRP theory of change

Gender analysis in the CRP ToC is a necessary pillar for progress towards all three SLOs and a route towards gender equity. Livestock development has gender-specific challenges and offers opportunities for gender equity.

For both trajectories, the gender strategic component focuses primarily on the partner and policy domains of change (1,4) and will influence policy and decision-makers and development partners to create the institutional frameworks and development practices that favour the adoption of gender-equitable behaviours at community and household levels.

Evidence generated by the CRP will influence decisions on the benefits of including gender equity in governance frameworks regulating livestock development providing long-term structural incentives for gender equity at regional, community and household levels. Assumptions are that household and community members are able and willing to adopt gender-equitable behaviours promoted by policies and regulations.

The CRP will also influence and build the gender capacity of local and national development partners to adopt gender transformative approaches in their current and future development work. In this way, the CRP's gender findings reach communities and households, premised on the assumptions that gender transformative approaches have long-lasting impacts on gender-equitable behaviours, and women have the capacity and interest to take advantage of new gender equitable norms.

The Tanzania value chain exemplifies this approach from the Livestock and Fish CRP. Working with partners on the ground, gender dynamics and norms affecting equitable participation in the dairy value chain (technology adoption, access to services and control over resources) were assessed and used to develop gender transformative approaches which were then tested in selected households. The program also started assessing what policies affect equitable participation in value chains at intra-household level. The results of these assessments and evidence on the benefits of gender equity for overall livestock development will be shared with policymakers involved in the CRP work in Tanzania, known as '*Maziwa Zaidi*' ('More Milk' in Kishawili) and through them reach other key policymakers with the aim of fostering more gender equitable legislation. Partners are planning to utilize these approaches beyond this study.

The gender-integrated research cross-cutting the CRP flagships will support changes to the markets, enterprises and consumer behaviour and producer system change domains (2,3) by providing systematic integration and analysis of gender components in the design and evaluation of interventions and implementation strategies.

Research to date on the livestock–gender nexus

Gender analysis allows the constraints and opportunities that women and men face to be better understood, to inform interventions that support gender equality. To meet poverty reduction and productivity objectives, gender-responsive solutions are a non-negotiable necessity. Yet relatively little research has been conducted on gender and livestock to inform the development of such solutions (Kristjanson *et al.*, 2010; Kristjanson *et al.*, 2014). To address this gap the Livestock CRP builds

on research undertaken in the Livestock and Fish CRP, which identified critical gender dimensions of livestock keeping summarised here.

Shift in focus from ownership to control over benefits. Livestock are assets and a form of insurance that build the resilience needed to cope with shocks and adversity for many rural poor, especially women. Women are generally more vulnerable to poverty and shocks because they have less access to assets, credit, opportunities and space for decision making than do men (Njuki and Sanginga, 2013; Meinzen-Dick *et al.*, 2011; FAO, 2011). Unlike other productive assets that are usually controlled by men (e.g. land, machinery or buildings), women in many countries can own animals—particularly poultry and small ruminants—as well as their products, especially milk or eggs, and can usually keep the related income, which may be increased by processing (Njuki and Sanginga, 2013; Galiè *et al.*, 2015). Galiè *et al.* (2015) showed that the informal definition of ownership can provide opportunities for women’s control over livestock but also constitutes a constraint, entailing an increase in labour without commensurate income benefits, as men market the products and keep the cash. This study also shows that gender norms can undermine women’s control over livestock by preventing them from using livestock for productive purposes, such as ploughing or transporting. Beyond ownership, the Livestock CRP will focus on 1) ensuring that women control the benefits of livestock keeping; and 2) exploring the gender norms that influence control, resulting in better livelihood outcomes.

Livestock hold varied and gendered importance. Different species and related products have been found to have varied levels of importance for women and men, and for different categories of women (Njuki and Sanginga, 2013). For example, dairy goats in East Africa offer unique opportunities for women to control and have direct access to milk for household nutrition and to revenues from sales (Galiè and Kantor, 2016); but have limited market potential. Dairy cows in East Africa tend to be controlled by men, with women controlling milk, some of its revenues and, in some pastoral communities, the fields to grow forage (Galiè *et al.*, 2015).

The Livestock CRP, will integrate gender into priority setting for breeding, and understanding of the role of different breeds (including crossbred animals) by gender. The program will also explore how species can complement one another in building livelihood assets to enhance resilience, an activity also affected by gender dynamics. Livestock species diversity is often important as a risk management strategy, especially relevant for the fragile growth trajectory.

Re-negotiating obstructive gender norms. The Livestock and Fish CRP underlined the value of gender-sensitive participatory approaches in enhancing women’s self-determination and progress towards social transformation (Galiè and Kantor, 2016; Galiè, 2014). Promising empowerment pathways and other approaches are being developed in Tanzania and Ethiopia. These include social media, social platforms for discussing social constraints to technology improvement or adoption, and support for positive deviants—people who challenge and offer alternatives to the social norms that constrain women’s and men’s behaviours. The impact of such approaches is unproven as they are still in the early stages of development; although evidence shows that gender norms affect the effectiveness of technological interventions and the role of livestock for livelihood enhancement. The program will build on approaches shown to be effective elsewhere e.g. empowerment pathways (Galiè, 2013) and the use of social media.

Synergies between empowerment and nutrition. In the Livestock and Fish CRP, and beyond, evidence illustrates the critical role of women’s empowerment in enhancing the nutrition of household members. The potential of livestock to enhance household nutrition is realized through access to animal-source food, which is strongly associated with control over livestock, making such control a unique opportunity to empower women. The program will continue exploring the empowerment–nutrition interface in livestock development, applicable to both trajectories.

Gender dimensions of new institutional arrangements in value chains: Women tend to participate in the less lucrative livestock value chains and/or nodes of these value chains. The Livestock and Fish CRP explored new institutional arrangements in the value chains including, the ‘hub approach’ which had gendered impacts on access to milk and revenues (Omondi *et al.*, 2014; Rao *et al.*, 2015; Basu and Galiè, 2015). Access to livestock services (Farnworth and Colverson, 2015), and to innovation platforms (Mulema and Mazur, 2015) was found to be gendered. The Livestock CRP will continue to assess what institutional arrangements favour equitable participation in livestock value chains, particularly for the rapid inclusive growth trajectory.

Gender in the Livestock CRP

The Livestock CRP will enhance gender equality by adopting tailored gender equity strategies. Gender analysis contributes to the program’s goal through a nuanced understanding of the people involved in livestock rearing, their gendered needs, preferences, constraints and opportunities. This knowledge allows for the development of gender-responsive technological and institutional solutions that are a better fit and more relevant for the end-users. The Livestock CRP will build on the Livestock and Fish CRP’s experiences with gender-transformative approaches in particular, seeking to alter social and gender norms that perpetuate discrimination while harnessing and building on those that enhance equity (Kantor, 2013). The program will continue with and develop new, strategic approaches, including those applicable to the fragile growth trajectory. Gender-equitable technological and institutional innovation packages that enhance both the achievement of the SLOs and progress towards gender equality will be developed.

The gender strategy of the Livestock and Fish CRP integrated gender into technology development and enhanced gender equality and inclusion. It provided evidence on gendered needs, priorities, constraints and opportunities, and on gender dynamics that affect the adoption, relevance and impact of technologies and interventions. It supports the enhancement of gender-equitable control of productive resources and the participation of women and men of all ages in decision-making processes. The gender strategy will be updated to contribute to CGIAR’s three SLOs and the sub-IDOs on equity and inclusion.

Research on gender and social equity is intentionally a cluster of activities within the Livelihoods and Agri-Food Systems flagship. It addresses two specific sub-IDOs under this cross-cutting issue, namely: **Gender-equitable control of productive assets and resources;** and **Improved capacity of women and young people to participate in decision-making.** The second equity and inclusion sub-IDO, **Technologies that reduce women’s labour and energy expenditure developed and disseminated,** is directly addressed by each of the other flagships and indirectly by the support that the Livelihoods and Agri-Food Systems flagship provides on gender integration.

Gender-integrated and strategic gender research questions

Gender analysis has informed the gender dimensions prioritized and articulated in the flagship agendas (Annex 3.3). Strategic and integrated gender research are complementary rather than distinct categories: the strategic research is informed by the integrated studies and the integrated studies use concepts or test hypotheses from strategic studies. Gender-integrated research across the Livestock CRP will be informed, coordinated and synthesized through a portfolio of research activities supported by and undertaken with the Livestock Livelihoods and Agri-Food Systems flagship. Gender-integrated research specifically addresses the sub-IDO: **Technologies that reduce women’s labour and energy expenditure developed and disseminated.** However, the questions addressed will go beyond this sub-IDO to explore gender relations and how they relate to the technological and institutional research conducted by the CRP.

In particular:

- How does gender (in-)equality affect the technological and institutional solutions that are designed, delivered and studied?
- How do the technological and institutional solutions developed affect gender relations?

Strategic gender research will be undertaken to address three research questions which, together with the results of the integrated research, will contribute towards the program's delivery of the gender sub-IDOs:

- How are gender norms shaping the social and institutional context in which livestock systems develop and animal-source food are consumed?
- What transformative approaches to addressing gender-based constraints (in particular, restrictive gender norms and asset gaps) stimulate women's agency and strengthen empowerment pathways?
- What opportunities can be harnessed to create an enabling environment for equitable livestock-related livelihoods and for equitable access to, control over and intake of animal-source food?

The program will include both women-focused studies and women-pro-active interventions whenever these are needed to make progress towards gender equity. Women comprise a large proportion of small-scale livestock keepers and have arguably the greatest potential to reduce poverty, enhance food security and safety, improve intra-household nutritional status and contribute to environmental protection. Women play key roles in livestock systems and produce a significant percentage of the world's livestock commodities, despite being disadvantaged in terms of access to information, services, productive resources and opportunities (FAO, 2011). This renders women among the poorest livestock keepers and target beneficiaries for the program.

All gender research in the Livestock CRP will consider the interaction of gender with other social determinants (such as age, ethnicity, education, status and wealth) in all the program's components: tool development, research, implementation, monitoring, evaluation, and learning and capacity development. Strategies along the continuum from gender-transformative to gender-accommodative research will be included and all will 'do no harm', rather seeking to change obstructive gender norms, work within them or at least ensure that women's current situations do not deteriorate.

Gender work will engage with accommodative approaches whenever these provide an entry point to enhance gender-equitable development.

Staff and partner capacity

The Livestock and Fish CRP included coaching activities to enhance the gender capacity of non-gender scientists and partners mainly through collaboration with the Royal Tropical Institute (KIT). The enthusiastic response of scientists involved and the increased understanding as to how gender analysis can improve interventions and research relevance continue to support interdisciplinary collaboration. The Livestock CRP will build on this 'proof of concept' to further institutionalize gender and build staff capacity. It will build on engagement with Transition International to undertake a needs assessment of gender integration in interventions and capacity development of partners.

Additional gender staff will be recruited by ILRI to be able to respond to the increasing demands for gender integration throughout the program and strategic gender research initiatives. Collaboration with KIT will continue and deepen.

1.0.5 Youth

Individual flagship narratives each address youth and Annex 3.4 has further information on the program's youth strategy.

Addressing the challenges of a growing and often unemployed population of young people is a challenge that preoccupies much of the developing world. By 2050 there will be some 1.3 billion people under the age of 25 years, with most of them in Africa (18%) and Asia (60%) (FAO, 2014). In Africa today, some 70% of the young people are among those with a daily income of less than USD 2.00. The role of agriculture, including the livestock sector, as part of the solution to such a challenge is increasing in prominence (FAO, 2014; CCARDESA, 2015; the (IITA) Youth Agripreneurs), although the role for livestock in particular is rarely highlighted.

Achieving the aspirational outcomes of the Livestock CRP will only be possible if new approaches to engaging young people in the livestock sector are identified and implemented. An expanding livestock sector could in theory create exciting opportunities for young people and be especially effective in curbing rural to urban migration. With the increasing interest in the potential of agriculture to be part of the solution for the young generation, the role of livestock with the many business opportunities emerging in this rapidly growing sector is a new area for the CRP, and one that will be systematically developed. The importance of partnerships in this regard cannot be underestimated, and modalities to engage with the expertise at KIT, FAO, CTA, IITA, and IDS among others will be explored.

The main focus of the livestock CRP's research on young people will be on employment, entrepreneurship and capacity development. Its objective will be to design and implement interventions that will allow young people to build their future in livestock development and associated subsectors. Research will be implemented in the Livestock Livelihoods and Agri-Food Systems flagship, as well as featuring in specific ways in other flagships.

1.0.6 Program structure and flagship projects

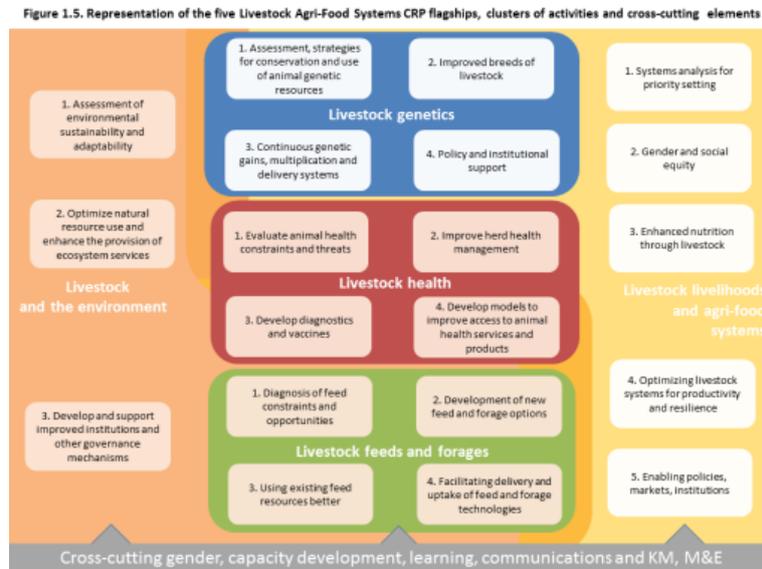
The CRP's objectives (section 1.0.2) will be addressed through five flagships:

- Livestock Genetics
- Livestock Health
- Livestock Feeds and Forages
- Livestock and the Environment
- Livestock Livelihoods and Agri-Food Systems

Research on gender, and on young people, will feature in each flagship with a strategic research agenda addressing issues of gender and social equity in the Livestock Livelihoods and Agri-Food Systems flagship. Capacity development, both capacity to undertake livestock research and to use research results is integral to the program's ToC as are innovative approaches to communication. To provide more focus, research in each of the flagships is framed to address the constraints and opportunities that typify each of the two major trajectories. For example, genetic selection objectives and strategies for delivery of genetic resources for intensifying production will be different from those for optimizing adaptation to harsh environments; feed interventions will differ, ranging from sown pastures and rangeland management to intensive feed production and processing; and vaccines will need different delivery routes.

Incremental improvements in production can be achieved through innovations in any one of the five areas, but given the high degree of interaction between them, successful livestock development often

requires an integrated approach and stepwise changes in the whole production system. For example, if genetically improved dairy animals are introduced, it will be necessary to provide better nutrition and health care as well as a market outlet for the increased milk produced, if the full benefit of the investment in genetic improvement is to be realized. The Livestock and the Environment flagship and the Livestock Livelihoods and Agri-Food Systems flagship will have particularly important integrating roles (see Figure 1.5) working with the other three ‘technology’ flagships.



The program’s approach also fosters such integration, and mirrors the Livestock and Fish CRP approach to focus and integrate its value chain work for particular commodities in priority countries, particularly for rapid growth trajectories. It will extend to selected sites where the Humidtropics and Drylands CRPs have worked on systems issues and apply a similar approach, focusing on the role of livestock within a systems perspective particularly aimed at enhancing resilience for fragile growth trajectories. Focus systems and value chains in priority countries—the ‘integrated field laboratories’ for the CRP are shown in Table 1.3.

The selected value chains are based on business cases developed for the Livestock and Fish CRP, or more recent major programs. Systems sites were chosen through the systematic processes of the Drylands and Humidtropics CRPs. At least three countries will have both ongoing value chain and systems work, offering efficiencies and synergies in terms of resources, as well as encouraging close interactions between the research strands on inclusive sustainable intensification and enhancing resilience. Beyond these, work in other locations will be undertaken to deliver research outputs in relation to particular flagship and cluster priorities, as well as the overall program portfolio. A good example of this type of research is that on poultry genetics, where the rationale for including work on species and locations not among the focus value chains and systems listed below includes:

- The Livestock and Fish CRP had not found a ready business case for immediately considering a focus on a pro-poor poultry value chain when it started given the perceived challenges of research improving on what existing commercial systems already offer, but had certainly not ruled it out, having committed to do more scoping work. Undertaking such a poultry genetics project provides that opportunity.
- The generational cycle for ruminants and pigs is fairly long, which considerably slows down the rate of genetics research. Thus, there are advantages of the much faster cycle with poultry to test different models and to speed up work on genetic approaches.

Further locations may subsequently be considered, identified and prioritized using the approaches from cluster 1 of the Livestock Livelihoods and Agri-Food Systems flagship.

Table 1.3. Summary of Livestock CRP focus systems and value chains in priority countries

Country	Value chain	System
Burkina Faso	Small ruminant value chain	
Ethiopia	Small ruminant value chain	Enhancing resilience in pastoral systems
India	Dairy value chain (TBC)	
Kenya	Dairy and beef value chains	Enhancing resilience in arid and semi-arid lands
Nicaragua	Dairy/dual purpose cattle value chain	
Tanzania	Dairy value chain	
Tunisia	Small ruminant value chain	Enhancing resilience in rangelands
Uganda	Pig value chain	
Vietnam	Pig value chain	Enhancing resilience in marginal, humid regions

A key lesson emerging from the Livestock and Fish CRP is that integrated work within a target site can only succeed if there are sufficient human and financial resources to implement the interdisciplinary model and bring the strengths of each flagship to bear. Given the current levels of human and financial resources in the priority countries, efforts to raise new resources for the currently under-resourced Nicaragua and Vietnam will be given precedence, with a similar approach for India and Burkina Faso subsequently phased in. In the absence of new resources, a fully integrated portfolio of research in these countries cannot be undertaken.

While all five research areas are essential for ultimate success, certain may hold more promise individually than others for generating returns to research investment in the longer term. To take this into account when deciding the relative level of effort to assign to each flagship, a rapid prioritization exercise has been undertaken to assess their relative impacts (see Annex 3.10.2). The exercise applied a weighted multiple objective ranking, including a standard returns-to-research model, to the proposed flagship areas of research, with the results informing the allocation of resources across the areas of research (see budget narratives). The results indicate the proposed agenda achieves a reasonable portfolio of outputs and outcomes targeted covering a range of those that are shorter term and lower risk through to longer term and higher risk. No clear outliers emerge at either end of the spectrum to guide a major reallocation of resources at this point in time.

1.0.7 Cross-CRP collaboration and site integration

At the CGIAR system level, key dimensions of partnership strategies relate to collaboration and integration with other CRPs and integration across sites.

For this CRP, six cross-cutting collaborative relationships will be important in addition to multiple links with other agri-food systems CRPs: with A4NH on issues of food safety, zoonoses and human nutrition (largely with the Livestock Livelihoods and Agri-Food Systems flagship and to a lesser extent with the Animal Health flagship); with FISH on animal-source food (also with the Livestock Livelihoods and Agri-Food Systems flagship) and on the joint technology research initiated under Livestock and Fish (with the three technology flagships); with LDC on production systems and productivity in the drylands (mainly with the Livestock Livelihoods and Agri-Food Systems flagships); with CCAFS on mitigation of

livestock emissions and engagement in global policy discussions (with the Livestock and the Environment flagship); with WLE on livestock and environment, particularly water (with the Livestock and the Environment flagship) and with PIM, on work to build livestock into IMPACT modelling in foresight and *ex-ante* impact studies and on value chain methodology development (all with the Livestock Livelihoods and Agri-Food Systems flagship) and on land tenure/property rights issues (with the Livestock and the Environment flagship). Annex 3.6 has details of these and other cross-CRP collaborations.

The CRP will contribute significantly to CGIAR site integration efforts, given its major engagement in five countries initially: two of the six Site Integration++ countries (Ethiopia, Tanzania) and two of the fourteen Site Integration+ countries (Uganda, Kenya), with intentions to strengthen engagement to two additional Site Integration++ countries (Nicaragua, Vietnam) and two more Site Integration+ countries (Burkina Faso, India).

CRP partners actively participated in recent site integration consultations and workshops in 7 countries. ILRI led the process in Ethiopia, ICRAF in Kenya, and CIAT in Nicaragua and Vietnam. The CRP is engaging with national partners and the other CRPs in these countries to explore how the systems work can be effectively integrated across CRPs in ways that respond to national agendas.

To further strengthen the CRP engagement in site integration activities, the CRP management budget will fund a portion of the salary and operational costs of a CRP country coordinator in each country, with modest resources for the CRP's contribution to site integration in each target country.

During the proposal development process, the team engaged with stakeholders and partners around the world to generate inputs and feedback on the proposal focus and implementation modalities. Insights from several CGIAR country/site integration workshops were fed back via centres that participated in each. Several Livestock CRP-specific face-to-face meetings were convened by CRP partners, and in a number of priority countries to introduce key elements of the proposal and provide an opportunity for feedback and inputs. Alongside the face-to-face discussions, an online space was set up to solicit inputs on the same questions (see Annex 3.10.4).

1.0.8 Partnerships and comparative advantage

The Livestock CRP's ToC (section 1.0.3) relies on a range of partnerships spanning local to global. Conventional scientific and AR4D partnerships will be key within the sphere of control; new partnerships that influence next users of research results and beyond are necessary for CGIAR to contribute better to wider impact-oriented innovation processes (Annex 3.1).

The program has three partnership objectives: (i) rationalize its role in a fast-changing landscape of scientific comparative advantage; (ii) building on efforts in first phase of CRPs to define catalytic roles in local value chain and systems innovation processes; (iii) contribute more directly to national, regional and global initiatives.

Objective (i) focuses on implementing research on specific problems especially by working closely with national counterparts to co-create research solutions. Examples also include new initiatives such as the recently established Centre for Tropical Livestock Genetics and Health—a consortium of the Roslin Institute, SRUC and ILRI; and a consortium on biological nitrification inhibition convened by JIRCAS. Private sector partners contribute cutting edge Intellectual Property and manufacturing capacity.

Objectives (ii) and (iii) aim to translate research into impact beyond the program's sphere of control. For (ii) work is largely at site level as in the Livestock and Fish and systems CRPs; it is exemplified by

novel partner alliances and stakeholder platforms in focus value chains, as described in the recent [external review](#) of Livestock and Fish. Work on particular value chains does not translate to an integrating and delivery mechanism for systems, so new modalities will be developed for the program's focus systems. The sphere of influence requires the program to engage with national and regional agendas and organizations such as FAO and Galvmed (the latter for vaccine delivery) and development agencies. Private sector actors, from medium-scale entrepreneurs to major commercial companies also feature here. Private sector actors, from small-to-medium-scale entrepreneurs to major commercial companies inform and pilot business-ready innovations, and are then critical in moving those innovations to scale beyond the program's sphere of control.

For (iii), work focuses on IPGs and will have high priority in the Livestock CRP. The program will also strengthen its engagement in regional and global multi-stakeholder platforms, such as [Dairy Asia](#), the [Global Agenda for Sustainable Livestock](#) and the [EAT Stockholm Food Forum](#).

The Livestock CRP partners relate to the partnership objectives, spanning biological to social sciences, research to development, and local to global issues.

The choice of Tier 1 and 2 CGIAR partners reflects the integration of CGIAR activities on livestock research. Tier 1 partners are: ILRI, with a core mandate on livestock and a robust portfolio of high-end biosciences research covering animal genetics, health and feed, and expertise in systems, markets, gender and policy research, livestock 'bads' and 'goods' for environmental and public health dimensions; ICARDA with work on animal breeding and rangeland systems; and CIAT with capacity in tropical forage and pasture research. Tier 2 partners are: ICRAF, with strengths in agroforestry, nutrient cycling and tree-based feeds; and IWMI, contributing systems perspectives at the nexus of livestock and natural resource management, particularly water. ILRI also brings the unique capacity development platform of the Biosciences eastern and central Africa (BecA)-ILRI Hub, co-created with the Africa Union New Partnership for Africa's Development and the Mazingira Centre for research on the livestock-environment nexus, the only centre of its kind in Africa.

Two non-CGIAR Tier 1 partners broaden research and innovation systems aspects. The Swedish University of Agricultural Sciences (SLU), has long collaborated with CGIAR and will address gaps among CGIAR partners and provide a link to developed world research and development networks. SLU's high-level policy commitments describe the positioning of its research and educational capacity to address global development challenges. The partnership with GIZ, the German development agency, goes beyond a technology delivery partner and originated in efforts by the Livestock and Fish CRP to integrate a development perspective into its research. Beginning with feeds, GIZ will help link the Livestock CRP directly into local and international development innovation processes. Wageningen UR will be a Tier 2 non-CGIAR partner building on its long history of collaboration on livestock research with the CGIAR and consistent with its mission to address global issues.

1.0.9 Evidence of demand and stakeholder commitment

As articulated above, livestock research for development is crucial. The exclusion of livestock could prevent CGIAR from achieving its goals and frustrate the achievement of the SDGs, barring countries and whole regions from fairer, more sustainable and healthier outcomes for people and the planet. Livestock research offers the potential to improve the livelihoods of almost one billion people, including the women and men of all ages who are small-scale producers, traders, processors and urban consumers. These are large groups of people whose activities matter for large areas of land: pastoralists, for example, are stewards of one-third of the earth's ice-free surface.

There is increasing recognition that the livestock sector has a vital role to play in sustainable development, albeit one that has hitherto been largely ignored. However, this is changing and demand

for livestock research to deliver relevant solutions are increasing. For example, the Ethiopian and Tanzanian governments recently requested ILRI to support a research-based prioritization of their livestock sector agendas. Similar requests have been received from the governments of Uganda and Kenya. And in Latin America, CIAT engages with national agencies on how forage-based livestock production can reduce greenhouse gas emissions. Through collaborative research with CIFOR, funded initially by CCAFS, ILRI is supporting the dairy NAMA (National Appropriate Mitigation Actions) that the ministry of agriculture, livestock and fisheries in Kenya is interested in developing. Seventy countries, mostly developing nations, mention the livestock sector in their Intended Nationally Determined Contributions submitted to COP21 (Richards *et al.*, 2015).

These initiatives are in addition to the many hundreds of working relationships already under way through the Livestock and Fish CRP and through the CRP partner institutions. These relationships, many of them ongoing for well over a decade and some considerably longer, testify to the strong and abiding national demand for an international research partner in such areas as livestock health, feeds and forages, genetics, and policy analysis.

At regional level, a livestock development strategy for Africa has been developed by the African Union Commission, as part of the CAADP agenda (AUC, 2014), with contributions from ILRI. This sets the scene for investment in the sector over the next decade. There is also a similar initiative for Asia. Major donors have recently put out significant calls for livestock research for development.

Livestock has featured on the world stage in the context of food security (see Economist).

Many of the CRP features were supported by participants in the face-to-face and on-line consultations described above. Key points are summarised below (see also Annex 3.10.4).

Participants supported the smallholder focus, which many considered to be an imperative not an option, recognizing the predominance of smallholders and their potential to be competitive, to evolve and engage in markets. There were also qualifications and concerns: The CRP should not ONLY focus on smallholders but remember other scales as well, such as pre-smallholder subsistence level and to ensure pastoralists are included.

The trajectories were appreciated and found useful. Participants stressed that the lines are blurred, trajectories should not be looked at independently nor framed as either/or, and that all will have externalities.

The program was encouraged to adopt inclusive participatory approaches, connecting well with extension and policy, and 'unpacking' notions around youth

Participants reinforced greater emphasis and support for capacity development and recognised it goes well beyond transfer of skills and knowledge at individual level. Capacity to undertake gender research was highlighted and the need to ensure women are not marginalised as systems transition stressed. Communications, should be multi-dimensional, community focused and employ diverse local information delivery systems, media, and ICTs and seek to influence the right people.

Different roles for public and private sector were sketched for the trajectories with the public sector role seen to support and allow the development of technologies for small-scale production (rapid growth) and flexible technologies for the drylands.

1.0.10 Capacity development

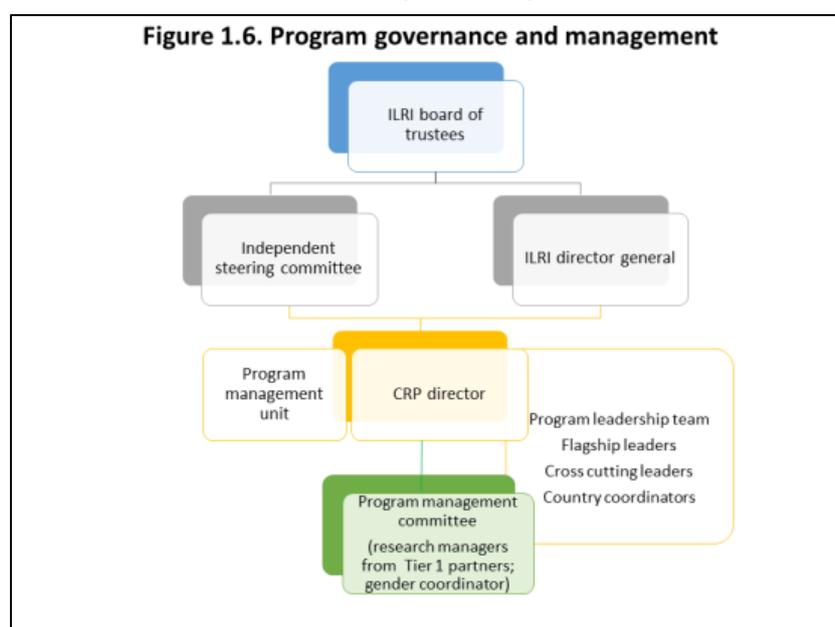
Capacity development role in impact pathway			
At CRP level, capacity development is identified as an enabler of the impact pathway, focusing on the ability of individuals and organizations to undertake research and use its results. This should result in accelerated progress towards IDOs and SLOs. At flagship level, analysis has been done, based on each flagship's ToC, to identify the key areas where capacity development will most be needed. This analysis has informed the strategic actions and budgets outlined below.			
Strategic capacity development actions			Please indicate any indicators that could be used to track progress and contribution to CapDev sub-IDOs
Intensity of implementation of chosen elements (Please indicate High, Medium, Low)	Give an indication of how chosen elements will be implemented		
1. Capacity needs assessment and intervention strategy design	High	All flagships will invest in detailed capacity needs assessments and intervention strategy design at the start of the CRP2 cycle, and when additional large projects come on board during the 2018-2022 period.	<ul style="list-style-type: none"> • (Adapted) needs assessment methodologies available in published form for each CRP. • Proportion of CRP flagships using capacity needs assessment methodologies. • Proportion of CapDev budget allocated to interventions consistent with capacity needs assessment recommendations (disaggregated by organization, CRP, flagship).
2. Design and delivery of innovative learning materials and approaches	High	Numerous projects across all flagships will produce training materials using instructional design expertise and harnessing cutting-edge learning technologies.	<ul style="list-style-type: none"> • No. of partner organizations using materials and approaches. • No. of training or learning events where the materials and approaches are used. • No. of people trained (disaggregated by sex, job/role, location, literacy). • Cost-effectiveness of materials and approaches. • Proportion of training events/workshops where knowledge and skills of participants increase significantly.
3. Develop CRPs and centres' partnering capacities	Medium	Some of the flagships (and especially the Livestock Livelihoods and Agri-Food Systems flagship) will invest in systematic efforts to identify and broker partnerships and to apply the resulting models as part of scaling up. One new area for the CRP could include alignment with business management in commercial agriculture, and partnering with the private sector.	<ul style="list-style-type: none"> • No. of assessments of suitability, capacity, and complementarity of potential partner organizations conducted. • No. of research outputs resulting from partnerships that are successfully scaled up. • No. of technologies/tools adopted across partner organizations.
4. Develop future research	High	There will be both 'traditional' MSc and PhD fellowships	<ul style="list-style-type: none"> • Amount of funding for fellowship programs • No. of fellowship places provided (disaggregated by level, gender, department).

leaders through fellowships		throughout the flagships and specific opportunities at the BecA-ILRI Hub (notably with the Africa Biosciences Challenge Fund fellowship program) and the Mazingira Centre (on a range of environmental and climate change issues). This area also builds on the many existing partnerships with higher education institutions in developing and developed regions.	<ul style="list-style-type: none"> • No. of scientific publications accepted. • Funding allocations for research programs involving returned fellows/post-docs.
5. Apply gender-sensitive approaches throughout capacity development	Medium	In partnership with the gender teams, ensure gender dimension is incorporated into capacity development activities throughout the CRP.	<ul style="list-style-type: none"> • Proportion of capacity needs assessments that proactively target women. • No. of capacity development activities in gender approaches/toolkits initiated (disaggregated by type).
6. Institutional strengthening	Medium	Several flagships will work to develop the capacity of decision-makers to use research outputs and to inform policy design and reform.	<ul style="list-style-type: none"> • No. of institutional assessments conducted with national programs. • No. of strategic plans for institutional strengthening formulated based on such assessments. • No. of policy-oriented knowledge sharing/training activities targeting human resources in national programs (disaggregated by focus—policy, technical) • No. of strategic plan recommendations implemented (disaggregated by agency).
7. Monitoring and evaluation (M&E) of capacity development	Low	The CRP will probably limit itself to the requirements of the CRP2 overall reporting, see Annex 3.2.	<ul style="list-style-type: none"> • No. of workshops/discussions organized on methods and reflections on outcomes of evaluations conducted. • Proportion of capacity development activities for which monitoring reports are produced.
8. Organizational development	Medium	Flagships that invest in this element will focus on strengthening boundary partners for research uptake, as part of a delivery/scaling up strategy. One example is the work of the BecA-ILRI Hub on upstream research and laboratory management, which	<ul style="list-style-type: none"> • No. of workshops or trainings provided on research management • Increase in funded research projects led by national programs and other partners • Increase in funded time for national staff for research planning, management and uptake activities • Implementation of incentive and reward system for engaging in uptake activities

		develops organizational capacities across Eastern and Central Africa, and aligning the CRPs work with national and regional research priorities (including the Comprehensive Africa Agriculture Development Program).	
9. Research on capacity development	Low	At this stage, specific research on capacity development is not a priority for the CRP.	<ul style="list-style-type: none"> • % of initiatives where implementers can show evidence of incremental improvement in course content and delivery. • Proportion of budget allocated to research on capacity development.
10. Capacity to innovate	High	Flagship projects will continuously identify and prioritize problems and opportunities, mostly through engagement with multi-stakeholder platforms.	<ul style="list-style-type: none"> • No. of groups and multi-stakeholder (innovation) platforms facilitated by CRP (disaggregated by gender, socio-economic status, organizational affiliation). • Composite index measuring rate and quality of group, platform or household experimentation with new ideas and technologies, including degree and source of innovation, quality of selection process and who is involved in making it.

1.0.11 Program management and governance

As the only CGIAR centre with a dedicated livestock mandate, ILRI is well placed to lead this CRP. It has scientific expertise and leadership capacity, outstanding bioscience facilities, and a global reach that includes offices in 16 countries. Established partnerships within and outside CGIAR provide a firm



footing on which to begin this new phase. The CRP will take up the best practices for management and governance that have emerged from Phase 1 CRPs and reviews, as well as lessons from the Livestock and Fish CRP. Figure 1.6 gives an overview of the program's proposed management and governance.

As the lead centre, the **ILRI Board of Trustees**, including the **ILRI Director General** has overall responsibility for the performance of the Livestock CRP.

Tom Randolph (CV see annex 3.7), currently director of the Livestock and Fish CRP, has been appointed **CRP director** by ILRI as the lead centre in consultation with CRP partners. The profile of the position is in Annex 3.10.6. The director reports administratively to the Director General of ILRI and programmatically to the ISC.

The current Livestock and Fish CRP Science and Partnership Advisory Committee will be replaced by an **Independent Steering Committee** with new terms of reference complying with the governance recommendations developed by the Consortium Board. It will consist of six independent and diverse individuals with expertise covering critical dimensions of the CRP agenda. It will also include the ILRI Director General (*ex officio*), the Director General of one CGIAR partner (on an annual rotating basis among the three partners), one senior management representative of one of the non-CGIAR partners (also rotating annually), and the CRP director (*ex officio*). The ISC will meet twice annually to review and approve work plans and budgets and to monitor progress, with interim virtual engagement. One of the independent members will be nominated by the ISC and approved by the ILRI Board as ISC chair. She or he will report to the ILRI Board once annually. ISC members will be appointed by the ILRI Board for three-year terms (renewable once). Possible candidates for the ISC are listed in Annex 3.10.5.

The **Program Management Committee** (PMC) will be chaired by the CRP director and composed of research managers from each Tier 1 partner institution and the CRP Gender Coordinator. The committee will meet regularly to take strategic management decisions on program implementation and make recommendations to the ILRI director general and ISC concerning CRP policies and priorities for program strategy, fund allocation and resource mobilization.

The **CRP management unit**, led by the CRP director, will include a full-time program support coordinator, an administrative assistant, an M&E learning specialist and a research quality specialist. It will draw on specialist skills from the CRP partners in monitoring and evaluation (M&E), research data management, communication/knowledge management and capacity development to develop and lead the strategy for each of these areas across the CRP. The management team will build on the performance indicator tracking system and project database established under the Livestock and Fish CRP, which the CGIAR Internal Audit review highlighted as assets, and integrate these with other CRP knowledge management systems. These systems will be further developed to support more timely and strategic results-based management by the CRP director, PMC and ISC (Annex 3.5). The program will use the M&E system developed under the Livestock and Fish CRP, but adapt it to Livestock CRP's ToC.

Flagship leaders have been proposed and will take on this leadership assignment as part of their institution's contribution, as approved by ILRI and to be subsequently endorsed by the ISC. The selection of flagship leaders is based on demonstrated capacity for outstanding and inspiring scientific leadership, as well as strong research and management skills. Flagship leaders are expected to conduct research themselves at the core of the program's agenda, with 20% of their time allocated to leadership, planning, management and reporting (with administrative support for these tasks). Most flagships have appointed cluster leaders to provide scientific guidance for specific outcomes. Biographical information on proposed flagship leaders is included in Annex 3.7. The leadership of the

Animal Health flagship will be provided by a non-CGIAR partner, SLU. ILRI and SLU recognize that these new roles will require innovative arrangements and will be reviewing and adapting the arrangements as needed.

A **program leadership team** led by the CRP director comprises flagship leaders, country coordinators and leaders of cross-cutting components. It will meet virtually each month and once annually during the CRP-wide review and planning event. It will manage day-to-day implementation of the program and engage with the management committee on significant research direction and management issues.

Country coordinators will be appointed in each priority country. Building on the approach developed under the Livestock and Fish CRP, the CRP flagships—especially the Livestock Livelihoods and Agri-Food Systems flagship—have staff based in CRP priority countries (section 1.0.6). These will work as a country team led by a Livestock CRP country coordinator. A portion of the coordinator's time and office costs will be paid by CRP management unit to enable internal cross-flagship coordination, planning, reporting and support, to manage relations with partners and stakeholders, to coordinate national resource mobilisation efforts, and lead the CRP's participation in CGIAR site integration processes. Country coordinators will also participate in the program leadership team and report on this country coordination role to the CRP director. Based on lessons learned by the Livestock and Fish CRP, annual country strategy and implementation plans (see Annex 3.5) will be prepared in consultation with country team members and submitted jointly to the CRP management committee by the country coordinator and flagship leaders.

The **Strategic Investment Fund** is a key instrument for adaptive management. This fund will comprise approximately 5% of W1/2 funding for special short-term initiatives to be proposed on a rolling basis by the CRP director in consultation with the PMC and approved by the ISC. Special initiatives will include: specific priority cross-cutting activities for capacity development, gender, youth, M&E, communications, etc. that complement the cross-cutting agenda within the flagships and are relevant to the overall CRP; resource mobilization efforts and proof-of-concept pilots for exploring new research areas; impact assessments; competitive calls to fund targeted topics such as priority research gaps and joint activities across flagships or CRPs. The Fund will be allocated to the flagships, cross-cutting or country teams who will implement or lead the initiatives.

The program will continue the practice adopted by the Livestock and Fish CRP to use the contractual architecture to ensure alignment of policies and procedures: program partner agreements will stipulate compliance with System and lead centre policies. The lead centre will assess the sufficiency of existing partner policies and procedures in meeting program requirements, including those related to scientific quality control, effective review and approval processes for outputs, attention to quality and cross-cutting elements in proposals, ethical standards, intellectual asset management, and open access and data management, rather than create a new set of CRP policies and procedures.

1.0.12 Intellectual asset management

All core partners in the program are committed to the global accessibility of research outputs as IIPGs, as a way of broadening impact. The program will aim for a balance between maintaining global accessibility and achieving targeted impacts by using intellectual property rights (IPRs), licensing and other strategies to ensure that specific outcomes are reached through appropriate public, public-private or other partnerships (see Annex 3.9).

Each of the partners has its own policies and guidelines on the management of intellectual assets. Those of CGIAR partners conform to CGIAR principles and implementation guidelines. As lead centre,

ILRI will incorporate these guidelines in the contractual arrangements and ensure compliance with CGIAR policies.

Given the range of partnerships required and the divergent intellectual-property (IP) ideologies between the private and public sector, developed and developing country partners, international laws and regulations and their implementation at country level, the program will apply the concept of intellectual asset (IA) management to align the various actions and actors with CGIAR principles.

At program and flagship level, IA management will: 1) advise and formulate appropriate and effective IP models for prompt and broad dissemination of research outputs consistent with CGIAR principles, 2) advise, identify and pursue IP protection when this supports the global access objectives, 3) develop and monitor IP and legal contracts for compliance, 4) as needed and subject to funds, support partner policy development and implementation in these areas, 5) report on these activities annually.

The CRP management unit and lead centre will coordinate IA management, together with related open access, data management and communication activities.

1.0.13 Open access and data management

The program's open access, open data and research data management are guided at CGIAR level by the CGIAR Open Access and Data Management Policy and the CGIAR Open Access and Data Management Implementation Guidelines. Open access and open data actions and platforms are key mechanisms for implementing CGIAR IA principles (see Annex 3.8).

The CRP, through its partners and collaborators, aims to ensure that its research outputs are globally accessible—findable, user-friendly, inter-operable and re-usable. Together with the legal aspects in IA management and other communication and capacity development interventions, these objectives will enhance innovation, impact and uptake.

Across the CRP, open access, including managing data efficiently and effectively to support open access, will normally be the responsibility of CRP partners. Each has its own tools, workflows, legal support, systems and platforms as well as necessary expertise, institutional buy-in and budget support to make it happen. The CRP will judiciously exploit and extend the open content they generate by adding value, aggregating and synthesizing across partners and amplifying the results. The CRP management unit will facilitate and support these efforts and monitor compliance.

Through investments at program level, open access and research data management will: 1) make all the program's research outputs, including data, open access, 2) support flagship activities to efficiently and effectively manage research data from data collection through processing to open access, 3) make the program's information, data and IA open and accessible.

Open access and research data management, together with related IA management and communication activities, will be coordinated through the CRP management unit and lead centre, with representation from program partners.

1.0.14 Communication

Communication, engagement and knowledge management are critical in the quest to transform livestock systems. They underpin the learning required to discover, adapt and deliver innovations. More specifically, they contribute to (1) the achievement of CRP outcomes at different scales; and (2) the sharing of program/flagship results to enhance visibility and demonstrate accountability (see Annex 3.10.7). To communicate high quality research that is widely accessible, the program's research will be published in combinations of peer-reviewed and open access journals, and in other forms as appropriate.

At program level, the CRP will invest in:

- Communication and collaboration tools, methods and approaches, including event and process facilitation, to connect, link, facilitate and inform key actors in priority livestock system sites, so that they co-create and co-adapt knowledge and take interventions to scale.
- Platforms and tools needed to make CRP information products open and accessible.
- Products, approaches and tools that communicate evidence and results and engage key stakeholders to achieve wider influence and investment in sustainable livestock systems, locally and globally.
- Platforms and processes that facilitate learning and sharing to improve program effectiveness and collaboration.

These investments at program level will: 1) support partnerships and policy processes so that results are scaled up, 2) communicate the program's science, results and progress towards achieving results, 3) promote learning and sharing to improve the program's effectiveness and collaboration, 4) make the program's information, data and intellectual assets open and accessible, 5) enhance gender, capacity development and monitoring, evaluation and learning activities, and 6) communicate evidence and results and engage key stakeholders to achieve wider influence and investment in sustainable livestock systems. Each flagship will use a similar portfolio of appropriately tailored communication investments.

1.0.15 Risk management

As an ILRI-led program, the Livestock CRP must comply with ILRI's risk management policy.

The ILRI Board of Trustees has overall responsibility for overseeing the Institute's risk management strategy and internal control systems and for reviewing their adequacy and effectiveness in alignment with the ILRI Risk Management Policy. This process lends support to the role of management in implementing the various policies on risk and control, which have been approved by the Board. Due to the limitations inherent in any system of internal controls, this process is designed to manage and mitigate, rather than eliminate, the risks entailed in efforts to achieve the CRP's objectives. Therefore, such internal controls and risk management can only provide reasonable, and not absolute, assurance against material misstatement or loss.

The Audit and Risk Committee of the ILRI Board reviews and determines the levels of different categories of risk, whilst management and unit/program heads, including the livestock CRP director or his or her designate, are delegated the responsibility of managing risks related to their respective units/programs. The process requires the CRP director to comprehensively identify and assess the relevant types of risk in terms of likelihood and magnitude of impact, as well as to identify and evaluate the adequacy and effectiveness of the mechanisms in place to manage and mitigate these risks. Key risks relating to the CRP's flagships, projects and operations are deliberated at the CRP and institute

management committees and significant risks are communicated to the Board at their scheduled meetings.

CRP and ILRI management is responsible for creating an awareness culture to ensure greater understanding of the importance of effective internal control and risk management and that the principles of these are embedded in key operational processes. This is undertaken through the Institute's procedures and policies manuals (which extend to the CRP), staff briefings, leadership by example and the Institute and program partners' code of conduct. To further enhance understanding of the importance of effective internal control and risk management systems, the Audit and Risk Committee reviewed and adopted the Integrated Risk Framework and Control Statement in April 2014. This, along with other risk management policies and systems, is reviewed regularly to reflect changes in donor conditions, the nature of the research undertaken, and its outputs and outcomes. Similar approaches have been adopted by CRP partners, and these will be reviewed for consistency with ILRI policies at the start of the CRP.

The effectiveness of ILRI's risk management strategy and its implementation is assessed by the Internal Audit unit, which is independent of ILRI's research and business units, including the livestock CRP. Further, the ILRI Board Audit and Risk Committee receives an update on risk management and progress against agreed targets annually.

1.1 CRP Budget Narrative

1.1.1 General Information

CRP Lead Centre: ILRI

1.1.2 Summary

Flagship Name	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
FP1- Livestock Genetics	10,549,446	11,076,918	11,630,764	12,212,302	12,822,918	13,464,063	71,756,412
FP2- Livestock Health	7,970,185	8,368,694	8,787,129	9,226,485	9,687,809	10,172,200	54,212,502
FP3- Livestock Feeds and Forages	6,598,000	6,927,900	7,274,295	7,638,010	8,019,911	8,420,906	44,879,023
FP4- Livestock and the Environment	5,305,958	5,588,938	5,906,261	6,221,658	6,532,741	6,859,378	36,414,933
FP5- Livestock Livelihoods and Agri-Food Systems	8,134,716	8,538,858	8,963,207	9,408,773	9,876,617	10,367,854	55,290,024
Management & Support Cost	2,408,620	2,529,051	2,655,504	2,788,279	2,927,693	3,074,077	16,383,224
Strategic Competitive Research Grant	2,533,074	2,659,728	2,792,714	2,932,350	3,078,967	3,232,916	17,229,749
	43,500,000	45,690,088	48,009,874	50,427,857	52,946,655	55,591,394	296,165,867

Cost drivers. The most significant cost driver in the CRP budget is the cost of personnel required to deliver the targeted 2022 outcomes and targets in the five flagships. To realize its 19 outcomes and various targets, 1,003 FTEs (35% of the total budget) are required over the 6 year life of the program (75% of this is funded from W1/W2 resources and the balance from W3 or bilateral funding). These staff include senior scientists, scientists, post-doctoral researchers, research assistants, technicians, administrative assistants. More detail is provided within each of the flagship budget narratives. They are supported by a Program Management Unit comprising 45 FTE over the 6 years. This matches historical expenditures on the Livestock and Fish CRP.

To conduct the research, expenditures are incurred for collaborators, consumables, other supplies and services, and travel. Two strategies have been applied to develop the budgets for these expenses: The budget for 2017 has been developed based on a combination of (i) the existing funded W3 and bilateral projects for which contracted budgets and work plans already exist; and (ii) detailed planning and budgeting of W1/2 funded activities. For later years when most activities will be funded through bilateral projects yet to be developed in consultation with partners, collaborators and donors, the cost structure is estimated based on the structure of expenditures during the first phase Livestock and Fish CRP. On average, this structure has been found to be fairly constant over time, though it may vary according to the nature and specificities of specific activities and funding sources.

Based on this approach, the second most important cost driver is supplies and services which represents 28% of the total budget. Almost 70% of this funding is from W3 or bilateral sources.

The third most important cost driver is non-CGIAR collaborators which represents 19% of the total budget and of which W1/W2 funding supports 25% of these costs with 75% funded by bilateral and W3 funding.

Rationale for funding levels for flagships. Overall, for reasons explained in the main narrative regarding the interdependency of productivity drivers and the need to ensure an enabling environment for successful inclusive uptake, the flagships are considered to be of approximately equal importance to achieve the outcomes and associated targets. The Livestock Livelihoods AFS Flagship has a higher share of the total budget as it has a large socio-economics research agenda in addition to having responsibility for multidisciplinary integration of the outputs from other flagships in the CRP's priority countries. Ideally, the CRP will allocate 17.5% of its resources to supporting each of the Livestock Genetics, Livestock Health, Livestock Feeds and Forages and Livestock and the Environment flagships, with 30% for the Livestock Livelihoods AFS Flagship.

For W1/2 funding, the allocation is maintained as proposed at the Rome meeting and in the second Call Guidance document, consistent with donor guidance that was provided. Thus a higher proportion is allocated to the longer term, more upstream work in the Livestock Genetics and Livestock Health flagships (25% of the total, not including CRP management); a medium level of 20% to the Livestock Feed and Forages flagship given its mix of upstream and adaptive research; and 15% each to the more downstream Livestock and the Environment and Livestock Livelihoods AFS flagships.

W3 and bilateral funding budgets for 2017 reflect the actual funding secured for each flagship. As of March 2016, 93% of the \$23.3m W3/bilateral budget assigned to the CRP has been secured. The resulting total budget consisting of the W1/2 allocation and secured W3/bilateral funding indicates that the Livestock Genetics flagship has secured a higher share of the total funding than the ideal described above, and the Livestock Livelihoods AFS flagship a smaller share. CRP management will seek to realign these shares towards the ideal through the priority given to W3/bilateral resource mobilization to the respective flagships. Note that given the constraints of the budget template, it is not possible to depict this re-alignment over the course of the six-year program, but it is certainly the intention.

Risks in executing the budget: The CRP faces several risks that are likely shared across the CGIAR. Key risks and strategies to mitigate them include:

1. Contractual disputes may occur with W3 donors as the projects they fund are now required to contribute to funding CRP management. W3 donors may not accept this provision and this issue is being raised with the Consortium and Fund Offices to seek their action in facilitating agreement with W3 donors. If this is not successful, ILRI as the lead centre will engage each W3 donor directly on a case by case basis to find solutions.
2. As the experience of the first phase has shown, W1/2 funding presents an extremely high risk when supporting multi-annual funding commitments to collaborators. The CRP is therefore giving priority to funding multi-year collaboration through W3/bilateral funding sources.
3. Staff recruitment and continuity has been a perennial challenge for the CGIAR. Many of the research posts require expertise drawn from a relatively small pool of potential candidates. This results in delays in filling posts with the appropriately qualified personnel and in disruptions when staff resign. The CRP will explore whether this risk can be addressed through increasing the flexibility by which the CRP can draw from the larger pool of expertise created by the program partnerships, by using arrangements such as secondments and joint appointments with the wide range of non-CGIAR program collaborators including national partners, or by strategic engagement of consultants, as the Livestock and Fish CRP did to address gender specialist staffing constraints.

Supporting country level activities: Each flagship will conduct activities in the CRP priority countries contributing directly to their own outcomes as well as generating inputs for the integrative activities of the Livestock Livelihoods and Agri-Food Systems flagship. Most activities at country level will be funded from W3/bilateral projects, including any research teams based in the target countries, and collaborator costs. The CRP management budget will fund 15% of the salary and office costs for a coordinator in each country from W1/2 funding to ensure stability of the CRP representation in the country. A budget of \$5,000 will be allocated annually to each CRP target country to support the CRP's contribution to CGIAR Site Integration coordination.

1.1.3 CRP Funding Plan

Funding Needed	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2	20,200,000	21,225,088	22,321,624	23,455,195	24,625,360	25,854,033	137,681,301
W3	6,759,184	7,097,143	7,452,000	7,824,600	8,215,830	8,626,622	45,975,381
Bilateral	16,540,815	17,367,856	18,236,248	19,148,061	20,105,464	21,110,737	112,509,184
Other Sources	0	0	0	0	0	0	0
	43,499,999	45,690,087	48,009,872	50,427,856	52,946,654	55,591,392	296,165,860

Funding Secured	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2(Assumed Secured)	20,200,000	21,225,088	22,321,624	23,455,195	24,625,360	25,854,033	137,681,301
W3	6,759,184	5,132,886	80,198	80,198	80,198	80,198	12,212,862
Bilateral	15,263,515	9,130,115	4,025,731	1,347,000	0	0	29,766,363
Other Sources	0	0	0	0	0	0	0
	42,222,699	35,488,089	26,427,553	24,882,393	24,705,558	25,934,231	179,660,523

Funding Gap	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2	0	0	0	0	0	0	0
W3	0	-1,964,256	-7,371,802	-7,744,402	-8,135,632	-8,546,424	-33,762,518
Bilateral	-1,277,299	-8,237,740	-14,210,517	-17,801,061	-20,105,464	-21,110,737	-82,742,821
Other Sources	0	0	0	0	0	0	0
	-1,277,299	-10,201,996	-21,582,319	-25,545,463	-28,241,096	-29,657,161	-116,505,334

As of March 2016, the program partners have secured \$22.02 million in W3 and bilateral project funding for 2017, leaving a funding gap of \$1.28 million yet to secure. Program partner SLU will also be aligning over \$1 million value of its own bilateral projects to coordinate and add value to CRP activities; these funds do not feature in the CRP budget. Secured W3/bilateral funding declines in the following years to: \$14.3 million in 2018; USD 4.1 million in 2019; \$1.4 million in 2020; \$0.1 million in 2021 and 2022. The W3/bilateral funding gap is estimated based on a 5% annual growth of the 2017 \$23.3 million W3/bilateral budget figure, less these secured amounts. The CRP is developing several selected large bilateral funding proposals expressly designed to deliver the non-W1/2 components of each flagship and for initiatives that cut across the flagships and other CRPs to deliver better the overall CRP. The priority proposal topics are described in more detail in each of the flagship budget narratives and in the table of cross-CRP collaboration. Given the realities of bilateral donor funding, resource mobilization will require a continuous effort throughout the program period and will be a major responsibility of both the CRP and flagship management, together with the research management of each of the program partners.

1.1.4 CRP Management and Support Cost

The CRP management and support cost includes the following main line items:

Program Management Unit

- CRP director, costed as a full IRS FTE with the standard ILRI staff cost, all 6 years
- CRP program support coordinator, costed as a full IRS FTE with the standard ILRI staff cost, all 6 years; this position will lead implementation of the M&E system
- CRP program administrative assistant, costed as a full Kenyan NRS FTE with the standard ILRI staff cost, all 6 years
- ILRI administrative support, including a senior financial manager costs as a 30% NRS FTE with the standard ILRI staff cost, all 6 years

Program Management Unit – M&E and impact assessment

- Senior biometrician, costed as a 20% IRS FTE with the standard ILRI staff cost, all 6 years
- 2 M&E research technicians, costed as a full Kenyan NRS FTE with the standard ILRI staff cost, all 6 years (new hires)
- Impact assessment and evaluation economist, costed as a 25% IRS FTE with the standard ILRI staff cost, all 6 years

Program Management Unit – Cross-cutting program coordination

- Gender coordinator, costed as a 20% IRS FTE with the standard ILRI staff cost, all 6 years. Note that this is just to cover the incumbent's specific management functions (planning, reporting, etc.), and the person's main research function is homed and funded in the Livestock Livelihoods and Agri-Food Systems Flagship (new hire).
- Communication specialist, entry level, costed as a full IRS FTE with the standard ILRI staff cost, all 6 years (new hire).
- Senior communications and knowledge management specialist, costed as a 10% IRS FTE with the standard ILRI staff cost, all 6 years
- Senior knowledge management and engagement specialist, costed as a 25% IRS FTE with the standard ILRI staff cost, all 6 years
- Senior capacity development specialist, costed as a 15% IRS FTE with the standard ILRI staff cost, all 6 years

Program Management Unit – Country coordination

- Country coordinators in CRP target countries, costed as a 15% IRS FTE with the standard institutional staff cost, all 6 years or that part of which the target country is operational

Program Management Unit – Supplies & Services

- Management Unit office supplies and space, IT and communications
- Proportional share of office supplies for cross-cutting staff and country coordination
- Consultancies for development and maintenance of IT platform for M&E and finance systems
- Internal audit services
- Data open access and IP support services

Program Management Unit – Travel

- Mission travel for Program Management Unit and cross-cutting coordination

Program Planning & Management Committee meetings, quarterly

- Travel and meeting venue; 4 pers x 2 trips/year

Leadership team meetings, quarterly

- Travel and meeting venue; 4 pers x 3 trips/year

Biennial program meetings and other CRP special events

- Travel and meeting venue for 150 participants

Independent Steering Committee, biannually

- Honoraria; 9 pers x 15 days/pers x \$500/day (20 days for the Chair)
- Travel (business) and meeting venue; 9 pers x 2 trips/year

The Strategic Investment Fund, to be allocated annually to research or management activities as proposed by PPMC and approved by ISC; this will represent 5-10% of the annual W1/2 funded budget. This represents the principal instrument for adaptive management available to CRP management in addition to reallocation of existing funding to specific activities or flagships. The Strategic Investment Fund is used for:

- Specific cross-cutting activities for gender, capacity development, youth, M&E, data management, communication relevant to the overall CRP and therefore not covered under flagship budgets, e.g. development of the CRP youth strategy
- Impact assessments
- Competitive calls for target country, cross-flagship, or cross-CRP activities

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- Priority resource mobilization initiatives, including seed grants for developing cross-CRP collaboration to support proposal development

The following table summarizes the components of management support costs (MSC) using line items agreed by the CRP directors and System Management Office. Note that there is a small discrepancy in the totals for 2019, 2022 and the 6 year total due to the internal audit costs which were mistakenly not included in the submitted budgets.

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Table 1.1.4. Explanation of MSC budget components:

COST COMPONENT		AMOUNT BUDGETED						
		2017	2018	2019	2020	2021	2022	6-year Total
A. Basic components as were given in the guidance document	SubTotal	1,045,557	1,097,835	1,238,977	1,210,363	1,270,881	1,420,675	7,284,288
A.1 Management fee charged by the lead centre to handle CRP Finance and Administrative matters (Finance, accounting, reporting, contracts management, legal, HR, IT, communication-if handled by lead centre)	Amount:	-	-	-	-	-	-	-
A.2 Combines three of the basic components to protect confidentiality of staff salaries – the sum total of these three component should be reported as a single amount: <ul style="list-style-type: none"> CRP director including related cost – benefits and on-cost if customary (computer, vehicle lease and office space) based on percentage time allocation Infrastructure and general and administrative charges if CRP leader is not located at the lead centre Financial and administrative support based on time allocation <i>Includes CRP Director, Program Support Coordinator, Administrative Assistant, lead centre Financial Support and PMU office supplies and services</i>	Amount:	510,577	536,106	562,911	591,057	620,610	651,640	3,472,900
A.3 Flagship leader and regional coordinators only if a significant percentage time (>50%) is dedicated to managerial activities. N/A	Amount:	-	-	-	-	-	-	-
A.4 CRP Management Committee and related costs <i>Travel and meeting costs</i>	Amount:	51,980	54,579	57,308	60,173	63,182	66,341	353,563
A.5 Independent Steering Committee (or Science Committee) and related costs <i>Travel, meetings and honoraria</i>	Amount:	301,875	316,969	332,817	349,458	366,931	385,277	2,053,327
A.6 Communication activity related specifically to CRP communication and webpage (not if handled by lead centre) N/A	Amount:	0	0	0	0	0	0	0
A.7 CRP internal audit by the CGIAR Internal Audit Unit, or its future equivalent in the new System governance structure	Amount:	-	-	86,250			86,250	172,500
A.8 CRP internal and external reviews (e.g. CCEEs and other evaluations and reviews), as well as impact assessments	Amount:	181,125	190,181	199,690	209,675	220,159	231,166	1,231,996
B. CRP-level cross-cutting components not mentioned in the guidance document	SubTotal	1,363,063	1,431,216	1,502,778	1,577,916	1,656,811	1,739,652	9,271,436
B.1 CRP special events (e.g. CRP-wide program meetings) <i>Annual CRP Program meetings</i>	Amount:	115,000	120,750	120,750	115,000	139,783	146,772	758,055
B.2 CRP leadership meetings (e.g. country coordinators, flagship leaders, cross-cutting coordinators) <i>Flagship and country coordinator travel and meeting costs</i>	Amount:	58,650	61,583	64,662	79,682	83,666	87,849	436,092

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B.3 CRP M&E coordination and systems (not including external evaluations and impact assessments) <i>M&E staff salaries (Evaluation and M&E Specialists), MEL online system development and maintenance costs, data collection, quality assurance</i>	Amount:	306,874	322,218	338,329	355,245	353,974	371,673	2,048,313
B.4 CRP communications, open access, IP assets, CKM (including lead centre staff budgeted as direct costs not allowed under A.6 above)	Amount:	505,609	530,889	557,434	585,306	614,571	645,299	3,439,108
B.5 CRP Capdev coordination <i>CapDev Coordinator's salary and travel</i>	Amount:	50,376	52,895	55,539	58,316	61,232	64,294	342,651
B.6 CRP Gender and youth coordination <i>Gender and youth coordinator's salary and travel</i>	Amount:	104,029	109,230	114,692	120,427	126,448	132,770	707,596
B.7 CRP Site integration support <i>Contributions to CGIAR country coordination activities</i>	Amount:	56,925	59,771	62,760	65,898	69,193	72,652	387,199
B.8 Other: Country Coordination <i>CRP country coordinator and office costs (15%)</i>	Amount:	165,600	173,880	188,612	198,043	207,945	218,342	1,152,421
C. Strategic Investment Fund	Amount:	2,533,074	2,659,728	2,792,714	2,932,350	3,078,967	3,232,916	17,229,749
		2017	2018	2019	2020	2021	2022	6-year Total
D. Funding source: MSC budget is assumed to be funded from W1/2. Some CRPs have been successful in mobilizing W3/bilateral funding to support CRP-level cross-cutting initiatives.		0	0	0	0	0	0	0
D.1 Grant: (note name, donor; purpose in this cell)	Amount:	0	0	0	0	0	0	0

1.1.5 CRP Financial management principles

1. **Allocation process for W1/2 funding to flagships:** The initial allocation of W1/2 to the flagships has been explained above. These allocations will be maintained to ensure stability for planning and management purposes of the program partners responsible to implement the W1/2 funded activities to improve the likelihood of achieving the agreed outcomes. However, performance monitoring and prioritization will be ongoing throughout the program period and the allocation will be subject to PPMC, ISC and periodic external review, and the allocation to activities or to specific partners revised based on performance or as adaptive management to address changing priorities. Performance will be largely based on demonstrated delivery of agreed outputs and outcomes on time and to specification, the evolving indicators of Value For Money, and also consider ability to attract W3/bilateral funding.
2. **Budget ownership by flagship leaders:** As demonstrated during the Livestock and Fish CRP, information about W1/2 was often uncertain and not timely, limiting the ability of the CRP and flagship management to execute W1/2 funded activities with certainty. Similarly, the cross-institutional nature of the CRP and variations and constraints of the partners' finance systems limit the ability of the CRP and flagship management to monitor budget execution in real-time. Investments already made in OCS and an online CRP management system during the first phase is expected to improve this situation. The first phase also demonstrated the limitations of adaptive management within a contractual architecture that requires formal amendment processes when agreed work plans or budgets are to be revised. Given these realities, flagship leaders will be responsible for leading the development of the annual work plan and budget in consultation with their teams and partners. They will be provided at least a mid-year financial report from each program partner to monitor budget and activity execution, as well as information solicited from team members, and will be expected to take action accordingly with support from the CRP management.
3. **Annual budget variances:** Annual budget variances of 10% for individual activities and line items funded by W1/2 will be allowed for partner and flagship budgets; any variance beyond these limits will require explanation and approval by CRP management and the ISC. It is recognized that W1/2 funding may be associated with significant uncertainty regarding its timing and level, in which case this variance requirement may be relaxed by the CRP management with ISC approval. W3/bilateral budget and expenditure is subject to its own contractual requirements.
4. **Expected major capital investments (>\$25,000)**
 - 2 mobile NIRS units at \$40,000 each for the CIAT component of the CRP NIRS platform in the Livestock Feeds and Forages flagship.
 - 2 servers at \$40,000 each for the National Dairy Farmer Recording and Information Centres in Ethiopia and Tanzania, funded by a bilateral project in the Livestock Genetics flagship.

1.1.6 Budgeted Costs for certain Key Activities

	Estimate annual average cost (USD)
Gender	6,858,754
Youth (only for those who have relevant set of activities in this area)	240,340
Capacity development	3,429,119
Impact assessment	845,012
Intellectual asset management	90,657
Open access and data management	453,285
Communication	362,628

Table 1.1.6a. Amount dedicated to M&E and Impact Assessment in the CRP budget

M&E investments		AMOUNT BUDGETED						
		2017	2018	2019	2020	2021	2022	6-year Total
M&E (including impact assessment)	SubTotal	1,399,625	1,469,606	1,102,087	1,598,191	1,215,050	1,275,803	8,060,362
Under the MSC budget	Amount:	369,625	388,106	407,512	427,887	449,281	471,746	2,514,157
Under the Competitive Grants Fund	Amount:	720,000	756,000	352,800	811,440	388,962	408,410	3,437,612
Under flagship budgets	Amount:	310,000	325,500	341,775	358,864	376,807	395,647	2,108,593
Impact assessment	SubTotal	960,000	1,008,000	617,400	1,089,270	680,684	714,718	5,070,071
Under the MSC budget	Amount:	0	0	0	0	0	0	0
Under the Competitive Grants Fund	Amount:	700,000	735,000	330,750	788,288	364,652	382,884	3,301,574
Under flagship budgets	Amount:	260,000	273,000	286,650	300,983	316,032	331,833	1,768,497

Table 1.1.6b. Explanation of the definitions used for the types of costs/activities included under each category

M&E	<p>The CRP defines M&E to include:</p> <ul style="list-style-type: none"> Establishing and maintaining an online system for planning and reporting that includes activities, budget, deliverables and a performance indicator database Establishing and monitoring CRP ToC and Flagship ToC, Strategy & Implementation Plans (e.g. milestones), Annual Plan of Work & Budget Planning and implementing baseline surveys and studies Establishing and maintaining our ToC evidence base Change pathway monitoring CRP-level impact assessments, ex-ante and ex-post (see below) External evaluations (CCEE, IEE, audits) are budgeted separately.
Under the MSC budget	<ul style="list-style-type: none"> Staff: part of the ToR of the Program Support Coordinator; M&E specialists, Research Methods Group Leader, Evaluation Specialist, Research Quality Specialist M&E software system and its maintenance Baselines (if not specifically designed for an individual flagship) Indicator data collection Quality Assurance
Under the Strategic Investment Fund	<ul style="list-style-type: none"> Initial investment in M&E system development and piloting Commissioned ex-ante impact assessments

Under flagship budgets	<ul style="list-style-type: none"> • Change pathway monitoring and reflection workshops • Flagship-specific ex-ante and ex-post impact assessments
Impact assessment	The CRP defines IA to include ex-ante impact assessment studies, adoption studies, ex-post impact assessment studies. Ex-ante impact assessment may be at CRP level as part of foresight to inform prioritization; or may be specific to a given innovation and flagship. Adoption and ex-post impact assessment studies will be mainly to evaluate discrete innovations or interventions.
Under the MSC budget	Staff to oversee planning and quality assurance
Under the Strategic Investment Fund	Commissioned CRP-level adoption studies, impact assessments; supplementing flagship impact assessments as needed
Under flagship budgets	Flagship-specific adoption studies, impact assessments

1.1.7 Other

The requested budget (\$43.5M in 2017) represents a relatively small overall increase from the levels realized under the Livestock and Fish CRP (\$36.7M in 2016), but with a significant increase in W1/2 funding (\$20.2M up from \$10.3M in 2016). This reflects recognition of:

1. The historical under-investment in CGIAR livestock research relative to its investment in crop research when compared to the relative contribution of livestock enterprises vis-à-vis crop enterprises in household and national income. There has been consensus in discussions with the CO and donors that an adjustment in relative funding between animal and crop research was long overdue.
2. The strong W2 support achieved by the Livestock and Fish CRP which was able to fund nearly all of its full W1/2 budget from W2 alone: it received only USD 3 million in W1 versus \$59M in W2 over 5 years. A more equitable share of W1 funding is sought for the Livestock CRP.
3. The Livestock CRP as the consolidation of the various livestock-related research components that were spread across several first phase CRPs, notably in the Systems and integrative CRPs. Significant shares of the original levels of livestock research funding had been allocated to these other CRPs in the form of W1/2 funding.
4. Similarly, with the consolidation of other livestock-related research components, W3/bilateral funding is expected to be higher than under the Livestock and Fish CRP alone, and growing. The fact that over 90% of the W3/bilateral funding envelope allocated to the Livestock CRP for 2017 is already secured as of March 2016 is evidence of this.

The initial high share of W1/2 funding (45%) of the total Livestock CRP budget is considered an appropriate initial adjustment to address these issues. The CRP is setting the objective of mobilizing substantial additional W3/bilateral funding to achieve a W1/2 share more in line with the System average by 2020.

Livestock CRP: Full Proposal 2017-2022

CGIAR Target	Country	Other Countries	Target contribution in country
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	Bangladesh		0.160091
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	Burkina Faso		0.069144
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	Other	Colombia	0.010392
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	Ethiopia		2.0521985
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	India		0.479189
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	Kenya		0.1363788
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	Malawi		0.322393
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	Mali		0.063365
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	Nicaragua		0.006123
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	Nigeria		0.759999
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	REST OF THE WORLD		0.390898
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	Rwanda		0.194852
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	Other	Tunisia	0.011041
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	Uganda		0.3108174
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	Tanzania		1.4398
100 million more farm households have adopted improved varieties, breeds or trees, and / or improved management practices	Vietnam		0.11282
30 million people, of which 50% are women, assisted to exit poverty	Bangladesh		0.704396
30 million people, of which 50% are women, assisted to exit poverty	Other	Colombia	0.039694

Livestock CRP: Full Proposal 2017-2022

CGIAR Target	Country	Other Countries	Target contribution in country
30 million people, of which 50% are women, assisted to exit poverty	Ethiopia		4.427948
30 million people, of which 50% are women, assisted to exit poverty	India		1.979047
30 million people, of which 50% are women, assisted to exit poverty	Kenya		0.785034
30 million people, of which 50% are women, assisted to exit poverty	Nicaragua		0.018902
30 million people, of which 50% are women, assisted to exit poverty	Nigeria		3.032386
30 million people, of which 50% are women, assisted to exit poverty	Other	Pakistan	0.224822
30 million people, of which 50% are women, assisted to exit poverty	REST OF THE WORLD		1.933862
30 million people, of which 50% are women, assisted to exit poverty	Other	Tunisia	0.060833
30 million people, of which 50% are women, assisted to exit poverty	Uganda		1.2115772
30 million people, of which 50% are women, assisted to exit poverty	Tanzania		3.189704
30 million people, of which 50% are women, assisted to exit poverty	Vietnam		0.359653
Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	Bangladesh		5
Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	Burkina Faso		0.5
Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	Other	Colombia	8.3
Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	Ethiopia		2.8
Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	India		3.6
Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	Kenya		5
Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	Mali		2.8
Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	Nicaragua		4.6
Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	Nigeria		4.7
Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	REST OF THE WORLD		8.3
Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	Other	Tunisia	5
Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	Uganda		3.6
Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	Tanzania		4.6
Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	Vietnam		4.6
30 million more people, of which 50% are women, meeting minimum dietary energy requirements	Burkina Faso		0.203975

Livestock CRP: Full Proposal 2017-2022

CGIAR Target	Country	Other Countries	Target contribution in country
30 million more people, of which 50% are women, meeting minimum dietary energy requirements	Ethiopia		5.109935
30 million more people, of which 50% are women, meeting minimum dietary energy requirements	India		0.540471
30 million more people, of which 50% are women, meeting minimum dietary energy requirements	Kenya		0.615244
30 million more people, of which 50% are women, meeting minimum dietary energy requirements	Mali		0.164745
30 million more people, of which 50% are women, meeting minimum dietary energy requirements	Nicaragua		0.018532
30 million more people, of which 50% are women, meeting minimum dietary energy requirements	Nigeria		0.507968
30 million more people, of which 50% are women, meeting minimum dietary energy requirements	REST OF THE WORLD		0.396451
30 million more people, of which 50% are women, meeting minimum dietary energy requirements	Other	Tunisia	0.001929
30 million more people, of which 50% are women, meeting minimum dietary energy requirements	Uganda		1.686116
30 million more people, of which 50% are women, meeting minimum dietary energy requirements	Tanzania		2.202398
30 million more people, of which 50% are women, meeting minimum dietary energy requirements	Vietnam		0.125836
Reduce agriculturally-related greenhouse gas emissions by 0.2 Gt CO ₂ -e yr ⁻¹ (5%) compared with business-as-usual scenario in 2022	Ethiopia		0.08
Reduce agriculturally-related greenhouse gas emissions by 0.2 Gt CO ₂ -e yr ⁻¹ (5%) compared with business-as-usual scenario in 2022	India		0.08
Reduce agriculturally-related greenhouse gas emissions by 0.2 Gt CO ₂ -e yr ⁻¹ (5%) compared with business-as-usual scenario in 2022	Kenya		0.08
Reduce agriculturally-related greenhouse gas emissions by 0.2 Gt CO ₂ -e yr ⁻¹ (5%) compared with business-as-usual scenario in 2022	Nicaragua		0.08
Reduce agriculturally-related greenhouse gas emissions by 0.2 Gt CO ₂ -e yr ⁻¹ (5%) compared with business-as-usual scenario in 2022	Uganda		0.08
Reduce agriculturally-related greenhouse gas emissions by 0.2 Gt CO ₂ -e yr ⁻¹ (5%) compared with business-as-usual scenario in 2022	Tanzania		0.08
Reduce agriculturally-related greenhouse gas emissions by 0.2 Gt CO ₂ -e yr ⁻¹ (5%) compared with business-as-usual scenario in 2022	Vietnam		0.08
55 million hectares (ha) degraded land area restored	Burkina Faso		0.589146
55 million hectares (ha) degraded land area restored	Ethiopia		4.746795
55 million hectares (ha) degraded land area restored	India		0.729399
55 million hectares (ha) degraded land area restored	Kenya		3.080755
55 million hectares (ha) degraded land area restored	Nicaragua		0.183977
55 million hectares (ha) degraded land area restored	Other	Tunisia	0.320902
55 million hectares (ha) degraded land area restored	Uganda		0.571342
55 million hectares (ha) degraded land area restored	Tanzania		2.642135
55 million hectares (ha) degraded land area restored	Vietnam		0.822295

2. Flagship Projects

2.1. Livestock Genetics

Box 2.1a Livestock Genetics Flagship—Summary

Ex-ante impact assessment indicates that the Flagship's research to improve poultry and pig genetics is among the highest ranked in addressing the CRP's multiple objectives. The proposed research on African dairy genetics also ranks in the top tercile for returns on investment. These two research areas also provide the greatest contribution to poverty reduction.

This flagship:

- Combines genetics with appropriate health and feeds to improve livestock productivity.
- Aims to ensure all stakeholders in livestock production systems, keepers and consumers can benefit from better livestock genetics.
- Identifies and promotes the most appropriate livestock breeds for specific value chains and systems.
- Develops improved breeds, capitalizing on new opportunities created by advances in genomic and reproductive technologies (within-breed improvement, cross-breeding).
- Creates effective delivery systems for improved livestock genetics (such as public-private partnerships and community breeding schemes).
- Improves policies and institutional arrangements to maximize the long-term effectiveness of genetic interventions.
- Contributes directly to sub-IDOs:
 - Closed yield gaps through improved agronomic and animal husbandry practices.
 - Enhanced genetic gain.
 - Increased conservation and use of genetic resources.
 - Increased livelihood opportunities.
 - Technologies that reduce women's labour and energy expenditure developed and disseminated.

2.1.1 Flagship Project Narrative

2.1.1.1 Rationale and scope

Why research on livestock genetics in developing countries?

Demand for livestock products is increasing against a background of rapid change in the agricultural sector, genetic erosion of indigenous livestock diversity, and increasing impact of climate change.

In developed countries, improved livestock genetics associated with better husbandry—better feeds, health care and housing—resulted in significant and sustained increases in livestock productivity. Today, new technologies, including better recording of production traits, statistical models to predict genetic merit, genetic marker information in selection programs (Henderson, 1975; Goddard and Hayes, 2007; Clark and van der Werf, 2013) and new reproductive technologies that speed up genetic gains (Kasinathan *et al.*, 2015) are leading to further productivity gains.

This is not happening in developing countries (Marshall, 2014) for many reasons including: (i) until recently, a lack of understanding of the potential of indigenous livestock genetic resources for productivity improvement; (ii) investment prioritized other avenues of livestock development; (iii) heterogeneity of livestock systems and preferences of livestock keepers; (iv) lack of supportive policies, institutional arrangements and capacity to undertake genetic improvement (Kosgey and Mwai, 2007; Rege *et al.*, 2011; Marshall *et al.*, 2013).

This flagship aims to address these issues and to apply new genetics and genomics opportunities to the developing world (ISPC 2014). This builds on the recently increased recognition that genetic improvement in low-input smallholder livestock production systems, when combined with

appropriate management strategies, represents a significant and largely untapped opportunity to increase livestock productivity (Thevasagayam, 2013).

Indigenous livestock breeds have sustained human livelihoods for centuries (Okeyo *et al.*, 2015). Today the world faces the challenge to respond quickly yet sustainably to a rapid increase in demand for livestock products, while addressing the poverty and poor nutrition typically found in livestock-producing households. Building on lessons learned from the Livestock and Fish CRP, (e.g. pigs in Uganda and Vietnam, small ruminants in Ethiopia, dairy cattle in Tanzania) and recognizing that successful improvement of productivity is a multi-dimensional challenge, the flagship proposes to apply new genomics technologies, knowledge and breeding approaches to livestock so they address yield gaps and create new livelihood opportunities in the short to medium term. It will explore and use crossbreeding and breed replacement strategies to achieve productivity improvement within the timeframe of the CRP. Examples of the opportunities for and role of genetic and genomic improvement are given below in Box 2.1b

Most flagship work will target 5 species in 5 priority countries and other locations, namely chickens in Ethiopia, Tanzania and Nigeria; pigs in Uganda and Vietnam; sheep and goats in Ethiopia; and dairy cattle in Ethiopia and Tanzania. It will mainly concentrate on the ‘rapid inclusive growth’ trajectory, since it is here that genetic gains are likely to find their maximum expression in more productive animals in more efficient, intensive and market-oriented systems. Improved genetics, delivery approaches in particular, will also relate to the ‘fragile growth’ trajectory, where there is demand for more resilient and reliably productive livestock leading to better food and nutritional security and resilience to environmental risks.

Box 2.1b Genetics and productivity improvement

The history of improved productivity of European dairy breeds illustrates the link between genetics/genomics approaches and livestock trait performance (Grosu *et al.* 2013). The initial gain in productivity was made by introducing herd books recording pedigrees, progeny testing and individual animal recording of productivity (Lush 1936). It started under traditional grazing production systems with little management interventions. Improved management practices and increased standardization of production parameters largely followed progeny testing based breeding approaches and phenotypic selection of the elite animals.

New technologies (Hill 2014) led to rapid genetic progress, continuing today thanks to the availability of genomic data and “genomic selection” approaches. Management interventions remain important to mitigate the side negative effect of intensive selection (e.g. decrease in fertility) but continuous productivity improvement relies on these new genetics and genomic strategies. These latest technological advanced are now also advocated to address new environmental production challenges such as the effect of climate changes (Nguyen *et al.* 2016).

The flagship anticipates that similar breeding improvement approaches (e.g. phenotypic recording) combined with new genomics will lead to major productivity gains for the agro-ecological systems of the tropics. In these conditions, the environmental challenges are often perceived as more intense than in the temperate zones. This is supported by Livestock and Fish CRP studies (dairy cattle, small ruminants) as well as several studies on chicken productivity (Dessie *et al.* 2000, Wodmeh *et al.* 2016a). The implication is that genetics is an important but not the only component for improving productivity.

A recent study on dairy production from cattle in Senegal (Marshall *et al.* 2016) nicely untangles the importance of genetics and management in improvement of livestock productivity (Figure 1) with the highest profits obtained with new genetics (crossbred animals) and feed supplementation (Figure 2).

Figure 1 shows that better management (feed supplement) does lead to increased milk production in indigenous breeds (A), the same level of improvement is obtained with new genetics (crossbreed with exotic taurine) under traditional management systems (B). However, a cost benefit analysis (Figure 2) indicates higher household profit for new genetics compared to improved management (3.4 *versus* 2.4 fold differences). With the largest profit obtained combining new genetics and improved management (8.0 fold difference in profit compared to indigenous breeds).

Figure 1: Average lactation level milk off-take per cow under two management systems and different levels of crossbreeding with exotic dairy breeds (Marshall *et al.* 2016)

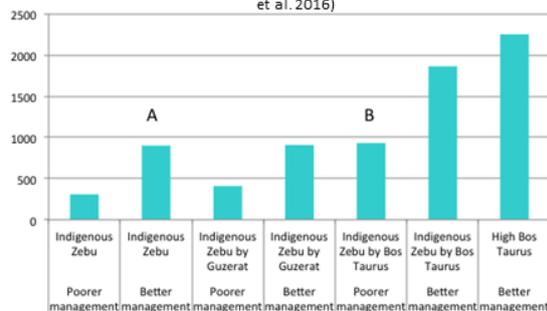
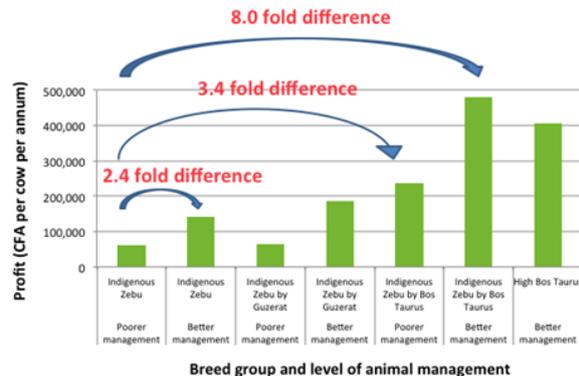


Figure 2: Household income under two management systems and different levels of crossbreeding with exotic dairy breeds (Marshall *et al.* 2016)



Addressing the grand challenges

The flagship will impact on the grand challenge of climate change: by increasing livestock productivity (though the use of improved genetics, including better feed conversion) greenhouse gas emission intensity will decrease (mitigation) (Gerber *et al.*, 2011; Gerber *et al.*, 2013). By targeting genetic improvement strategies to produce productive and resilient livestock, livestock will remain fit for future environmental conditions (adaptation) (Hayes *et al.*, 2013); provide nutritious and diverse agri-food systems and diets (increasing the availability of animal-source food); and improve food safety (disease-resistant breeds will lower drug load in food products and reduce zoonoses).

Increased livestock productivity, will lead to a relative reduction in the number of animals kept, lowering competition for land and potentially decreasing the risk of soil degradation and of overdrawn and polluted water supplies. Increasing productivity could also make a contribution to reducing malnutrition, providing vulnerable groups (the rural and urban poor) are targeted.

Genetic improvement strategies can contribute to adaptation to climate change, through selection for such traits as drought or heat tolerance. By ensuring that its genetics research reflects the needs of women and young people, the flagship will also, indirectly, tackle the problems associated with age and labour in agriculture. It will make a direct and sizeable contribution to animal genetic resources conservation, by documenting their diversity at genome level and by utilizing it in its breeding programs. Work on policy guidelines and advocacy addressing livestock conservation issues, together with the repositories with *in-silico* data and *ex-situ* material will also impact on diminishing genetic resources.

Why should CGIAR invest in this?

CGIAR provides a unique conducive environment in which to develop and deliver a genetic, genomic and breeding program targeting developing countries. ILRI and ICARDA scientists have relevant in-house expertise and successful track records in these areas and convene a strong partner network, including with national systems in animal breeding and genetics who in some cases would be unlikely to achieve the same outcomes working alone. ILRI–Nairobi, the BecA-ILRI hub has up-to-date genetics, genomics and bioinformatics infrastructure and facilities.

From the ex ante impact assessment, research to improve poultry and pig genetics is among the highest ranked in addressing the CRP's multiple objectives. The proposed research on African dairy genetics also ranks in the top tercile for returns on investment. These two areas also provide the greatest contribution to poverty reduction (see Annex 3.10.2).

Overall goal

The overall goal of the flagship is to ensure that, by 2022, appropriate livestock breeds are readily available, affordable and widely used by poor women and men livestock keepers, resulting in increased livestock productivity, improved food and nutritional security, better livelihoods and improved natural resource management.

2.1.1.2 Objectives and targets

This flagship addresses the SLOs reduced poverty and improved food security for nutrition and health in smallholder and pastoral livestock systems. It does so through two IDOs, increased productivity and increased income and employment. It directly addresses 5 sub-IDOs: closed yield gaps through improved agronomic and animal husbandry practices; enhanced genetic gain; increased conservation and use of genetic resources; increased livelihood opportunities; and technologies that reduce women's labour and energy expenditure developed and disseminated.

The program recognizes that livestock genetics lies at the root of other successful, sustainable and cost-efficient interventions in the livestock sector which, when working in synergy, will maximize its impact. The flagship advocates that the present genetics of livestock species is a main limiting factor for improvement of productivity and thus include a portfolio of genetic interventions such as within indigenous breed improvement (small ruminants, chickens), crossbreeding (dairy cattle) and breed replacement (chickens). The flagship will therefore collaborate with the Livestock Health and Livestock Feeds and Forages flagships to investigate the interface between animal health, genetics and feeds (e.g. responses to vaccination, feed conversion ratio), with the Livestock and Environment flagship to examine responses to changing environmental conditions, and with the Livestock Livelihoods and Agri-Food Systems flagship to optimize livestock systems for productivity and resilience. Outside the livestock CRP, the interaction of livestock with human health, including the impact of breeding zoonotic disease-resistant livestock, will be explored with A4NH. The impact of climate change on livestock performance and genetic improvement strategies will be modelled with CCAFS.

The flagship will directly address national, regional and international livestock research and development priorities. For example, at national level in Ethiopia, it follows the strategies of the Ethiopian Livestock Master Plan (Shapiro *et al.*, 2015), which recommends research on improved pure-line local and crossbred poultry and crossbred cattle, together with expansion of the successful community-based small ruminant breeding improvement program developed in the Livestock and Fish CRP (Shapiro *et al.*, 2015). At the regional level, the flagship responds to and supports decision-making by the African Union Interafrican Bureau for Animal Resources (AU-IBAR), in particular within the scope of its Strategic Priority 2: Strengthening the capacity of African countries in the conservation and use of African animal genetic resources. The flagship also aligns with the recommendations of the second Global Conference on Agricultural Research for Development, responding, from a livestock genetics perspective, to the request to reshape agricultural research so that it better meets the needs of resource-poor smallholder farmers. Last but not least, it may be expected that the flagship's activities will also largely follow the priorities of the ongoing GCARD3 (2015–2016) consultation, with, for example, a strong focus on gender and youth.

The flagship's objectives are:

- Identify and promote the most appropriate existing livestock breeds for systems and value chains (including promotion of breed substitution as relevant).
- Develop improved breeds, capitalizing on recent advances in genomic and reproductive technologies (within-breed improvement, cross-breeding).
- Develop effective delivery systems (public–private partnerships, community breeding schemes).
- Seek improvements in relevant policies and institutional arrangements.

Flagship outcomes to 2022

- 790,000 , 20,000 , 20,000 and 115,000 livestock keeping households (representing 3.7 million , 84,000 , 115,000 & 600,000 individuals, respectively) realizing a 30-50% increase in income, on average, of the household enterprise from chicken, pigs, small ruminant and dairy cattle, respectively, through the use of genetically improved livestock combined with other appropriate animal husbandry practices, across 5 countries.
- 1.5million, 40,000, 45,000 and 230,000 livestock keeping households realizing an 20-25, 20-25, 5 and 20-25% increase in productivity, on average, for chicken, pigs, small ruminants, and dairy cattle, respectively, through the use of genetically improved livestock combined with other appropriate animal husbandry practices, across 5 countries.
- 1.5million, 40,000, 45,000 and 230,000 livestock keeping households realizing an 50-100, 25-50, 6-12 and 50-100% increase in genetic gain, on average, for chicken, pigs, small ruminants, and dairy cattle, respectively, through the use of genetically improved livestock, across 5 countries.

- Guidelines on policy and institutional arrangements for informing breed improvement and conservation options adopted by policy-makers and/or national research partners for one or more species in 4 countries, influencing the practices of 2.2 million livestock keeping households.
- 3.6 million; 50,000; 70,000 and 230,000 women, across 5 countries, enjoy 5-10% increase in returns to their labour, on average, for chicken, pigs, small ruminants and dairy cattle, through the use of genetically improved livestock combined with other appropriate animal husbandry practices.

2.1.1.3 Impact pathway and theory of change

Figures 2.1a and 2.1b present the flagship's ToC and assumptions. The flagship seeks to ensure that resource poor women and men livestock keepers, as well as others in livestock value chains, can access and equitably benefit from improved livestock genetics. It responds to key animal genetics challenges and opportunities related to the two Livestock CRP trajectories:

- For the rapid inclusive growth trajectory, where livestock keepers are most able to access the inputs needed for expression of genetic potential (such as animal health-care and feed), there is an opportunity to increase livestock productivity through the provision of genetically superior livestock for productive traits, whilst ensuring the livestock remain well adapted to the environment under which they perform.
- For the fragile growth trajectory, where productivity is limited by harsh environments and scarce resources, opportunities lie in ensuring that livestock are reliably productive, highly resilient, and that they retain sufficient functional genomic diversity to continue adapting to new environmental challenges.

To respond to these opportunities the flagship will identify the most appropriate genetic improvement strategies in conjunction with national policymakers, research and development partners, the private sector and other stakeholders. These may consist of different avenues and approaches, including breed-substitution, within-breed improvement, cross-breeding, or the development of new breeds through the use of genome editing. Productivity jumps in dairy cattle and chicken will arise from identification of more productive genotypes and their distribution at large geographic scale. For small ruminants, slower but continuous gains across generations are anticipated through breed/population selection approaches. The strategies will consider the needs and preferences of women and men livestock keepers and other stakeholders, the present and future conditions of the production system, including the effects of climate change, mechanisms to ensure long-term sustainability, and the required scale to achieve impact. The identified strategies will be implemented together with partners, first at pilot-scale and then at national or sub-national levels. In tandem, delivery systems for improved livestock genetics will be implemented by national research and development partners and the private sector, ensuring accessibility of the improved livestock genetics to livestock keepers. Supporting these genetic improvement strategies and delivery systems will be guidelines on policy and institutional arrangements for improvement and conservation of animal genetic resources, developed with, and adopted by, research partners, the private sector and policymakers. Attention will be paid to enabling conditions and actions needed for women and men livestock keepers to capitalise on their investment in improved livestock genetics. Embedded in all these steps are the capacity development of partners and stakeholders. Previous lessons have shown that without these any genetic improvement programs will be short-lived and/or of insufficient scale to achieve substantial impact (FAO, 2010).

To further support these changes, the flagship will produce several international public goods (IPGs), including models for genetic improvement in developing country livestock production systems,

improved breeds of livestock, and publicly available data (on livestock systems, livestock performance and livestock genomic diversity).

The changes above will happen because: a vision for a genetic improvement and delivery strategy will be agreed by all stakeholders, including national research and development partners, the private sector, and other stakeholders; and national research and development partners and the private sector will invest in building capacity on genetic improvement and delivery strategies, and support the development and delivery of improved livestock genetics in a sustainable and cost-effective manner.

Previous work in the Livestock and Fish CRP revealed that these assumptions are appropriate and will support these changes among 'next users' of the outputs. This process is already initiated in Ethiopia, Tanzania and Nigeria; partnerships were established, genetic improvement and delivery strategies identified, capacities began to be built, and pilots initiated. In these sites, the focus will be completion of the pilot testing, further strategy refinement and capacity building, and scaling-out. In Uganda and Vietnam, work is at an earlier stage and the focus will be on identifying appropriate genetic improvement strategies and their piloting.

The flagship believes that the changes across different domains of 'next users' will contribute to development outcomes of: increased livelihood opportunities, enhanced genetic gain, closed yield gaps, increased conservation and use of genetic resources, and increased returns on women's labour and energy expenditure. For this to happen, women and men livestock keepers will access feed and health inputs required for the improved livestock to express their genetic potential, and appropriate market incentives for the use of improved livestock genetics will exist and to ensure uptake by women and youth, improved livestock genetics and their delivery systems must be attractive to these users.

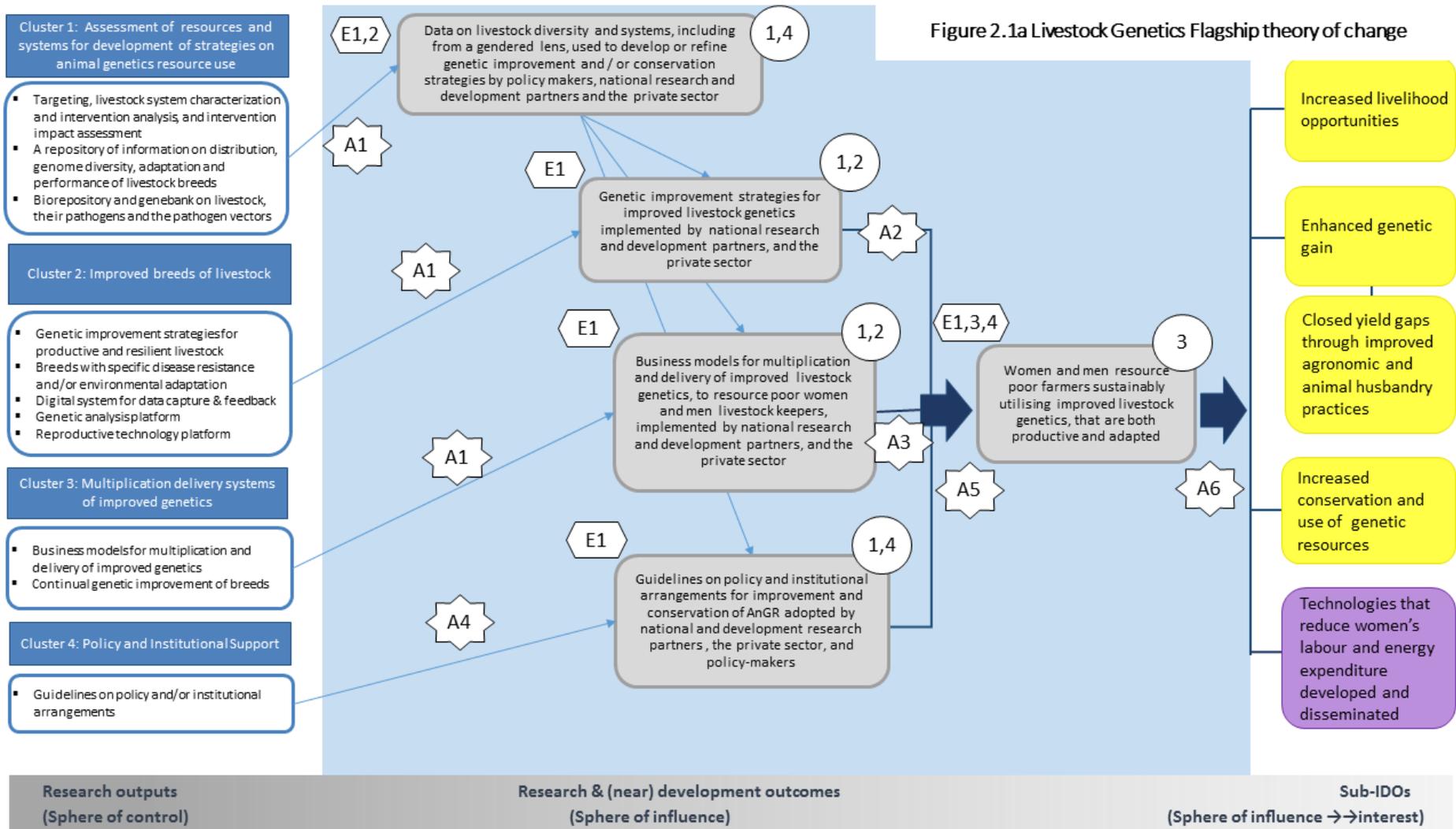


Figure 2.1b Livestock Genetics Flagship theory of change, assumptions, enabling actions and change domains

A1		E1
Assumptions		Enabling cross-cutting actions
A1	<ul style="list-style-type: none"> ▪That genetic improvement of livestock is recognized by stakeholders as providing potential for increased livestock productivity ▪That stakeholders engage in dialogue around national or sub-national genetic improvement and delivery strategies ▪That the needs and preferences of women and men livestock keepers, as well as other stakeholders along the livestock value chains including the youth, and present and future conditions of the production system, are adequately considered in development of the genetic improvement and delivery strategies ▪That a vision for a national or sub-national genetic improvement and delivery strategy is agreed by all stakeholders, including national research and development partners, the private sector, women and men livestock keepers, and the youth 	E1 "Next user" capacity development E2 Consideration of gender & youth issues in strategy assessments E3 Capacity development inclusive of resource poor men and women farmers E4 Consideration of issues affecting use of the improved livestock genetics for different stakeholder groups, including women, men and
A2	<ul style="list-style-type: none"> ▪That national research and development partners and the private sector agree on appropriate institutional arrangements to support the genetic improvement strategy ▪That national research and development partners and the private sector invest in building capacity on genetic improvement strategies ▪That national research and development partners and the private sector support the development of improved livestock genetics in a sustainable and cost-effective manner ▪That national research and development partners and the private sector appropriately monitor the genetic improvement program, and adjust it as necessary ▪That engagement in the development of improved livestock genetics is attractive to women and youth ▪That there is an enabling policy environment 	1
A3	<ul style="list-style-type: none"> ▪That national research and development partners and the private sector agree on appropriate institutional arrangements to support the delivery of improved livestock genetics ▪That national research and development partners and the private sector invest in building capacity on delivery of improved livestock genetics ▪That national research and development partners and the private sector support the delivery of improved livestock genetics in a sustainable and cost-effective manner ▪That national research and development partners and the private sector appropriately monitor the delivery program, and adjust it as necessary ▪That engagement in the delivery of improved livestock genetics is attractive to women and youth ▪That there is an enabling policy environment 	Domains of Change 1 Changes in local, national and international research and development systems 2 Changes in markets, enterprises and consumer behaviour 3 Changes in producer systems (producers and communities) 4 Changes in policy and investment systems for scaling
A4	<ul style="list-style-type: none"> ▪That policy makers are willing to adopt the guidelines on policy and institutional arrangements for improvement and conservation of animal genetic resources ▪That policy makers are willing to resource the implementation of new policy arising from adoption of the guidelines 	
A5	<ul style="list-style-type: none"> ▪That women and men livestock keepers, as well as others involved in the livestock value chains, invest in building capacity on the utilization of genetically improved livestock, including on appropriate livestock management practices ▪That the keeping and use of improved livestock genetics is attractive to women and youth ▪That policy makers and other stakeholders monitor implementation of the new policy, and make adjustments as necessary 	
A6	<ul style="list-style-type: none"> ▪That women and men livestock keepers can access the necessary inputs - in relation to animal health-care, feed and animal housing - required for the improved livestock to express its genetic potential ▪That appropriate market incentives exist for the use of improved livestock genetics ▪That the improved livestock genetics continue to meet the needs and preferences of women and men livestock keepers, and other actors along the livestock value chains ▪That the use of improved livestock genetics results in and lower environmental impact per unit of livestock product 	

2.1.1.4 Science quality

The flagship hypothesizes that informed utilization in breeding programs of functional genome diversity found in indigenous and exotic livestock breeds will lead to major productivity jumps in intensifying systems, while retaining and improving adaptive ability in more fragile systems. Previous successful examples include in the developed world the Myostatin gene (Grobet *et al.*, 1997) in cattle and in the developing world the prolificacy Booroola genes in sheep (Nimbkar *et al.*, 2005). A further hypothesis is that the diversity present in indigenous livestock and crossbreeds will allow continuous genetic gains down the generations, through the design of tailored breeding programs. These are reasonable assumptions. Indeed, recent developments in genomics, phenotypic recording, and breeding and reproductive technologies provide new opportunities for innovative applied research in these areas. However, these technologies remain so far mainly in the developed world and emerging economies, where they have mainly benefited the commercial sector. Links between genetics/genomics approaches and livestock trait performances have been extensively documented for the commercial improved livestock breeds (see Hill, 2014 for dairy cattle, Dekkers *et al.*, 2011 for pigs, and Martins *et al.*, 2012 for broiler chickens).

The flagship strategically includes relevant proven scientific developments and technologies as well as partnerships with advanced research institutes, for example:

1. The flagship will intensively use genotyping tools and develop its own as required, including new generation sequencing and array genotyping technologies that allow probing the entire or targeted region of the genome of an animal at relatively low cost⁷.
2. The flagship will overlay livestock diversity with geo-referenced multi-scale and multidisciplinary data on livestock production systems, allowing a range of analyses including modelling in the field of livestock landscape genomics (Stucki *et al.*, 2014a; Stucki *et al.*, 2014b; Joost *et al.*, 2010).
3. The flagship will further develop the ILRI biorepository of geo-referenced biological samples linked to genome sequences, gene expression, phenotypes, etc.
4. Novel phenomics approaches, as a means of measuring the physical and biochemical traits of animals (e.g. the use of rumen boluses with sensors to monitor rumen condition; automatic recording of respiration rates as an indicator of adaptation to heat stress, etc.) will be combined with the use of mobile phone-based applications to record animal measurements and provide feedback. These will narrow information gaps on livestock performance and provide feedback to farmers, who will have an evidence base for making informed management decisions (Houle *et al.*, 2010; Wanga *et al.*, 2015).
5. The flagship will also apply new and improved genome analysis tools to improve the understanding of the genes and gene networks (genomic architecture) underpinning important livestock traits such as resilience and disease resistance (Rothschild and Plastow, 2014; Bishop and Woolliams, 2014; Boettcher *et al.*, 2014).
6. Genetic markers and genome-wide selection approaches will be implemented (e.g. genomic selection in crossbred animals) (Goddard and Hayes, 2007; Clark and van der Werf, 2013), and genome editing and precision breeding approaches (CRISPRs and TALENs) will be applied to capitalize on recent genome architecture and diversity discoveries (Hackett *et al.*, 2014; Carlson 2014).
7. The flagship will explore and pioneer advanced reproductive technologies relevant to developing country livestock systems, for example the use of primordial germ cell technology for indigenous

⁴ Today, the cost for re-sequencing at 10 x coverage a mammalian livestock around USD 700-800, and around USD 25 for a bird genome (Novogene and Macrogen quotations, February 2016).

village chicken (Nakumura *et al.*, 2013), and the optimization of semen viability and delivery in dairy cattle.

8. The flagship will also continue to develop novel sequence-based technologies as a means of identifying and quantifying pathogen burdens in African livestock and linking these to animal genotypes, in collaboration with the Livestock Health flagship. Joint research with the Livestock Feeds and Forages flagship will be conducted on the relationships between livestock breed-type, feeding regimes and productivity.

Program partners recently partnered with the University of Edinburgh and Scotland's Rural College to establish a joint Centre for Tropical Livestock Genetics and Health (CTLGH). This new centre is at the core of the flagship's strategy for achieving scientific quality. The partnership, as well as others with advanced research institutes such as the University of Nottingham and Wageningen UR will ensure that the program's livestock breeding programs benefit from the latest scientific developments in the fields of genomics and reproduction. These will be expected to catalyse the scientific quality and impact of the flagship's work⁸.

Results will be co-published in high-impact peer-reviewed and open-access journals, and in other forms as appropriate. Staff from these academic institutions will either lead or participate in genomics and animal breeding training programs. The CTLGH partners will also oversee the establishment of new technological platforms at ILRI laboratories, as well as help to strengthen existing platforms (e.g. genome editing and primordial germ cell technology platforms). These institutions will also provide focal points for the registration of ILRI project students at post-graduate levels (MSc and PhD).

The flagship may also partner with the CGIAR Genetic Gains platform, in particular its modules on bioinformatics and data management tools. For the genotyping and sequencing tools and services, it will team up with private companies when they provide quality service at lower cost than CGIAR facilities. It will make use of the BecA-ILRI hub genomic facilities, holding relevant capacity development activities on livestock genomics and bioinformatics. All these partnerships will complement this flagship's critical scientific mass, as well as provide access to up-to-date genomics and bioinformatics facilities.

2.1.1.5 Lessons learned and unintended consequences

This flagship will build heavily on initiatives undertaken in the first round of CRPs, but take into account lessons learned over the years while capitalizing on new technologies and approaches.

Examples of previous projects include:

1. Dairy genetics projects in East Africa and Senegal, which demonstrated the productivity increases possible in smallholder dairy herds when appropriate crossbred animals are used (Ojango *et al.*, 2014; Marshall *et al.*, 2016). This CRP will considerably expand the scope of these studies by increasing the number of crossbred animals being genotyped and by developing new low-cost genetic screening tools.
2. Community-based breeding programs for small ruminants in Ethiopia, which demonstrated the feasibility of this breeding strategy for improvement of meat productivity in low-input systems and highlighted the need for supporting institutional arrangements to ensure sustainability (Muller *et al.*, 2015; Gizaw *et al.*, 2014). This flagship will focus more on supporting policy and institutional arrangements, but also expand this approach to more populations and breeds in Ethiopia, and in North African countries including Morocco.

⁵ University of Edinburgh, Wageningen UR, University of Nottingham are all classified within the 1% top best academic institutions in [worldwide rankings](#).

3. A pilot project for a mobile phone-based data capture and feedback system on livestock performance, which showed the viability of this technology but also the importance of providing sufficient farmer incentives for participation. The flagship will adopt tablet or mobile phone-based data capture for its chicken and dairy cattle projects.
4. A project established a platform for transgenesis from which a cloned bull was generated as proof of concept (Yu *et al.*, 2013). This flagship will complement this work by establishing a platform for genome editing. This may be more easily accepted by the general public than transgenesis and might therefore be prioritized during implementation of the new CRP.
5. The value chain assessments under the Livestock and Fish CRP indicate the lack of data as a basis for making strategic decisions on conservation and use of animal genetic resources (Lagese *et al.*, 2014; Ouma *et al.*, 2015; Sikira *et al.*, 2013). The flagship will respond to this by conducting large-scale livestock genome diversity studies, as well as more market studies for individual livestock products.

The flagship will monitor potential unintended consequences of its interventions and address these. For example:

1. If farmers raise the same number of more productive livestock, this may increase the pressure on natural resources. This will be addressed by working with the Livestock and the Environment flagship on monitoring and introducing mitigation interventions.
2. The contribution of improved livestock genetics to intensification may result in the movement of some livestock keepers out of livestock, and the introduction of business models to deliver superior livestock genetics may displace some current providers of this service. This will be managed by working with the Livestock Livelihoods and Agri-Food Systems flagship to provide opportunities for alternative livelihood options.
3. Promotion of superior livestock genetics could negatively affect livestock biodiversity, particularly in relation to indigenous livestock. This will be mitigated by the promotion of conservation strategies, including *in silico* through the full genome sequencing of the diversity of the livestock population concerned.
4. Introduction of livestock with altered genomic sequences may raise public concerns, which will be addressed by engagement with national counterparts, public awareness and the provision of evidence.

2.1.1.6 Clusters of activity

The flagship is organized in four interlinked clusters of activities. Cluster 1 will provide necessary knowledge and information on livestock and their production systems. These are needed for the successful implementation of cluster 2, which deals primarily with enhanced genetic gains to close the yield gap. Cluster 3 addresses the issue of continuous genetic gains and medium- to long-term sustainability. Finally, cluster 4 deals with the enabling policy and institutional environment that is equally essential for long-term sustainability. These clusters were developed recognizing the important roles that women, men and young people play in livestock production, and they all include strong capacity development components (see the Impact Pathway and ToC section).

W1/W2 as well as substantial W3/bilateral funding will support the activity clusters. The flagship's W1/W2 fund will support the key research elements for the delivery of the 3 sub-IDOs, with W3/bilateral funding supporting more downstream activities (e.g. dairy cattle and chicken projects). This W1/W2 funding will also be used to protect key research (e.g. on small ruminants, pigs) while bilateral funding sought. As needed W1/W2 will be used for new, exploratory and pilot research activities.

Cluster 1: Assessment of resources and systems for development of strategies relating to the conservation and use of animal genetic resources

Better targeting of genetic interventions requires improved knowledge of the systems in which animal genetic resources are used, the phenotypic and genetic characteristics of the resources themselves, and of the broader economic, social and environmental contexts. This activity cluster aims to obtain this information (where it does not yet exist), as a basis for designing better tailored and more appropriate genetic interventions. The approach will involve a broad system assessment complemented by detailed assessments of animal genetic resources and their uses, including productivity and adaptation traits, both studied at the phenomic and genomic levels.

A unique livestock biorepository located on the ILRI compound in Kenya, of mostly geo-referenced biological samples that are linked to genomic sequences, gene expression, performance and other information, will be further expanded (new samples) and developed (use of new genome technologies for analysis of the samples). This asset which is primarily a resource for the study of genetic variation and functional genomics in livestock species, has proven to be invaluable in providing opportunities to access samples and information collected over decades, that can be analysed to provide new information on the genetics underpinning important livestock production and resilience traits. ILRI's Domestic Animal Genetic Resources Information System (DAGRIS), will be linked to the biorepository through information geo-referenced in both databases. Such integration will facilitate modelling of livestock diversity, the identification of livestock populations with unique adaptive traits as resource populations for genomic architecture studies, evidence-based predictions of livestock performance under a future changed environment, and improvement and better matching of livestock breeds to production systems/environments.

The flagship is building on the Livestock and Fish CRP where piloting testing of genetic improvement programs and linked delivery systems were initiated for chicken, goats and sheep, and dairy cattle. Best-bet interventions identified from these various assessments will be shared with stakeholders for joint agreement on which ones potentially take to scale. Targeted systems characterization, as well as gender-sensitive *ex-ante* and *ex-post* impact assessments of interventions, will be performed, resulting in better targeted, selected and monitored genetic interventions, and documented lessons. As a component of this, trade-off assessment will be performed in relation to the keeping of different livestock breeds/genotypes (considering, for example, intra-household livelihoods and environmental sustainability).

Given the strategic and baseline nature of the research activities within this cluster, W1/W2 funds will support all 3 main research outputs as required for successful delivery.

Main research outputs

- A repository of information on the distribution, genetic diversity, adaptation and performance of livestock breeds in developing countries, linked to information on the systems in which they perform.
- Biorepository of biological material and genome sequences of livestock, their pathogens and pathogen vectors.
- Livestock system characterizations and intervention analyses, together with impact assessments, for development of strategies on animal genetic resource use.

Outcomes by 2022

1. Data on livestock diversity and systems, including from a gendered lens, used to develop or refine genetic improvement and / or conservation strategies by policymakers, national research and development partners, and the private sector, in 5 priority countries and other locations.

Milestones

- Data on livestock diversity and systems used to develop or refine genetic improvement strategies in 3 priority countries and other locations (2019).

Cluster 2: Improved breeds of livestock

Improved livestock genetics will increase productivity and resilience and decrease the impact of animal diseases, including zoonoses.

This cluster of activities aims to promote or develop superior genetics, so as to increase the availability of breeds that fit the needs and preferences of women and men livestock keepers, other actors within the livestock value chain or system, and consumers, both now and in the future. The approach will be tailored to the livestock species, system characteristics and stakeholder requirements of specific production systems. Options include increasing the genetic merit of existing populations through within breed improvement programs, breeds substitution and the introduction of improved breeds (for use either as pure-breds or crossed with existing populations) for pilot testing and scaling up, or the creation of improved breed types through innovative approaches such as genome editing. In particular, the genome editing approach will be tested for its value in producing livestock with specific adaptive attributes or disease resistances. Targets include cattle resistant/tolerant to infection with African trypanosomiasis and East Coast fever, and pigs resistant to African swine fever.

Genetic improvement strategies for productive and resilient livestock will be piloted and then scaled up at national or sub-national level. They will be monitored and adjusted as needed. Supportive policy measures and capacity building will help to ensure sustainability (cluster 4).

Information technology will play an important part in engaging the participation of producers in improving their own animals. Hand-held devices and mobile phone-based data capture and feedback systems on animal performance will be refined, such that livestock keepers can make routine assessments of performance and take evidence-based management decisions, including decisions on breeding. Special attention will be paid to ensuring that different socio-economic groups, including women and young people, can have access to and benefit from this system. Given the technological nature of this activity, there is a real opportunity for young people. Analysis platforms will complement the data capture and feedback system. These will be able to capture and merge data from individual farmers into collective datasets, perform analyses to identify genetically superior animals, and generate the feedback for delivery to farmers. In combination, the data capture and feedback systems, and the linked analysis platforms, will underpin national livestock genetic improvement efforts.

A reproductive technology platform as a tool for germplasm multiplication, dissemination and conservation will be further developed in this cluster, at the BecA-ILRI hub. This platform will be supported and used by research programs from the CTLGH.

This cluster of activities has attracted substantial bilateral funding. W1/W2 will be used to ensure delivery of the outputs and the more upstream research components of the activities.

Main research outputs

- Genetic analysis systems for identifying genetically superior livestock.
- Breeds with specific disease resistance and/or environmental adaptation.
- Genetic improvement strategies for productive and resilient livestock.
- Digital systems for capture and feedback to farmers of data on animal performance further tailored to specific systems.
- Reproductive technology platform to support the creation and conservation of improved livestock breeds.

Outcomes by 2022

1. Genetic improvement strategies for improved livestock genetics implemented by national research and development partners, and the private sector in 6 priority countries and other locations.

Milestones

- Genetic improvement strategies for improved livestock genetics implemented at pilot levels in 4 priority countries and other locations (2019).
- Data on livestock diversity and systems, through a gendered lens, used to develop or refine genetic improvement and/or conservation strategies by policymakers, national research and development partners and the private sector, in 3 priority countries and other locations (2019).
- Genetic improvement strategies for improved livestock genetics implemented at pilot levels in 2 additional priority countries and other locations (2022).

Cluster 3: Continuous genetic gains, multiplication and delivery systems

In the previous cluster, the objective is to identify, develop and promote genetically superior livestock. In this cluster, the aim is to continually improve the performance of these livestock and link them to sustainable multiplication and delivery systems. The flagship will therefore also aim to develop business models and create public–private research partnerships for breed improvement programs. For example, partnerships with private chicken breeding improvement companies will be established in Nigeria, Ethiopia and Tanzania, while involvement of the private sector or breed associations will be explored to sustain community-based breeding programs for small ruminants in Ethiopia. Business models will also be established for the multiplication and delivery of improved genetics, including private–public partnerships and franchise models. Specific attention will be paid to ensuring that different socio-economic groups, including women and young people, are involved in, and benefit from, the establishment of business models. Experiences in this area will be exchanged with the other technology flagships.

It is clear that genetically superior livestock require not only their effective dissemination to producers but also the provision of inputs (feed, health) so they can express their full genetic potential. The provision of inputs will be achieved by packaging genetic interventions with other interventions, notably those emerging from the Livestock Health and Livestock Feeds and Forages flagships. Monitoring of adoption and intra-household benefits of these packaged interventions, and initiatives to overcome the barriers to adoption or to the equitable distribution of benefits, will be undertaken with the Livestock Livelihoods and Agri-Food Systems flagship. Similarly, continual monitoring and system refinement will be performed to ensure that the genetically improved breeds continue to meet the needs and preferences of their female and male keepers, as well as the market demands, under (potentially) changing climatic conditions.

This cluster of activities has also attracted some substantial bilateral funding and will be expected to attract more bilateral funding in the future. Again W1/W2 will be used to ensure delivery of the outputs and to support key components, while more bilateral funding is being sought.

Main research outputs

- Business models for continuous genetic gains tested and refined through public–private research partnerships and community-based programs.
- Business models for the multiplication and delivery of improved genetics.

Outcomes by 2022

1. Business models for multiplication and delivery of improved livestock genetics, to resource poor women and men livestock keepers, implemented by national research and development partners, and the private sector in 5 priority countries and other locations.

Milestones

- Business models for multiplication and delivery of improved livestock genetics implemented at pilot levels in 3 priority countries and other locations (2019).
 - Data on livestock diversity and systems, through a gendered lens, used to develop or refine genetic improvement and/or conservation strategies by policymakers, national research and development partners and the private sector, in 3 priority countries and other locations (2019).
2. Women and men resource poor livestock keepers sustainably utilising improved livestock genetics, both productive and adapted, in 3 priority countries and other locations.

Milestones

- The activities of the entire flagship contribute to this 'near' development outcome where technologies, genetic improvement strategies, business models and policy and institutional arrangements are integrated together at pilot levels to create changes for women and men resource-poor livestock keepers.

Cluster 4: Policy and institutional support

Policies on animal genetic resource use, ownership, improvement and conservation are key to ensuring equitable benefits from livestock genetics, as well as sustainable genetic improvement.

In this cluster the flagship will support national partners by ensuring sustainability of the genetic improvement strategy and delivery systems through appropriate policies and institutional arrangements. Capacity development, training and communication initiatives will provide further support. Existing policies, legal frameworks and institutional arrangements will be reviewed, including from a gender perspective, and changes proposed and advocated. This will be done in partnership with key national stakeholders, including agencies and ministries responsible for livestock development, and in alignment with national livestock development strategies. Regional organizations, such as AU-IBAR, will also be involved, together with FAO's Animal Production and Health Division. Initially, this work will focus on selected countries in Africa, but later it will be expanded to other African and possibly to Asian countries.

Closely linked to the other clusters of activities, W1/W2 funds will be used to develop the 'technical' outputs of this cluster.

Main research outputs

- Guidelines on policy and institutional arrangements for informing livestock breed/population improvement and conservation options in developing countries.

Outcomes by 2022

1. Guidelines on policy and institutional arrangements for improvement and conservation of animal genetic resources (AnGR) adopted by policymakers, national research and development partners, and the private sector, in 7 priority countries and other locations

Milestones

- Institutional arrangements supporting genetic improvement strategies and multiplication and delivery systems in place for 3 priority countries and other locations (2019).
- Guidelines on policy and institutional arrangements for improvement and conservation of AnGR adopted by at least 4 priority countries and other locations (2022).

2.1.1.7 Partnerships

Core flagship partners: These are advanced research institutions (new technologies and new sciences), national programs (testing and use of new genotypes, new technologies and new sciences), and private-sector companies (delivery of improved livestock breeds and continuous genetic improvement strategies).

Partners to leverage scientific comparative advantage: To harness the necessary scientific comparative advantages, building-up on partnership already ‘piloted’ in the Livestock and Fish CRP, the flagship will further develop its strategic partnerships with leading academic institutes, through the CTLGH which combines complementary expertise from the developing and the developed worlds in the areas of livestock genomics and health. It includes research programs aiming to harness bovine and poultry tropical adaptation and disease resistance to improve productivity and to develop novel reproductive and germplasm technology in poultry. It also includes a platform for genome editing. Wageningen UR will partner on poultry research (molecular and breeding) and support the flagship’s research-oriented capacity development initiatives. SLU leads the Livestock Health flagship and accordingly will provide scientific expertise at the interface between genetics and health. It also has a strong bioinformatics team collaborating with BecA-ILRI Hub and hosts the International Bull Evaluation Service, an important delivery partner.

Through CTLGH, the program will have access to relevant research consortia, such as the International Functional Annotation of Animal Genomics. The flagship will also contribute to several ongoing or emerging initiatives to set up genome diversity research consortia (e.g. ‘1000K’ cattle, sheep or chicken genome projects) by contributing its livestock genome diversity data and gaining access to other genome information relevant for its activities. Flagship partners are part of the African Goat Improvement Program and the ADAPMap Consortium. All of these provide further opportunities to interact with advanced research institutes such as Iowa State University, USDA, etc. Besides these academic research partners, the flagship will team up with private partners, including Recombinetics (for genome editing) and genome sequencing companies, such as Novogene.

Partners for effective innovation systems in program sites: the flagship’s partners in priority countries and locations are actors throughout the value chain. Given the multi-country focus of its activities, the flagship will continue to work with FAO and AU-IBAR, which provide overarching knowledge and policy frameworks to national program partners. It will work closely with these partners, which will be implementing genetic improvement strategies at sites. For example, in the dairy genetic improvement activities in Ethiopia and Tanzania, the partnership includes the Ethiopian Institute of Agricultural Research, the Tanzania Livestock Research Institute, and national artificial insemination centres in both countries. Together with the private sector (Genus, an artificial insemination company) and NGO partners (e.g. Land O’ Lakes), these national partners will lead in the importation, introduction and delivery of improved dairy genetics in line with national policies and livestock strategies, as well as country-endorsed international treaties.

Partners for effective scaling as part of regional and global innovation systems and multi-stakeholder platforms: Private-sector partners will be involved in the development of business models, but also in breeding improvement and in supporting intervention and scaling up in target

countries and beyond. The flagship will identify these partners at an early stage and bring them into the design and implementation of breeding schemes. They could include, for example, subsidiaries of major chicken breeding companies (Cobb-Vantress, Aviagen, Hendrix, Hyline, etc.).

2.1.1.8 Climate change

Genetic improvements can help livestock production systems adapt to and mitigate climate change. Adaptation involves reducing the vulnerability of people and ecosystems by developing genetic improvement strategies that produce resilient and productive genotypes (Hayes *et al.*, 2013). The flagship will focus on breeds that are already adapted to harsh agro-ecological conditions and aim to identify at genome level their adaptive traits linked to heat tolerance in addition to the ability to survive, grow and reproduce under conditions of poor nutrition, parasites and infectious diseases. The distribution and severity of these environmental challenges are already being altered by climate change.

Mitigation involves reducing the impact of climate change in the long term by reducing the emission of greenhouse gases per unit of animal product, through increased genetic-based productivity (e.g. lowering the number of heads required per unit of livestock commodity) and better management (especially of feed), allowing for higher reproductive potential (earlier age at first calving, shorter calving intervals) and faster growth rates, such that animals reach sale weight at an earlier age (Gerber *et al.*, 2011; Gerber *et al.*, 2013). This flagship will work closely with the Livestock and the Environment and the Livestock Feeds and Forages flagships on these issues.

2.1.1.9 Gender

Understanding gender issues in genetic resource use, and designing interventions based on this understanding are critical (see Annex 3.3). Research on these issues will be done with the Livestock Livelihoods and Agri-Food Systems flagship.

Key gender issues to be addressed include (i) ensuring the participation of women and men livestock keepers in establishing genetic improvement priorities (based on their different needs, different species preferences and different priority traits), and in choosing a genetic improvement strategy (for example, considering different impacts of gender norms on participation in community-based genetic improvement programs); (ii) ensuring that chosen genetic technologies meet the different needs and preferences of women and men identified in (i), increase the benefit per unit of women's labour expended and/or reduce women's net labour expenditure; (iii) ensuring gender-equitable access to genetic technologies and to associated information; and (iv) addressing issues of control, for example in decision-making on genetic technologies, over access to and use of the technologies, and over any benefits resulting from their use.

Youth

The flagship recognizes that young people are not a homogenous group but will have varied appetites for participating in the genetic improvement of livestock. It will work across the CRP to ensure that interventions in livestock genetics lead to opportunities for youth entrepreneurship and employment (see Annex 3.4). Young people appreciate opportunities to make money, preferably relatively quickly and without excessive upfront investment. Areas for possible engagement, and income generation, include the keeping of genetically superior livestock, participation in livestock genetic improvement programs, recording animal performance, serving as feedback agents, developing locally relevant digital applications for extension packages, and acting as a service provider in genetic improvement and scaling up.

2.1.1.10 Capacity development

The flagship has a strong capacity development component in its ToC. Capacity development is central for the flagship to take its research results to scale and ensure the sustainability of genetic interventions (see Annex 3.2).

This component will involve actors throughout the value chain in embracing new genetics and genomic science and its implications for their livelihoods. The flagship will therefore have an impact on all the capacity development sub-IDOs: Enhanced individual capacity, increased capacity for innovation in partner research organizations, increased capacity for development in partner development organizations, and enhanced institutional capacity.

The focus will be on capacity development among individuals (farmers, scientists, policy-makers), organizations (e.g. farmer communities, breed associations), national institutions (agricultural research centres, relevant academic bodies) and the local private sector. The flagship will combine traditional and novel capacity development activities, including farmer field schools, video, mobile applications, MSc/PhD training, and innovation platforms. Capacity development initiatives will draw on needs assessment and use innovative learning materials and approaches, including gender-sensitive approaches and attention to young people.

Curricula and training modules for post-graduate programs in animal breeding, genomics and genetics for African regions will be developed, building on past projects such as the Animal Genetics Training Resource. It will develop capacity development partnerships, for example with the PICO-team East Africa and with academic institutions such as SLU, Wageningen and the BecA-ILRI hub.

The CGIAR capacity development elements to be addressed are: needs assessment and intervention strategy; learning materials and approaches; development of future research leaders; gender-sensitive approaches throughout capacity development; and institutional strengthening.

2.1.1.11 Intellectual assets and open access management

Robust IA management, open access and research data management and communications help in uptake and achieving outcomes (sections 1.0.12, 1.0.13 and 1.0.14 and annexes 3.8, 3.9, and 3.10.7). Specific issues relevant to this flagship are listed here.

For IA management, an important element of the flagship's breeding work (breed multiplication) may be conducted in partnership with private companies. This will be managed through materials transfer agreements that will allow the flagship to use and disseminate the company's products. In other cases, the focus is on community-based breeding, where the results are generated and owned by rural communities and those using the information and data must recognize farmers' communal and legal rights. In still other cases, flagship projects collect data through partners and agreements are needed that recognize the ownership of the data by the third party and the flagship's rights to disseminate any analysis and results from the data (with attribution). More generally, flagship activities will be guided by the Global Plan of Action for Farm Animal Genetic Resources and the [Interlaken Declaration](#), which ensures that the world's livestock biodiversity is used to promote global food security and remains available to future generations.

Ensuring that raw data are well documented and accessible will be tackled through partner open access and data management plans. Most of the information products of the Livestock and Fish flagship are already open access. This includes materials accessible through [CGSpace](#). Additionally, the flagship will reserve funds each year to enable bilateral projects to pay article open access fees when

needed. Further upstream, genome sequencing generates large amounts of data that will be put into open databases such as NCBI, while for other types of data (e.g. results of breed surveys, phenotypic information) it will make use of digital repositories such as DRYAD.

2.1.1.12 Flagship management

Implementation of the flagship will be led by a flagship leader (FL). The flagship core team (flagship leader and senior scientists) will develop and update the research agenda and impact pathway, as well as monitoring the quality and delivery of the outputs and reporting. The FL will lead guide priority strategic research and allocation of W1/2 resources as well as any strategic exploration of new research areas; guide development of bilateral projects to ensure alignment to the flagship their ability to contribute to strategic synthesis funded by W1/2; coordinate all reporting; lead cross-flagship initiatives; support and sometimes lead resource mobilisation and lead bi-monthly meetings (face-to-face or virtual). Senior scientists in the flagship will help develop the flagship strategy, and in particular will guide the design of research within their scientific areas of expertise. They will also monitor the science quality of outputs.

The flagship will adopt a flat management structure with ILRI and ICARDA scientists leading specific projects and contributing, within the remits of their scientific expertise and experience, to the entire flagship portfolio. The flagship will be led by Olivier Hanotte (ILRI); 20% of his time will be supported by W1/2, with 20% administrative support, and an annual Flagship meeting.

Regular (monthly) virtual flagship meetings will be held, supplemented by a yearly face-to-face meeting with all key flagship partners to reflect on lessons and re-set strategies as needed. The yearly meeting will be the opportunity for flagship members to present their scientific results.

2.1.2 Flagship Budget Narrative

2.1.2.1 General Information

CRP Lead Centre's Name: ILRI

Centre Location of Flagship Leader: Ethiopia

2.1.2.2 Summary

Total Flagship budget summary by sources of funding (USD)

Funding Needed	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2	3,793,723	3,983,410	4,182,580	4,391,709	4,611,295	4,841,859	25,804,579
W3	5,049,093	5,301,548	5,566,626	5,844,957	6,137,205	6,444,065	34,343,496
Bilateral	1,706,628	1,791,959	1,881,557	1,975,635	2,074,417	2,178,138	11,608,336
Other Sources	0	0	0	0	0	0	0
	10,549,444	11,076,917	11,630,763	12,212,301	12,822,917	13,464,062	71,756,404

Funding Secured	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2 (Assumed Secured)	3,793,723	3,983,410	4,182,580	4,391,709	4,611,295	4,841,859	25,804,579
W3	5,049,093	5,132,886	80,198	80,198	80,198	80,198	10,502,772
Bilateral	1,706,695	1,368,565	1,209,000	1,152,000	0	0	5,436,260
Other Sources	0	0	0	0	0	0	0
	10,549,511	10,484,861	5,471,778	5,623,907	4,691,493	4,922,057	41,743,607

Funding Gap	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2 (Required from SO)	0	0	0	0	0	0	0
W3 (Required from FC Members)	0	-168,662	-5,486,428	-5,764,759	-6,057,007	-6,363,867	-23,840,723
Bilateral (Fundraising)	67	-423,394	-672,557	-823,635	-2,074,417	-2,178,138	-6,172,074
Other Sources (Fundraising)	0	0	0	0	0	0	0
	67	-592,056	-6,158,985	-6,588,394	-8,131,424	-8,542,005	-30,012,797

Total Flagship budget by Natural Classifications (USD)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
Personnel	3,260,437	3,423,459	3,594,632	3,774,364	3,963,082	4,161,236	22,177,214
Travel	329,749	346,236	363,548	381,725	400,811	420,852	2,242,923
Capital Equipment	145,000	152,250	159,862	167,855	176,248	185,060	986,277
Other Supplies and Services	2,449,625	2,572,106	2,700,712	2,835,747	2,977,535	3,126,411	16,662,138
CGIAR collaborations	0	0	0	0	0	0	0
Non CGIAR Collaborations	2,979,346	3,128,313	3,284,729	3,448,965	3,621,414	3,802,484	20,265,254
Indirect Cost	1,385,287	1,454,551	1,527,279	1,603,643	1,683,825	1,768,016	9,422,603
	10,549,444	11,076,915	11,630,762	12,212,299	12,822,915	13,464,059	71,756,394

Livestock CRP: Full Proposal 2017-2022

Total Flagship budget by participating partners (signed PPAs) (USD)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
ILRI	9,688,789	10,173,228	10,681,890	11,215,984	11,776,784	12,365,622	65,902,298
SLU	53,323	55,989	58,788	61,728	64,814	68,055	362,698
ICARDA	807,333	847,700	890,085	934,589	981,319	1,030,385	5,491,414
	10,549,445	11,076,917	11,630,763	12,212,301	12,822,916	13,464,062	71,756,404

The flagship aims to deliver 5 targeted outcomes including a gender cross-cutting one, through clusters of activities.

Personnel costs is the main cost driver in the budget. To deliver the 5 targeted outcomes to which this flagship is aligned, a total of 42.41 FTEs/per annum are required over the 6 year life of the program (214.98 FTE in the current budget). It represents approximately 47% of the total flagship budget. These staff include Principal Investigators (Program Director/Leader, Principal Scientists, Senior Scientists, Scientists), Research support staff (Post-doctoral scientists, Research Associates/Assistants, Bio-repository Manager, Reproductive Platform Manager, Research Technicians, Technical Assistants, Field Assistants) and Administrative Support staff (Program Manager Officer (International and national), Administrative Assistant, Accountant). This number also includes new hires:

- Bioinformatician (Years 1, 2, 3 and 4 at 1.0 FTE): W3/Bilateral funding. A scientist senior position (5B level 3). This position will be implementing and leading the daily bioinformatics operations that underpin bilateral/window 3 projects.
- Linux Systems Administrator (Informatics) (Year 1: 0.5 FTE, Year 2: 0.5 FTE, Year 3: 0.25 FTE, Year 4: 0.25 FTE): W3/Bilateral funding. A national recruited staff based at ILRI - Nairobi. This systems administrator will be responsible for both hardware and system-level software that underpin all of the informatics needs of all of the Animal Genetics Flagship Project.
- A Post-Doctoral Bioinformatic position (Years 1, 2, 3 at 1.0 FTE): W1/W2 funding. This full-time position will be expected to lead the bioinformatic analysis at ILRI – Addis Ababa, more particularly in relation to the analysis of full genome sequences analysis from different projects. Initially, funded by W1/2 for a maximum of three years it is expected to be supported through bilateral/W3 project in subsequent years.
- A Post-Doctoral Quantitative/Animal Breeding position (Years 1, 2, 3, 1.0 FTE). W1/W2 funding. Based at ILRI – Nairobi. This full-time position will be expected to support the quantitative/molecular and animal breeding analysis of all relevant flagship not predominantly funded by W3/bilateral funding. This is therefore a strategic position for the flagship in support of activities currently, deemed essential for the delivery its outcome target but currently poorly funded by bilateral funding (e.g. pig breeding in Uganda/Vietnam, cattle dairy West Africa).
- An Animal Scientist (Years 1, 2, 3 at 1.0 FTE). W1/W2 funding. Based at ILRI – Addis, this person will be leading the development of ILRI – DAGRIS (Domestic Animal Genetic Resources Information System), currently on-hold following the decline in W1/W2 funding for the Phase 1 Livestock and Fish CRP). It will be funded by W1/W2 for a maximum, of three years, in subsequent years, it is expected to be supported through bilateral/W3 project funds (e.g. 10K Livestock Genome project).

Delivery of Outcome 1 (790,000 , 20,000 , 20,000 and 115,000 livestock keeping households (representing 3.7 million , 84,000 , 115,000 and 600,000 individuals, respectively) realizing a 30-50% increase in income, on average, of the household enterprise from chicken, pigs, small ruminant and dairy cattle, respectively, through the use of genetically improved livestock combined with other appropriate animal husbandry practices, across 5 countries will require approximately 30% (\$7,600,000) of the flagship's W1/W2 allocation. A total of 45.72 FTEs is required over the life of the

program at a cumulative cost of approximately \$5,000,000. Skill categories here include animal geneticists, animal breeders, animal systems specialists, agricultural economists, capacity development specialists. No new hires are required for this outcome.

Lesser amounts of W1/W2 budget are assigned to operational costs (travel, capital equipment and supplies and services) associated with delivering this outcome. Included here are the budget for communication, open data access and data management. A small travel budget of about \$30,000 is required for visits to partner institutions, attendance to country meetings, capacity development activities and field sites visits and activities.

Bilateral funding to the value of about \$5,000,000 also supports the achievement of Outcome 1. Of this amount, approximately 30% is budgeted for personnel, representing a total of 18.92 FTEs over the life of the program. No new staff will be hired on bilateral funding. Smaller amounts of the projected bilateral funding are assigned to operational costs, namely \$176,000 for essential within country travel, \$146,000 for supplies and services (consultancy cost for baselines studies and review of protocols). No bilateral funding is allocated to capital equipment for this outcome.

Outcome 2 (1.5 million, 40,000, 45,000 & 230,000 livestock keeping households realizing an 20-25, 20-25, 5 and 20-25% increase in productivity, on average, for chicken, pigs, small ruminants, and dairy cattle, respectively, through the use of genetically improved livestock combined with other appropriate animal husbandry practices, across 5 countries) will require approximately 15% (\$3,800,000) of the flagship's W1/W2 allocation, including 22.85 FTEs over the life of the program at a cumulative cost of just over \$2.5M. Skill categories here include animal geneticists (molecular and quantitative), animal breeders, bioinformatician and animal geneticists, animals breeders. 3.00 FTEs of new hires (bioinformatics, quantitative geneticists) are required.

Lesser amounts of W1/W2 budget are assigned to operational costs (travel, capital equipment and supplies and services) associated with delivering this outcome. Included in the supplies and services line items are major funding for Genomic and Phenomic approaches as well as the analytical platforms, namely \$1.1M. A travel budget of about \$150,000 is required for visits to partner institutions, attendance to country meeting, capacity development activities and field sites visits and activities as well as the livestock industry advisory meeting.

Bilateral funding to the value of approximately \$2.5 million also supports the achievement of Outcome 2. Of this amount, approximately 15% is budgeted for personnel, representing a total of 9.46 FTEs over the life of the program. 2.75 FTE will be hired on bilateral funding in order to have capacity in bioinformatics and database management.

The following amounts of the projected bilateral budget are assigned to operational costs, namely about \$90,000 for travel is required for project inception and annual planning meeting, inter-country and in country meetings. \$520,000 for laboratory supplies and genotyping expenses and \$109,000 for capital equipment (for on-site recording of performance of livestock performance, laptop and country computing servers).

Outcome 3 (1.5million, 40,000, 45,000 and 230,000 livestock keeping households realizing an 50-100, 25-50, 6-12 and 50-100% increase in genetic gain, on average, for chicken, pigs, small ruminants, and dairy cattle, respectively, through the use of genetically improved livestock, across 5 countries will require 15% (\$3,802,000) of the flagship's W1/W2 allocation, including a total of 22.87 FTEs over the life of the program. Skill categories include animal geneticists (molecular and quantitative), animal breeders, bioinformatician and animal geneticists. Three FTEs of new hires (bioinformatics, quantitative geneticists) are required.

Lesser amounts of W1/W2 budget are assigned to operational costs (travel, capital equipment and supplies and services) associated with delivering this outcome. Included in the supplies and services line items are major funding for the reproduction platform at \$550,000. A travel budget of about \$150,000 is required for visits to partner institutions, attendance to country meeting, capacity development activities and field sites visits and activities as well as meeting with breeding companies.

Bilateral funding to the value of almost \$2,5M also supports the achievement of Outcome 3. Of this amount, approximately 15% is budgeted for personnel, a total of 9.46 FTEs over the life of the program. 2.75 FTE will be hired on bilateral funding in order to have capacity in bioinformatics and databases management. The following amounts of the projected bilateral budget are assigned to operational costs, namely \$88 000 for travel is required for project inception and annual planning meeting, inter-country and in country meetings. \$520,778 for supplies and services (laboratory supplies and genotyping cost) and \$110,000 for capital equipment (for on-site recording of performance of livestock performance, laptops and country computing servers).

Delivery of Outcome 4 (Guidelines on policy and institutional arrangements for informing breed improvement and conservation options adopted by policy-makers and/or national research partners for one or more species in 4 countries, influencing the practices of 2.2 million livestock keeping households), will requires 20% of the flagship's W1/W2 allocation, including 31.36 FTEs over the life of the program with the following skill categories - animals breeders, animals systems scientists and capacity development specialists. Three FTEs of new hires (Animal Scientist DAGRIS) are required. Lesser amounts of W1/W2 budget are assigned to operational costs (travel, capital equipment and supplies and services) associated with delivering this outcome. Included in the supplies and services line items are major funding for the bio-repository platform at about \$500,000. Capital equipment supported by W1/W2 funds included computer servers and workstations at \$200,000. A travel budget of \$200,000 is required for visits to partner institutions including international (FAO) and regional partners (AU-IBAR) attendance to country meeting and capacity development activities.

Bilateral funding to the value of \$2,977,000 also supports the achievement of Outcome 4. Of this amount, approximately 18% is budgeted for personnel, representing a total of 11.27 FTEs over the life of the program. No FTE will be hired on bilateral funding. Operational costs include only travel costs (about \$100,000 for within countries meeting with policy makers, meeting at the country ministries, capacity development including training workshops) and a total of approximately \$600,000 for supplies and services (support for activities leading of the delivery outcome 1, 2 and 3).

Outcome 5 (3.6 million; 50,000; 70,000 and 230,000 women, across 5 countries, enjoy 5-10% increase in returns to their labour, on average, for chicken, pigs, small ruminants and dairy cattle, through the use of genetically improved livestock combined with other appropriate animal husbandry practices) absorbs 20% (\$5,067M) of the flagship's W1/W2 allocation, including 30.48 FTEs over the life of the program. The main skill categories here include gender and capacity development specialists beside animal geneticists (molecular and quantitative) and animal breeders. Budget provision has been made for input from the ILRI Gender unit.

Lesser amounts of W1/W2 budget are assigned to operational costs (travel and supplies and services) associated with delivering this outcome. Included in the supplies and services line item are e.g., field operation inputs (e.g., survey material), consultant's fees for gender and capacity development as well as surveys. A travel budget of \$200,000 is required for sites visits, field work, demand prioritization, participation in national and international conferences.

Bilateral funding to the value of just over \$1,000,000 also supports the achievement of Outcome 5. Of this amount, approximately 5% is budgeted for personnel, a total of 12.61 FTEs. The following amounts of the projected bilateral budget are assigned to operational costs, namely: \$120,000 for travel for field work, participation in international meetings and conferences; \$700,000 for supplies and services (surveys, materials, capacity development).

Management of the Flagship (W1/W2) is budgeted at 20% of the Flagship Leader's time while smaller amounts are provided for other management staff such as a Program Management Officer and a Program Accountant. Also, all major flagship bilateral projects benefit from the input of a Program Manager Officer or Senior Administrative assistant, full time FTE 1.0) or part-time in the case of smaller, bilaterally-funded projects to provide overall administrative, financial and human resource support. The remaining of the cost of the flagship leader is covered through bilateral funding. The management costs are pro-rated across the outcomes.

2.1.2.3 Additional explanations for certain accounting

For the CGIAR partners, personnel costs are defined as the total remuneration costs of an individual: base salary, fringe benefits and other employment costs. Actual computations on average for fringe benefits and employment costs in relation to base salary would translate to an average multiplier of 97% and 68% for international and national staff respectively. The reason for the higher average multiplier for international staff is because of the housing allowance, security and education allowance that are not provided to nationally recruited staff. Fringe benefits include: pension, housing allowances, education allowance, security, health insurance, other insurances, catastrophe fund, annual leave and severance pay. Other employment related costs include staff training and development; transportation, recruitment, appointment and repatriation allowances and payroll administration fees.

For SLU, the 51.3% fringe benefits is constituted as a Swedish tax that the employer must set aside for the employees and covers vacation, sick-leave, parental leave, part of the pension, full professional insurance and part of health care costs.

The cost structure of research undertaken during the first phase CRPs has been applied to estimate the average research costs for collaborators, consumables, other supplies and services, and travel. The actual cost structure for secured W3/bilateral projects is first applied, and the average research cost factors are then applied to the remaining portions of the budget yet to be secured. The laboratory cost estimates are based on the cost estimates provided by the BecA-ILRI Hub in providing these range of laboratory services to current Hub users in ILRI - Nairobi, for ILRI - Addis it is based on CRP Livestock and Fish current cost, but it should be noted that these may change following the opening of a new biotechnology lab at ILRI- Addis Campus.

2.1.2.4 Other Sources of Funding for this Project

This flagship is funded by a mix of W1/2 and W3/bilateral funding. Funding from W3 and bilateral sources is fully secured for Year 1 and under the base budget scenario and to a large extent for Year 2 and Year 3. Years 4, 5, 6 will require new W3 and/or bilateral funding.

Cash and in-kind funding: Partners provide substantial cash or in-kind funding. For example (i) flagship activities in China benefit from cash and in-kind support from the Chinese Academy of Agricultural Science for housing, laboratory supplies and consumables at an estimated cost of \$45,000 year; (ii) for the African Chicken Genetic Gains (ACGG), an additional \$3,385,906 mainly in-kind funding has been

secured from partners. This includes \$1,059,606 from ILRI (office space, ICT and research coordination costs that are not covered by the donor, \$710,000 from the Ethiopian Government, \$420,000 from the Nigerian Government, \$650,000 from the Tanzanian Government, \$101,500 from Wageningen UR and \$44,800 from PICO East Africa. The Koepon Foundation has committed \$400,000 in cash; (iii) similarly for the African Dairy Genetic Gains (ADGG) project, also supported by the Bill and Melinda Gates foundation, ILRI will provide in-kind contributions US\$ 254,699 (US\$ 85,766 in Year 1 and US\$ 94,063 in Year 2); the University of New England provides in-kind support of \$309,810 (Year 1 and 2); (iv) the Centre for Tropical Livestock Genetics and Health (CTLGH) will cover the balance of the overheads on the flagship staff time funded by the Bill and Melinda Gates foundation at a total amount of \$ 719,890 (total for Years 1, 2, 3, 4).

New funding initiative: Recognizing the high degree of uncertainty with W1/2 funding, both in terms of whether the indicative allocation assigned to the CRP in the CRP2 guidance document will be maintained once the CRP portfolio has been approved, and in terms of whether the projected budget assigned to the CRP in the System Financial Plan each year is actually achieved through donor W1/2 commitments, the program will be prepared to reduce the scope of its activities and outcomes to reflect any W1/2 funding shortfalls, especially after Year 3. The flagship's strategy is to maintain a minimum of capacity (molecular, breeding, quantitative genetics, socio-economist etc.) to ensure outcomes are delivered. It will scale down activities by focusing on a smaller number of project sites rather than eliminating any cluster of activities as they are all interlinked and needed to deliver outcomes.

In addressing such a scenario, high priority will be given to mobilise bilateral funding to implement the full program and achieve the outcomes.

Two fully-funded bilateral projects are in the pipeline: A TCP submitted to FAO "Regional cooperation for conservation, improvement and sustainable utilization of sheep and goats genetic resources affected by the ongoing crisis in West Asia" , \$0.5M (anticipated start date 2017) and a project submitted to the OCP Foundation on "Tapping camel genetic resources to build resilience and improve livelihoods of pastoralists in the Horn of Africa and North Africa regions" \$0.75M (anticipated start date 2017). While the former will geographically expand the scope of flagship activities, the latter represents an important pilot project exploring the importance of a 'non-traditional' animal genetic flagship species.

This flagship has also identified the following two new major projects to address the need for replacement funding as current projects end insuring that priority targets and outcome are delivered and to secure resources for the uplift budget scenario.

1. Funds will be sought for a major new initiative to sequence the genomes of all currently recognized livestock breeds. Called the 10K livestock genomes project, it will have a very strong capacity development component to empower national livestock research institutions in bioinformatics and genomics, Expected outputs will respond to the needs and demands from these institutions for scientific knowledge (genome sequences data and their analysis) to facilitate the prioritization of breed conservation. This project will directly contribute to sub-IDO, increase conservation and use of genetic resources by providing a catalogue of the genetic diversity present in a livestock breeds (in silico ex-situ diversity conservation) and a catalogue of candidate functional polymorphisms linked to genome signature of adaptive traits in the same population opening the door to marker-assisted improvement of productivity and genome editing. It will also contribute to sub-IDOs Enhanced genetic gain and Close yield gaps to improve agronomic and animal husbandry practices. It is therefore linked to increased productivity. Expected project outcomes are: (i) Distributed in silico gene bank of livestock genetic diversity; (ii) sustainable improvement of livestock productivity with breeding programs using genome diversity information (e.g. marker-assisted selection, genome

editing); (iii) identification of livestock pathogens and commensal reservoirs, including zoonotic species; (iv) new understanding of genome function and new sources of diversity for developed world breeds; (v) genome analysis capacity embedded in developing countries. Initially, funds will be sought for a pilot study involving 100 breeds/ecotypes from each of 3 ruminant species (cattle, sheep, goats) plus chickens, sampled across 10 African countries at an approximate cost of \$3.7M. The flagship expects the pilot to start in 2018. The eventual target is to sequence some 10,000 livestock breeds/ecotypes from 9 species (cattle, sheep, goats, chickens, pigs, yak, buffalo, dromedary, yak) with an approximate total cost of around \$70M. This project will represent an extraordinary value in terms of knowledge and capacity embedded into developing country systems and genomic understanding to secure the future of livestock productivity in a rapidly changing world.

2. A second major initiative is the development of a Long Term Genetic Gain Program (LTGG) to follow-up the already-funded African Chicken Genetic Gains (ACGG) and African Dairy Genetic Gains (ADGG) projects focusing on tropically-adapted and farmer preferred chickens and dairy cattle for sustainable productivity growth. The project will be a research for development initiative jointly designed by the Animal Genetics flagship, National Agricultural Research Systems, and private chicken and dairy cattle breeding companies. The program will aim to set-up (i) a long term and sustainable genetic gains program, using farmer preferred strains (chickens) and optimal agro-ecosystems dairy x indigenous cattle crossbred as base population, using the National Agricultural Research System and/or private sector breeding facilities to continually improve poultry strain productivity and dairy crossbred productivity; (ii) establish a multiplier flock (chickens) and delivery AI system (crossbred dairy cattle) through a network of hatcheries/multipliers or artificial insemination centres that should become self-sustaining and functioning in the long-term. Piloting of these activities are included in the current ACGG and ADGG projects but they will need to be scaled and sustainability mechanisms will need to be put in place. The target is to increase the productivity level by 2% annually (e.g. eggs and/or milk production). The estimated budget for the first five-year period is \$20M each for the chicken and the crossbred dairy cattle projects, starting from 2019/2020 onwards.

Project focus	Total amount (\$)	Start Year
Conservation, improvement and sustainable utilization of sheep and goats genetic resources in West Asia	0.5M	2017
Camel genetic resources to build resilience and improve livelihoods of pastoralists in the Horn of Africa and North Africa regions	0.75M	2017
10K livestock genomes project (Pilot phase Africa)	3.7M	2018
Long Term Genetic Gain Program (LTGG) chicken	20M	2020
Long Term Genetic Gain Program (LTGG) dairy cattle	20N	2020
TOTAL FUNDING GAP	26,950 M	

2.1.2.5 Budgeted Costs for certain Key Activities

	Estimate annual average cost (USD)	Please describe main key activities for the applicable categories below, as described in the guidance for full proposal
Gender	2,280,502	Funding for gender activities are from two sources: First is gender-specific funds, this includes a gender post-doc position (FTE 1.0) for Year 1, as well as support for a Gender Scientist position (W1/W2, FTE 0.20) over the six years CRP period. The second source is bilateral Funding related to gender supports a national staff gender specialist position (FTE 0.10) over years 1, 2, 3.
Youth (only for those who have relevant set of activities in this area)	90,000	Areas for possible engagement include income generation, include the keeping of genetically superior livestock, participation in livestock genetic improvement programs, recording animal performance, serving as feedback agents, developing locally relevant digital applications for extension packages, and acting as a service provider in genetic improvement and scaling up.
Capacity development	1,544,424	Capacity development activities have a strong gender focus and the CRP estimates that half of the CapDev budget is linked to gender-related activities.
Impact assessment	0	Funding for Impact Assessments is managed out of the Strategic Investment Fund.
Intellectual asset management	2,721	A small budget has been set aside for ad hoc IP advice and support for contract development. This will be supported by in-kind investments of the partners and support from management level.
Open access and data management	253,816	The budget is allocated to covering costs of open access. Since some journal articles are limited access and the flagship will reserve funds each year to supplement bilateral projects to pay article open access fees. The flagship has allocated funds on an annual basis to ensure proper curation and publishing, including inputs to research quality and design.
Communication	58,270	The budget covers staff time as well as direct costs to ensure effective communication of its results. Bilateral projects in this flagship are expected to budget for these activities.

2.1.2.6 Other

Overall, there are relatively few risks for the flagship to operate within the proposed budget. There are risks associated with the complex and dispersed nature of the project which makes costing and monitoring potentially challenging and will require monitoring and flexibility. The CRP will attempt to reduce the level of interdependence among activities while maximizing their synergies. These issues

place a significant responsibility on the flagship team to monitor execution and to coordinate and communicate as rapidly as possible. All members of the project have worked together and the senior leadership team is experienced in managing projects of this scale and complexity. The most common cause of delay is associated with recruitment but in the case of this flagship the key personnel are already identified and/or in place. However, this risk is likely different across the different parts of the Flagship. For example, recruitment may be difficult for certain skill sets, e.g bioinformatic positions, as people with such skills are in high demands worldwide. The flagship's partnerships with advanced research institutions delivering bioinformatic courses will mitigate against such risk.

A major risk is around sub-grantees not delivering their outputs. The CRP plans to mitigate the risk by working closely with partners to ensure that milestones are being met and budgets are properly managed. Sub-grantees will be required to report to standard and frequently against milestones, and regular reporting and joint meetings will be used to ensure progress, fiduciary, and administrative compliance. Project burn rates will be discussed in the flagship monthly meetings to ensure that there is minimal disruption to the work.

2.1.3 Flagship Uplift Budget

2022 additional outcome description	Amount needed (\$)	W1 + W2 (%)	W3 (%)	Bilateral (%)	Other (%)
Livelihood Opportunities - Additional West African country for dairy cattle (Senegal), India for small ruminants and Nepal for chicken; 3 additional African countries for chicken (Uganda, Cameroon, Burkina Faso), two additional African countries in dairy (Kenya, Uganda) and two additional countries in goats (Tanzania and Malawi)	12,597,000	0	0	100	0
increased genetic gain - Additional West African country for dairy cattle (Senegal), India for small ruminants and Nepal for chicken; 3 additional African countries for chicken (Uganda, Cameroon, Burkina Faso), two additional African countries in dairy (Kenya, Uganda) and two additional countries in goats (Tanzania and Malawi)	6,298,500	0	0	100	0
Closed yield gap - Additional West African country for dairy cattle (Senegal), India for small ruminants and Nepal for chicken; 3 additional African countries for chicken (Uganda, Cameroon, Burkina Faso), two additional African countries in dairy (Kenya, Uganda) and two additional countries in goats (Tanzania and Malawi)	6,298,500	0	0	100	0
Reduced labour for women - Additional West African country for dairy cattle (Senegal), India for small ruminants and Nepal for chicken; 3 additional African countries for chicken (Uganda, Cameroon, Burkina Faso), two additional African countries in dairy (Kenya, Uganda) and two additional countries in goats (Tanzania and Malawi)	8,398,000	0	0	100	0
Conservation of genetic resources - Additional 8 countries	8,398,000	0	0	100	0

2.2 Livestock Health

Box 2.2a Livestock Health Flagship—Summary

The ex-ante impact assessment indicates that the Flagship’s research to develop health packages and diagnostics is among the highest ranked in addressing the CRP’s multiple objectives. These together with research on existing vaccines offer among the highest returns on investment. The Flagship ranks high in contributing to poverty reduction.

This flagship:

- Performs advanced biosciences research on animal vaccines and diagnostics.
- Evaluates and adapts new holistic approaches to improve herd health.
- Explores new solutions to improve product and service delivery.
- Has a strong commitment to a gender-integrated research approach.
- Provides leverage and value for money through ‘crosstalk’ among laboratory and field-based staff, leading to faster and more efficient deployment of new products and services.
- Contributes directly to sub-IDOs:
 - Closed yield gaps through improved agronomic and animal husbandry practices.
 - Reduced livestock disease risks associated with intensification and climate change.
 - Reduced biological and chemical hazards in the food system.
 - Technologies that reduce women’s labour and energy expenditure developed and disseminated.

2.2.1 Flagship Project Narrative

2.2.1.1 Rationale and scope

Why research on animal health in developing countries?

As demand for animal-source food in developing countries soars, the scope to increase productivity through interventions to improve livestock health in rapid and fragile growth trajectories is massive. Infectious livestock diseases are one of the main constraints that impede livestock development; they are further exacerbated by climate change. Global estimates indicate that annually livestock disease kills 20% of ruminants and more than 50% of poultry, valued at about USD 300 billion (Grace *et al.*, 2015) and an estimated USD 10 to 35 billion in Africa (Smith, 2014). Livestock diseases have public health implications, with food-borne diseases killing 410,000 people a year (Havelaar *et al.*, 2015) and global zoonotic diseases costing over USD 85 billion annually (Grace, 2014).

In high-income countries the herd health approach, combining control of infectious and non-infectious diseases with improved reproductive management, animal welfare, nutrition and performance monitoring, has improved productivity. In developing countries, improved herd health management is primarily a matter of skills and knowledge, and less about costly inputs, making this approach attractive in low-income settings.

The Livestock and Fish CRP confirmed the importance of endemic diseases, such as ECF, African trypanosomiasis and CCPP which continue to cause serious losses and need continued long term research. Trans-boundary diseases, such as CBPP, PPR and FMD affect regional and international trade. ASF, an epidemic disease, threatens not only the African continent but also the global swine industry. RVF affects ruminants but also causes disease in humans and is a growing public health threat. In addition, chronic viral, bacterial and parasitic diseases weaken livestock, reducing their resistance to other infections thus contributing to the yield gap.

Vaccines can reduce the high rates of livestock mortality and morbidity due to infectious diseases and are among the most effective interventions for disease control, especially in under-resourced agricultural systems (e.g. the eradication of smallpox and rinderpest). Vaccines are available for some of the disease listed above, e.g. ECF, PPR and CBPP, but they are not optimal and need to be improved. Others have no vaccines, e.g., trypanosomiasis and ASF. Given advances in science, the development of a vaccine against ASF is technically feasible, but that for trypanosomiasis seems remote and alternative control strategies via novel therapeutics and exploiting host disease resistance traits are likely to yield a better return on investment.

While research to develop vaccines can be costly, technologically challenging and long term, the game-changing pay-offs are well recognised in human medicine and livestock production. Through the application of genomics and high-throughput 'omics' technologies, which rely on whole genome sequence data, many scientific advances in vaccinology have emerged over the past few years giving rise to renewed optimism in vaccinology (Nakaya and Pulendran, 2015). A basic principle is that vaccine development has finally entered the era of a 'systems approach', with supportive big data and multidisciplinary science and technology. Novel paradigms set by new tools in three key areas of vaccinology, namely, 1) monitoring of immune responses to infection and immunization, 2) candidate vaccine antigen identification and 3) re-design of vaccine antigens to increase their efficacy are accelerating the rate of vaccine development. These principles are used in an iterative manner to implement new and refine existing technologies within ILRI's vaccine platform (ILVAC), aiming to accelerate vaccine discovery and product development.

Efficient vaccines that are applied with good coverage have a tremendous positive impact on animal health. The success story of the global eradication of rinderpest is the most prominent example of this (Mariner, et al, 2012). In addition, there is growing capacity and knowledge in how to react to disease outbreaks, e.g., vaccination against the recent bluetongue virus, which causes severe production losses in sheep and cattle, in European Mediterranean countries (Savini *et al.*, 2008), and, in dealing with unknown outbreaks such as the sheep Schmallenburg viral disease (Doceul *et al.*, 2103).

The losses and poor productivity caused by inefficient livestock markets, gender and other social inequalities, poor animal health services, lack of access to existing animal health products (including vaccines and therapeutics), and a lack of supportive agricultural infrastructure and policies are largely unquantified, but also add to the animal health burden in developing countries.

Poor animal health is also detrimental to the environment. Inefficient use of natural resources such as feed and water, result in increased emission intensity of GHG per unit of food produced.

Poor animal health also poses a risk for public health, by transmitting zoonotic pathogens and the non-rational use of veterinary drugs. The latter contributes to the emergence of anti-microbial resistance (AMR) and acaricide resistance and the persistence of chemical residues in livestock products, an area crucial to address as small-scale production systems intensify.

Herd health and technical disease solutions will thus be relevant for both trajectories, but will require different delivery modalities and public sector roles to ensure access and availability. For the fragile growth trajectory interventions could include products less reliant on a cold chain with public sector support that will enhance resilience by preventing the loss of livestock assets. For the rapid growth trajectory, delivery of herd health along with other interventions may include the private sector and be facilitated by innovative hub-type arrangements.

This flagship is designed to address significant livestock health constraints including:

- Diversity in disease and health landscape addressed through continuous assessment of new threats and constraints and overall prioritisation;

- Inclusion of herd health approaches that tackle issues beyond single diseases and incorporate other technological solutions;
- Focusing the application of biosciences for diseases that are of limited commercial interest;
- Mitigating constraints to the uptake of solutions by including research on delivery models and partnerships.

Addressing the grand challenges

By preventing losses and increasing productivity, this flagship directly addresses three of the grand challenges: Nutrition and diverse agri-food systems and diets, post-harvest losses and food safety and new entrepreneurial and job opportunities. Climate change, is indirectly addressed given healthier animals are more efficient producers of milk, meat and eggs, reducing GHG emissions per unit of product.

Why should CGIAR invest in this?

This flagship will produce short- and long-term outputs that are IPGs. For instance, vaccines and diagnostics are globally applicable technologies, while herd health approaches will have relevance for poor livestock keepers worldwide.

Holistic herd health delivery, integrating knowledge and available technologies using a systems approach, particularly in the rapid growth trajectory builds on CGIAR system strength, further enhanced by ILRI's strength in delivering already-existing vaccines and diagnostics and the partnership with SLU.

Emerging issues of AMR and other drug-based imbalances as well as connecting animal health to human health are important global problems that CGIAR – by connecting the Livestock and A4NH CRPs is well placed to address.

ILRI's strength in upstream animal health research and its location enabling research on endemic diseases with lower containment, supported by the facilities, expertise and capacity development opportunities at the BecA-ILRI hub in Kenya enables longer-term research on new and improved vaccines with potential impact across diverse livestock systems.

Animal health management and service delivery is an area offering strong opportunities for young people and women to improve their livelihoods, through novel business models related to animal-health products and services in rural areas.

The ex-ante impact assessment identified research to develop health packages and diagnostics as among the highest ranked in addressing the CRP's multiple objectives. These together with research on existing vaccines offer among the highest returns on investment. The flagship ranks high in contributing to poverty reduction (see Annex 3.10.2).

Overall goal

The overall goal of the flagship is to improve livestock productivity, contribute to food security, nutrition and food safety through improved animal health, while increasing business opportunities for women and young people and reducing the negative environmental footprint of livestock production.

2.2.1.2 Objectives and targets

This flagship has direct strategic relevance to SLOs 1 and 2: Reduced poverty and improved food and nutrition security for health. It also contributes to four SDGs: end poverty, end hunger, ensure healthy lives, and achieve gender equality.

The flagship's objectives are:

- Develop and deploy methods and tools for evaluating animal health constraints and identifying emerging threats.
- Refine and adapt herd health approaches to improve herd health management, including appropriate drug use.
- Develop diagnostics and vaccines to improve animal disease control programs.
- Test different gender-responsive business models to improve access to animal health services and products.

Flagship outcomes to 2022

- 1.6 million livestock-keeping households (4 million individuals) realizing 15%, on average, increase in productivity through the use of integrated herd health packages in 9 countries.
- 5.6 million people in livestock keeping households experiencing 15% (or actual) reduction in prevalence of zoonotic pathogens and applying rational use of antibiotics in the livestock food system, translating into reduced risk for increase in anti-microbial resistance and improved food quality for 2.7 million consumers in 7 countries.
- 20% reduction in morbidity and mortality of livestock and 25% reduction in disease control costs through early diagnosis of disease, impacting 6.4 million people in livestock keeping households, across 10 countries.
- Improved health practices that reduce women's labour and energy expenditure by 10% developed and disseminated, reaching 2.8 million women, across 11 countries.

Outcomes from the flagship focus on alleviating the challenges of poor animal health and disease present in low-income countries and also of emerging health risks. The flagship will perform high-end bioscience research to develop vaccines against priority diseases and diagnostic tools that are rapid and functional in the field. In addition, recognizing the holistic nature of animal productivity and taking into account the gender inequalities already identified (Wieland *et al.*, 2015; Dione *et al.*, 2015), approaches to improving herd health will combine tools developed under the Livestock and Fish CRP and other national and international counterparts, for example deworming protocols for cattle or tools to improve biosecurity in smallholder pig farms, identify new tools and combine all of these with improved husbandry, welfare, feed and genetics.

Although the CRP targets specific value chains and livestock systems, this flagship will produce outputs that are IPGs. For instance, vaccines and diagnostics are globally applicable technologies, while herd health approaches will have relevance for poor livestock keepers worldwide. Unhealthy and poorly managed livestock produce less, adding to the yield gap, and reduce the economic returns and market opportunities for farmers, thereby threatening food and nutrition security of the poor. Furthermore, poor animal health poses a risk for public health through transmission of zoonotic pathogens and through non-rational use of antimicrobials, which contributes to anti-microbial resistance (AMR) and the persistence of residues in livestock products, an area crucial to address when smallholder systems intensify. Poor animal health is also detrimental for the environment because of the inefficient use of natural resources such as feed and water and increased emission intensities of greenhouse gases. Gender and other social inequalities in most CRP priority sites are pervasive in terms of division of labour, access to and control over resources (including livestock), and participation in decision-making, but are critical factors in animal health management and improvement of livestock productivity.

2.2.1.3 Impact pathway and theory of change

Figures 2.2a and 2.2b present the flagship's ToC and assumptions. The flagship aims to improve livestock productivity, contribute to food security, nutrition and food safety through improved animal health, increased business opportunities for women and young people, and reduced negative environmental footprint of livestock. This flagship addresses the limited availability, access to and use of animal health services and products in low-income countries needed for the rapid inclusive and fragile growth trajectories. The work builds on years of animal health and delivery research to respond to challenges embedded in the two trajectories targeted through the CRP. From high-end bioscience solutions, e.g. vaccines and diagnostics, to experience in the current Livestock and Fish CRP, which has undertaken assessments enabling the improved targeting and prioritizing of animal health challenges and solutions in selected commodity value chains. It also develops further the concept of herd health, a critical gap for bridging from high-end research to practical health management that was identified by the Livestock and Fish CRP as a priority.

To prioritize pro-poor animal health research and development interventions, tools to improve the measurement and evaluation of the burden of livestock disease and health constraints, together with emerging risks affecting different species and production systems will be developed. This will be achieved by combining epidemiological and socio-economic studies, adequately incorporating gender aspects, to provide a clearer picture of the intervention points and investment levels that will result in impact at scale. Foresight modelling to predict how changes in production systems and climate change lead to new emerging health threats is an additional focus, to identify the most relevant existing and new constraints. The resulting models and assessment tools, once widely available, adapted and used by researchers and donors, translate into IPGs to inform future research and development interventions beyond the CRP; this will require continued dialogue with policymakers and donors, these outputs thus mainly contribute to reduced livestock risks associated with intensification and climate change.

As biological and institutional constraints and emerging risks are identified, the flagship develops integrated technological solutions, including inputs that improve animal husbandry and which act to protect and enhance investment in improved health, through applied research in CRP priority countries. The resulting gender-responsive herd health management packages will help to optimize livestock productivity and drug use by ensuring that the concerns and needs of both men, women and the youth are adequately addressed. To complement the research on herd health packages and prevention of emergence of drug resistance, upstream research on vaccines and diagnostic tools on diseases which are not addressed through the private sector will be conducted. This research will translate into changes in research partners and government agencies in the use of novel diagnostic assays and vaccines.

These changes are important contributions to development outcomes, but they cannot achieve them alone. This will be achieved by ensuring that tools and technologies are available for interested stakeholders, through a various context-specific capacity development activities and continued engagement with relevant decision-makers at national levels and with development partners at national and international level. For example, the delivery and use of antimicrobials (AM) and antiparasitics (AP) by research partners and subsequently, livestock keepers having the necessary knowledge on AM and AP resistance and changing their practices accordingly. These up- and downstream discoveries thus significantly help reduce the yield gap, but also impact upon livestock risks associated with intensification and climate change and biological and chemical hazards in food systems. In addition, the herd health packages will be gender-sensitive by reducing women's labour and energy use.

An important step to ensure that technologies and tools reach target 'end users', the livestock producers, there is a need to engage with the private sector and to test different business models for the delivery of products and services. This is where the flagship closely interlinks with other flagships that work on delivery, e.g. Livestock Genetics, Livestock Feeds and Forages, and the Livestock Livelihoods and Agri-Food Systems flagships, to ensure that composite animal health solutions and services are integrated into strategies to improve livelihoods and increase resilience at scale.

This will provide exciting opportunities to engage youth and women in business development to encourage their participation in livestock production and developing sustainable systems. However, this can only be achieved when emerging small-scale businesses are supported and where demand from farmers for services and products is sufficient. Experiences and findings from the Livestock and Fish CRP suggest that, indeed, livestock producers do prioritize animal health. To provide an enabling environment, engagement with policymakers is also important. In addition to consideration of gender and youth equity and inclusion, the flagship will link capacity development and other interventions as necessary to achieve outcomes.

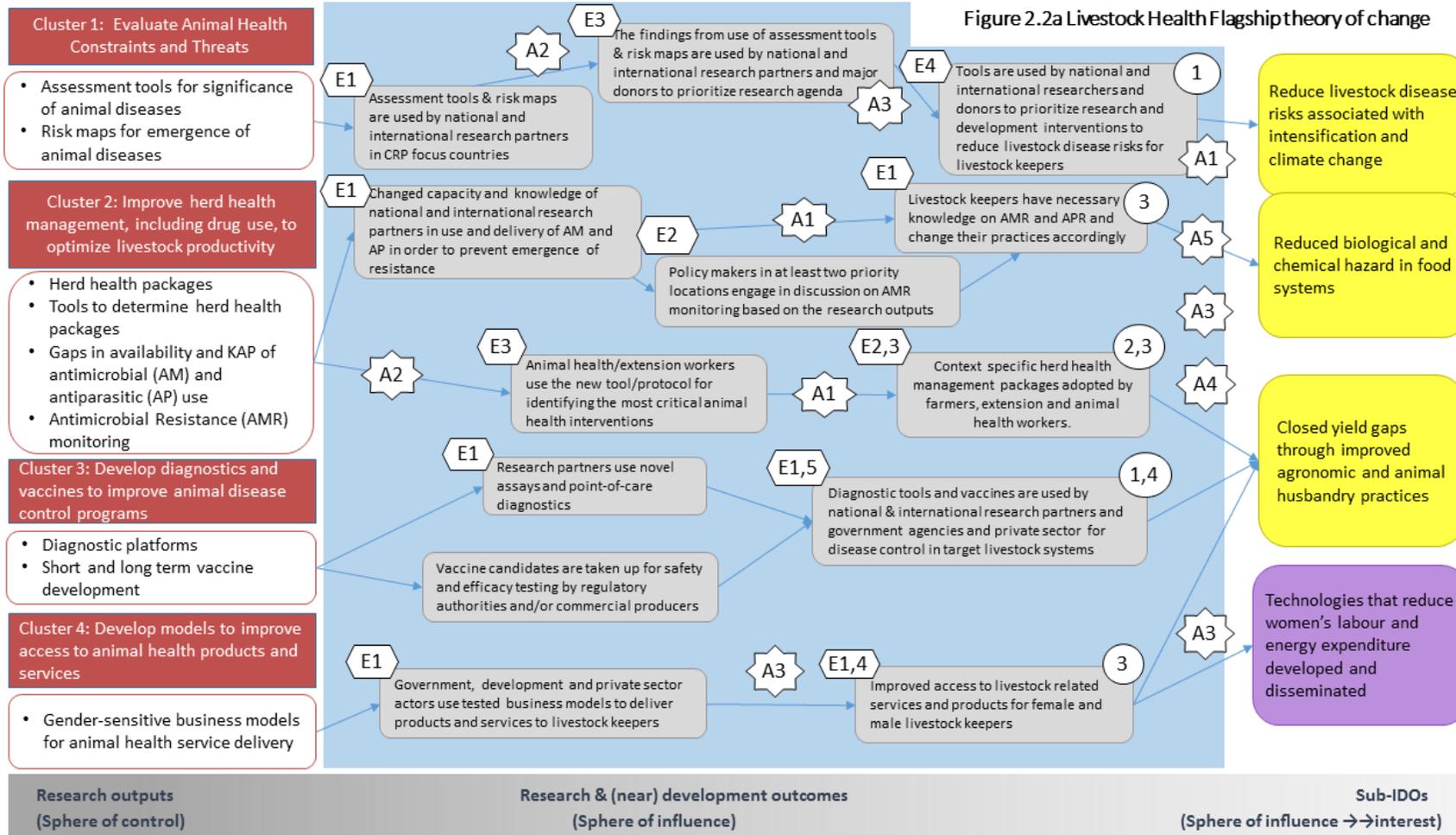


Figure 2.2b Livestock Health Flagship theory of change, assumptions, enabling actions and change domains

A1

Assumptions	
A1	▪Animal Health service delivery personnel and farmers willing to take up tools
A2	▪Tools published and considered relevant by researchers and policy makers
A3	▪Sufficient demand from farmers for services and products
A4	▪Animal health options generate sufficient benefits to attract private investors and emerging small-scale businesses are supported
A5	▪Good herd health management reduces antimicrobial use

E1

Enabling cross-cutting actions	
E1	Develop "next user" capacity
E2	Develop "next user" capacity to innovate
E3	Including gender sensitive approaches
E4	Continued dialogue with policy makers and donors
E5	Continued engagement with relevant decision-makers at national levels and with development partners at national and international level

1

Domains of Change	
1	Changes in local, national and international research and development systems
2	Changes in markets, enterprises and consumer behaviour
3	Changes in producer systems (producers and communities)
4	Changes in policy and investment systems for scaling

2.2.1.4 Science quality

This flagship takes a new, holistic approach to maximize the gains from investing in animal health beyond single diseases. Herd health management simultaneously addresses issues such as reproduction, husbandry and animal welfare and facilitates the integration of genetics and feed outputs to increase productivity. This allows existing and new products and services to be rapidly deployed, to improve animal health and thus, livestock production as well as reducing the risk of zoonoses and antimicrobial resistance.

The experience and findings of gender-integrated studies on animal health management practices conducted in Ethiopia (Wieland *et al.*, 2015) and Uganda (Dione *et al.*, 2015) in the Livestock and Fish CRP provide protocols and tools that will be key in the evaluation and prioritization of animal health constraints and threats in the priority countries. This will enable socio-economic aspects to be reflected in models quantifying disease burden, from diseases with high mortality and the 'production' diseases which have to date been under-represented (Rich *et al.*, 2011). Frameworks to assess disease impact have been proposed, but all struggle with the difficulty of measuring the true impact of animal disease (Perry *et al.*, 2009). A novel approach combining epidemiological and economic studies with tools derived from complex systems theory for prioritizing diseases and disease complexes will be developed, simultaneously allowing ex-ante assessment of gender-sensitive interventions. These studies thus directly inform research to develop herd health packages and helps to prioritize upstream vaccine and diagnostic research.

The investigation of emerging risks in changing livestock systems is a new area. Such risks may arise from climate change or by shifts in production systems due to intensification and changing markets. Predictive spatial risk models will be developed in collaboration with other CRP flagships to complement foresight and climate change modelling. These tools will enable better disease emergence preparedness and early detection of novel pathogens, facilitating engagement with policymakers to get the necessary regulations in place to prevent or minimize the impact of emerging disease threats. Furthermore, they are key to inform future research priorities in upstream research, i.e. pathogens or pathogen groups to target in vaccine and diagnostics research as well as testing appropriate practices.

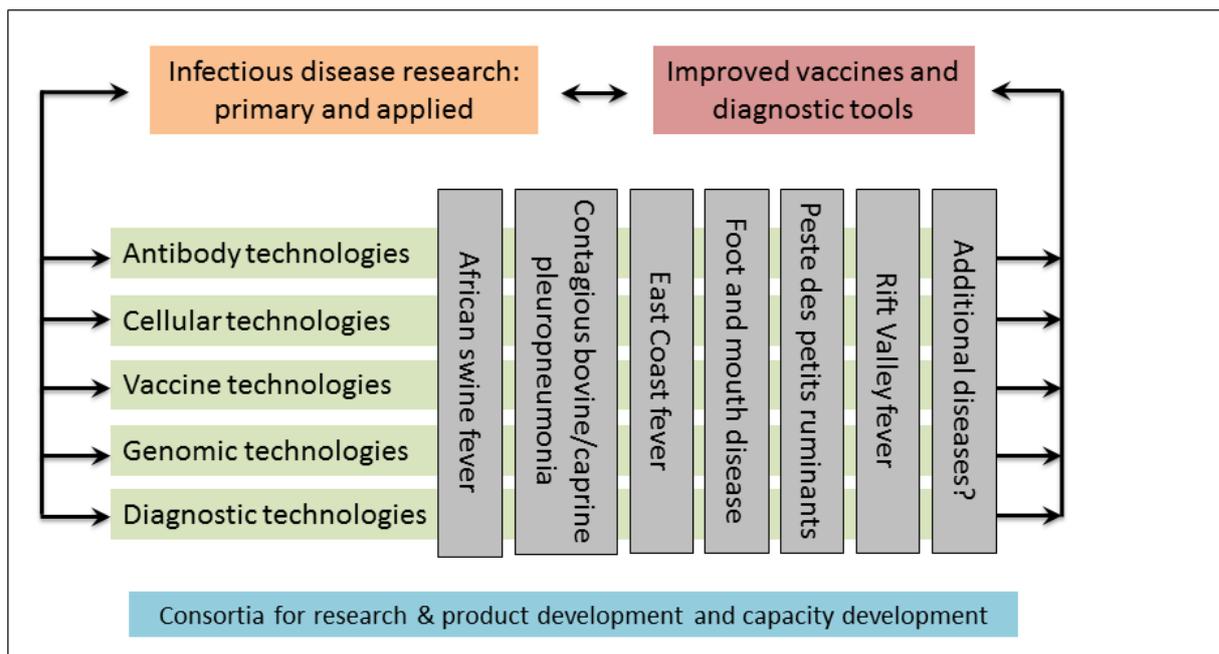
Emerging drug resistance and the growing unregulated and non-rational use of anti-microbials and other veterinary drugs is an emerging threat. Drawing on expertise from SLU and ILRI and complementing the work on AMR undertaken in A4NH will allow integration of qualitative research on the public health and policy aspects of anti-microbial resistance with surveys investigating farmers' knowledge, attitudes and practices in veterinary drug use as a basis for advancing research on this topic. Analysis of options for animal management and biosecurity measures will provide alternatives to antimicrobial use to inform recommendations and capacity development tools to promote more rational use of anti-microbial and anti-parasitic drugs (van Boeckel *et al.*, 2015; Abbas *et al.*, 2014).

The impact of fighting single diseases by novel vaccines and treatments may be limited if other health conditions are not addressed, hence the proposed holistic herd health approach. Such an approach, with reproductive health, husbandry, welfare, biosecurity management, performance monitoring and interaction with nutrition and genetics forming herd health packages, demands new research that combines prioritization among interventions, their effectiveness, feasibility sustainability and acceptability in different livestock systems. The livestock CRP, has an extraordinary comparative advantage to address the knowledge gap in this area, building on its broad competence, long experience and physical presence in different parts of the world. Using an R4D approach, different interventions will be systematically evaluated in a range of systems with partners on the ground.

This holistic herd health approach is *the* opportunity to provide farmers with alternatives to the non-rational use of antimicrobials and to investigate the effects of such alternatives on antimicrobial resistance. Impacts will be measured against baseline data on disease prevalence and human capacity which is available from Livestock and Fish CRP work in Ethiopia, Tanzania and Uganda and to some extent India and Vietnam.

To complement the field-based research outlined above, the flagship proposes state-of-the-art upstream research on vaccines and diagnostic tools. Through the application of genomics and high-throughput 'omics technologies, which rely on whole genome sequence data, many scientific advances in vaccinology have emerged over the past few years (Nakaya and Pulendran, 2015) giving rise to renewed optimism in vaccinology. A basic new principle is that vaccine development has finally entered the era of a 'systems approach', with big data and multidisciplinary science and technology supporting these endeavours. This principle is used to implement new and refine existing technologies within ILRI's vaccine platform (ILVAC, see Figure 2.2c), aiming to accelerate vaccine discovery and product development.

Figure 2.2c ILVAC vaccine platform applies generic technologies to target diseases



ILVAC's core capacity and agenda are supported by three inter-related activities. (i) monitoring immune responses in animals to infection and immunization includes comparison of networks of gene expression profiles allowing development of gene signatures that correlate with immunity to disease and guide the re-design of immunization protocols that fail during vaccine trials. (ii) rapid identification of candidate vaccine antigens through a combination of conventional and reverse vaccinology approaches. The latter relies on the application of bioinformatics tools. This activity also includes assessment of the efficacy of recombinant antigens, using a range of conventional and novel molecular adjuvants based on immuno-modulatory molecules, and recombinant bacterial and viral systems in

experimental vaccine trials. (iii) enhancing the efficacy of candidate vaccine antigens—combines results from (i) and (ii) in an iterative manner. It includes manipulating antigens based on crystal structure data, engineering pathogens to an attenuated form, and formulating them to a thermostable state so as to enhance delivery options to the end-user. Vaccine research is expensive, high-risk and long-term in nature, but with high rewards.

It is often perceived that the requirement of cold chains prohibits the uptake of vaccines. While thermo-stabilized vaccines may alleviate such types of delivery constraints, “market failure” due to institutional matters, e.g., a lack of appropriate networks for delivery of vaccines is often the real challenge. Counter-intuitively, long-term storage of thermos-stabilized vaccines still requires a cold chain and experience shows that a product marketed as a thermos-stable is often mistreated due to erroneous assumptions and expectations.

An intriguing strategy to overcome such issues is being tested by Hester Biosciences Inc., a veterinary vaccine company in India. First, Hester deliver on a full cost commercial basis a Newcastle Disease (ND) vaccine to backyard poultry farmers in India under its own cold chain infrastructure. Second, Hester markets a thermo-stabilized ND vaccine using this system. The rationale is to first demonstrate a return on investment. Once delivery of the vaccine using the cold chain becomes self-sustaining a non-thermo stabilized ND vaccine, which is cheaper to produce can be delivered at lower cost to the farmer to further stimulate uptake and at scale. This approach could be replicated for other livestock vaccines in developing countries.

ILRI has developed a thermo-stabilization protocol for PPR. The principles described above will be tested in Mali, where Hester is helping the Central Veterinary Laboratories to produce different formulations on the vaccine to field-testing.

Short- to medium-term products will be derived from the improvement of existing vaccines, while longer-term research will be devoted to developing next-generation solutions.

Vaccine development is strongly linked to the development of diagnostic assays which are needed during experimental vaccine trials, and for the deployment of commercial vaccines. Many new technical and engineering developments have also taken place in the field of diagnostics research, particularly in the development of simpler, field-based diagnostic tests (Weigl *et al.*, 2013). Such research will be accelerated under a new diagnostics platform and used to facilitate a service and research function for livestock productivity. In addition, opportunities to incorporate diagnostic test results into databases and link them with telecommunications networks to facilitate rapid diagnosis will be further developed. These are new solutions for remote communities (such as in the fragile trajectory), where enhancing resilience through disease mitigation and management will be paramount.

The high-end biotechnology infrastructure of the BecA-ILRI Hub will be integral to the work of this flagship and will play a key capacity development role. Critical animal infrastructure at ILRI includes large and small animal facilities, a secure animal disease facility that operates at an enhanced biosecurity level 2, and a tick unit that maintains seven different species of tick. In addition, there is easy access to indigenous animals, wildlife, pathogens and field sites.

The flagship will capitalize on ILRI’s comparative advantage in setting up innovation platforms to test different business models, including public–private partnership approaches for the delivery of health products and services. Innovation systems will be an important tool towards improved understanding of acceptable animal health service delivery options for farmers and their willingness to pay. Testing and evaluation of the resulting business models and their responsiveness to the needs of women and

young people, will result in best practice recommendations to improve access to inputs and services for small-scale producers.

The use of the latest ICTs and of novel transport mechanisms (refined cold-chains using solar power, mobile phone technology, unmanned aerial vehicles UAVs as drone-ports, etc.) as tools not just for gathering data or samples but also for distributing health-related information and goods, such as veterinary drugs and vaccines, to livestock producers is a new research area to be explored.

2.2.1.5 Lessons learned and unintended consequences

Rapid value chain assessments conducted in the Livestock and Fish CRP pointed towards important health constraints, but failed to capture and quantify the importance of endemic production diseases and constraints related to poor husbandry and lack of access to services and products. Such metrics are important, to prioritize technology research and interactions between technology, adoption, social constraints and impacts, and for the flagship's engagement with value chain stakeholders and policymakers. Gender-integrative research conducted in Ethiopia, Uganda and Tanzania provided important insights into the socio-economic impact of livestock diseases on different household members and on the roles and constraints of different household members in animal health management. Potential unintended negative consequences for workloads, access to and control over resources (animals, income, benefits, and so on), animal health, and the decision-making authority of different household members will be incorporated into the flagship's assessment tools. These will also be refined to take account of constraints emerging through climate change and changes in livestock production systems.

Technology outputs to date in the Livestock and Fish CRP may seem limited, mainly because the key emphasis was on long-term research, for example the development of new vaccines. The flagship's aim for the Livestock CRP is to develop a balanced portfolio of research with more short- and medium-term outputs through the herd health packages using existing disease control and preventive tools, as well as continuation of long-term vaccine research on key diseases, recognizing the potential game-changing results this can lead to. Emphasis will be given to optimizing herd health interventions that address husbandry and a wider range of productivity problems, including diseases for which the uptake of existing control options has been limited.

Research and product development consortia will play an important role in meeting the flagship's objectives. Each research objective needs to be supported by a critical mass of scientists and program-level funding, otherwise progress will be slow or, at worst, may stagnate. For example, for each vaccine disease focus group it is desirable to have program-level funding of USD 10-15 million over a five- to eight-year period. This was achieved for the ECF project, which now has over 50 participants. The increase in administration and management transactional costs for such consortia is large. However, rapid progress has been made in ECF research, which would have been impossible with lower levels of funding and effort.

The CRP includes a number of approaches that mitigate the risk that this long term, upstream research does not also deliver results in the six year time frame of the CRP. Included here are:

- The potential for technological breakthroughs in vaccinology that may have applications beyond the focus diseases of the CRP.
- Application of new technologies such as "omics" provides more powerful tools than in past and combined with participation in large international consortia increases the efficiency in the vaccine research and likelihood of success.

- Inclusion of processes to ensure ‘stop-go’ decisions so that investment in this research does not continue without due cognizance of the likelihood of success. These will be informed by both the technical progress and feasibility as well as the realities of disease prioritisation in focus systems and value chains (cluster 1 of this flagship and broader prioritisation in the LLAFS flagship).

The CRP also includes activities that will deliver results based on vaccines in the short term based mainly on the (considerable) past work of ILRI and partners, as well as the new partnership with SLU that brings a strength in herd health management. Deliverables in the short term – within the six year time frame include:

- Support to a more enabling policy environment to support livestock healthcare strategies suited to supporting smallholder-based livestock systems through engagement or events to provide evidence to policy makers regarding AMR and APR (national governments, OIE), PPR control (AU-IBAR, OIE and FAO), FMD control (Global Foot and Mouth Research Alliance: GFRA), African swine fever control (Global African Swine Fever Research Alliance: GARA), better coordination of research (STAR-IDAZ), and veterinary policies and veterinary service delivery strategies geared to the developing country context (OIE).
- Improvements to existing vaccines (PPR and CCPP; ITM for ECF).
- Delivery strategies for existing and improved vaccines (as also stressed by ISPC, 2014), including partnership with the private sector, such as for ITM testing in Tanzania, PPR in Mali or implementation in the context of major research for development programs ([AVCD, Kenya](#)). The flagship, and indeed CRP focus on ensuring delivery approaches are inclusive for gender, and increasingly young people will also ensure robust delivery of solutions.
- Solutions for herd health management that have been shown to be part of transforming the efficiency of animal agriculture (Capper *et al.*, 2009; Capper, 2011) and especially in the CRP focus systems and value chains will be increasingly important as part of the approach to mitigate against the emergence of AMR.
- Integration of vaccine solutions with those related to genetics and feeds as well as livelihood, market and policy interventions to address broader livelihood, resilience and nutrition outcomes (in the LLAFS flagship).
- Partnership management and monitoring (Annex 3.1) as well as appropriate IP arrangements where the private sector is engaged will be integral for the success of delivery approaches.

2.2.1.6 Clusters of activities

The flagship uses a systematic approach with four R4D clusters that 'cross-talk' with each other to ensure learning and refining or redirecting of the research agenda. Cluster 1 evaluates animal health constraints and threats, provides the foundation, with fact finding and foresight on health constraints. Cluster 2 combines herd health management, appropriate drug use and the search for farm- and system-level solutions to improve livestock productivity, while cluster 3 develops diagnostics and vaccines to improve animal health control, conducts upstream research using state-of-the-art methods to develop vaccines and diagnostic assays. Cluster 4 develops delivery models to improve access to animal health services and products.

The allocation of W1/W2 funding within the flagship is based on the following principles:

- Support research that is crucial for addressing the IDOs and that might not be supported by bilateral funding.
- Protect research that is long term in nature and vulnerable to fluctuations in bilateral funding.
- Shift priorities more towards upstream research activities rather than downstream development activities.

Cluster 1. Evaluate animal health constraints and threats

This cluster aims to develop and deploy methods and tools to identify the extent and impact of animal health constraints on animal productivity and livelihoods. These approaches will first be used in the focus systems and value chains in the program's priority countries and then in other locations.

At global scale research will contribute to the systems analysis work of in the Livestock Livelihoods and Agri-Food Systems flagship assessing current and future global and regional significance of animal diseases. Input parameters will be generated through epidemiological, economic, gender and multi-pathogen surveys, combined with existing and new knowledge of disease burdens caused by endemic diseases. Tools will have a strong gender dimension so they better target the interventions developed in cluster 2 and provide inputs to the business models tested in cluster 4. Knowledge, attitude and practice (KAP) surveys should reveal important gender differences related to disease constraints and be combined with analyses of access to and control of relevant resources. New modelling approaches, such as those based on complex systems theory and emergent properties of systems, will be used to assess the biophysical and socio-economic impact of livestock diseases and to inform the development of interventions in clusters 2 and 3. The resulting outputs are directly related to W1/W2 funds.

The insights gained will build on animal health assessment tools developed in the Livestock and Fish CRP to facilitate future data collection and to improve the quality and usefulness of the outputs for disease prioritization. The improved tools will be applied in the priority value chains and systems, and in other CRPs where livestock are an important contributor to livelihoods.

New assessments will be carried out on the animal health threats due to the emergence of new diseases because of climate change and the changing distribution of vectors and changes in gender relations and dynamics in systems and value chains. For the strong growth trajectory, these models will focus mainly on changes in production systems, whereas for the fragile growth trajectory, the role of climate change will be of major importance. For both, an essential factor is the changing position of women, which may lead to changes in risks of exposure and in needs for capacity development. Risk assessments and studies on emerging diseases, including tick distribution and vector-borne diseases, will be conducted in collaboration with A4NH and Livestock CRP flagships. This work is likely to attract bilateral funds and thus limited outputs are related to W1/W2 funds.

Main research outputs

- Assessment tools for significance of animal diseases.
- Risk maps for emergence of animal diseases.

Outcomes to 2022

1. Assessment tools for significance of animal diseases and risk maps for emergence of animal diseases are used by 100 local and national and 50 international research partners and donors to prioritise research and development interventions to reduce livestock disease risks for livestock keepers.

Milestones

- Assessment tools for significance of animal diseases and risk maps for emergence of animal diseases are used by 50 local and national and 5 international research partners, across 10 priority countries and other locations (2019).
- The findings from the use of assessment tools for significance of animal diseases and risk maps for emergence of animal diseases are used by 75 local and national and 25 international research partners and major donors, in both priority countries and other locations, to prioritise research and development interventions (2020).

Cluster 2. Improve herd health management, including appropriate drug use

A key theme of the flagship's core agenda is to improve animal health by evaluating, refining and adapting holistic herd health approaches.

Research will be conducted on the priority value chains and systems (Table 1.3) using robust performance monitoring protocols to evaluate herd health packages and their elements such as reproductive management protocols, biosecurity measures, vaccination and anti-parasitic schemes, feeding regimes, improved animal welfare measures, protocols for rational use of drugs. Obviously the weight and profile of the elements in the packages will vary by focus system and value chain. The herd health interventions are in place in other parts of the world – in this flagship it is the testing and evaluation of the various combinations of these interventions that is the issue – this will likely contribute to a rapid delivery of outputs.

Efficient herd health interventions will reduce the need to use antimicrobials—especially relevant for the rapid growth trajectory—and thus reduce the risk of AMR. An important part of this research is how health relates to reproductive management and interacts with other management factors, such as genetics and feed resources. Thus there will be close consultations with other Livestock CRP flagships on how to optimize and make the most cost-effective interventions for closing the yield gaps. Best management practices for the constraints identified in cluster 1 will be refined and their cost-efficiency assessed. Interventions will be combined into herd health packages, and tested in site-specific contexts taking into account how women, men and young people are using specific interventions and what integrated approaches could strengthen equitable usage of such options. Appropriate novel training tools for farmers, community animal health workers and veterinarians will be developed and tested. Lessons on how best to address holistic herd health will be generated and may be applied elsewhere in the developing world. Opportunities for deploying diagnostics for broader herd health dimensions and related service provision approaches may also be explored. The feasibility of different approaches to monitoring anti-microbial and anti-parasitic resistance and alternatives to drug use will be investigated and presented to national and international policymakers. Gaps in the KAPs related to drug use will be investigated, including analysis of social, gender and institutional factors in managing animal health and drug use. The resulting outputs will be generated by W1/W2 funds.

The delivery of herd health packages and the findings on AMR and drug use will be refined in collaboration with cluster 4 and the Livestock Livelihoods and Agri-Food Systems flagship. Work to assess environmental implications, undertaken with the Livestock and the Environment flagship will depend on bilateral resources thus limited outputs are related to W1/W2 funds.

Main research outputs

- Evaluated herd health packages.
- Tools to determine herd health packages.
- Gaps in availability and KAP of antimicrobial and antiparasitic use identified.
- Antimicrobial resistance (AMR) monitoring systems.

Outcomes by 2022

1. Context specific herd health management packages adopted by farmers, extension and animal health workers in priority countries and other locations.

Milestones

- Animal Health/extension workers in at least 6 priority countries and other locations use the new tool/protocol for identifying the most critical animal health interventions (2019).
2. Livestock keepers have necessary knowledge of AMR and antiparasitic resistance (APR) to change their practices accordingly, piloted in two priority countries.

Milestones

- Changed capacity and knowledge of national and international research partners in use and delivery of AM and AP in order to prevent emergence of resistance, in priority countries (2019).
- Policymakers in at least two priority countries engage in discussion on AMR monitoring-based on the research outputs (2020).

Cluster 3. Develop diagnostics and vaccines to improve animal disease control programs

This cluster aims to develop products for controlling livestock diseases in targeted livestock production systems. The research portfolio from the Livestock and Fish CRP, which included ASF, CBPP/CCPP, ECF, PPR and RVF, will be expanded in response to demand according to assessment outputs from clusters 1 and 2. The portfolio will also be shaped by demands from other Livestock CRP flagships and from relevant flagships in other CRPs, to ensure inclusion of research on emerging animal diseases due to changes in production systems, climate change and changing vector distribution.

Research outputs from this cluster will become products for delivery in cluster 4, which will provide feedback for product refinement. Early engagement in developing a target product profile and product development plan is essential. Private-sector collaboration to determine the feasibility of scaling up and of larger-scale clinical trials for dossier and registration purposes will be needed for promising solutions. Adopting and implementing technical advances in vaccine and diagnostic platform technologies will be key to success. W1/W2 funds will be used to develop technical outputs, which will in turn be used to apply for disease-focused bilateral funds.

Diagnostics: Rapid diagnostic tools will be developed in response to three dimensions of demand: (i) The need for broad, non-specific diagnostic approaches that can help to identify a range of (new) pathogens; (ii) The development and application of diagnostic tests for priority diseases (CBPP/CCPP in particular); (iii) Dissemination of existing (but new and not yet rolled out to national veterinary services) diagnostics such as for MERS-CoV, FMD and RVF. Technological advances to be further explored for diagnostic tests include the application of novel materials, micro-fabrication/fluidics and genome-based high-throughput screening methods. To enable a rapid response to both service and research requests from this and other CRPs on, for example, emerging diseases (e.g. recent work on MERS-CoV) the technical capacities established in-house under the Livestock and Fish CRP will be developed into a diagnostic platform. Responding to demand for more user-friendly diagnostic tests and point-of-care tests could involve, converting ELISA tests to lateral flow formats and PCR based DNA detection to recombinase polymerase amplification (RPA) tests in micro-fluidic formats. This is currently being done for CBPP/CCPP. Opportunities to incorporate diagnostic test results into databases and link them with telecommunications networks to facilitate rapid feedback will be further developed. Several additional diagnostic platforms, for example paper-based ELISA, multiplex lateral flow tests and luminex fluorescent bead assays, are being developed. A service area to be explored is the provision of diagnostic testing using assays that are relatively new, and not yet ready to be taken

up by national veterinary laboratories—for example, a luminex technology for RVF and sequence-based diagnostics for FMD surveillance and vaccine matching.

Vaccines: Several recent technological advances, often developed for human vaccine studies, have led to new paradigms in vaccine development and are being incorporated into ILVAC. These include the monitoring of immune responses to infection and immunization, new methods for antigen identification and immunization, and the re-design of antigens to optimize the efficacy of candidate vaccines. Activities include research on how best to combine vaccines for simultaneous control of multiple diseases of small ruminants and the thermostabilization of vaccines (for which partnerships are key). This will follow up ongoing work on a new vaccine for CCPP together with the improvement of existing vaccines. Activities will include the scaling up of a protocol developed at ILRI for production of a thermostabilized PPR vaccine, and back-stopping of the commercialization of the live ECF vaccine by the Center for Tick and Tick Borne Diseases (CTTBD) in Malawi. This cluster will thus contribute to short-term opportunities through the improvement of existing vaccines. It will also continue longer-term research following on from the Livestock and Fish CRP, which identified candidate antigens for new vaccines for the control of ASF, CBPP/CCPP, ECF and ticks. Testing the efficacy of vaccine antigens to provide proof-of-concept often requires access to proprietary technologies, hence the flagship's aim to strengthen partnerships with the private sector. Work on a novel viral-vectored vaccine for RVF suitable for use in cattle, sheep, goats and camels will be undertaken, with relevance for delivery in A4NH.

Main research outputs

- Diagnostic platforms.
- Short- and long-term vaccine development.

Outcomes by 2022

1. National and international research partners, government agencies and the private sector use 2 novel diagnostic assays and vaccines for control of ASF, CBPP, CCPP, ECF and PPR in at least 6 priority countries.

Milestones

- Research partners use novel assays and point-of-care diagnostics in priority countries (2020).
- At least 4 vaccine candidates are taken up for safety and efficacy testing by regulatory authorities and/or commercial producers (2022).

Cluster 4. Develop models to improve access to animal health services and products

As part of the core agenda, this cluster will address the broad constraints of access to animal health products and services.

In close collaboration with the Livestock Livelihoods and Agri-Food Systems flagship, this cluster contributes to research on demand-driven, efficient and gender-responsive delivery models for both rapid and fragile growth trajectories. Multi-stakeholder innovation platforms will be set up in Ethiopia, Tanzania, Vietnam, Mali and Uganda and will bring together stakeholders from livestock producers to policymakers. These also foster improved understanding of acceptable animal health service delivery options by farmers and their willingness to pay for these and thus ensure that business development initiatives are demand driven. Privatisation of veterinary services is high on the agenda in many countries, but research on how this is best achieved has been limited so far. This cluster will explore different models on how farmers, community animal health workers, private and public vets can engage in order to improve access to needed products and services for rapid and fragile trajectories. This will first be implemented in Ethiopia through a bilateral project and subsequently in other countries depending on available funds. In Tanzania different models to improve infection and

treatment method (ITM) delivery for ECF control will be compared in collaboration with NGO and development partners to provide recommendations on how to optimize ITM delivery elsewhere. Where appropriate and feasible, the flagship aims for a One Health approaches, in collaboration with A4NH, exemplified by the delivery of herd health packages in Uganda that include cysticercosis control in pigs.

Technological outputs from clusters 2 and 3 are the model products and services to test delivery systems and to ensure that products and services reach their intended beneficiaries. For example, in Mali traditional and thermostable PPR vaccine protocols will be evaluated from production to measuring their effectiveness in the field to identify the most cost-efficient ways to produce and deliver vaccines while maintaining effectiveness. This will be done in collaboration with NGO and development partners through a bilateral project. This is also a direct contribution to global efforts to control and eradicate PPR.

Capacity development in delivery systems will be provided through R4D approaches using multi-stakeholder innovation systems, outputs of which will be related to W1/W2 funds. Introduction of novel technologies for the transport of goods, such as drones, and modern ICTs for knowledge dissemination, activities may be explored, depending on bilateral funds.

Key activities in this cluster will include training of women or young people in setting up and running businesses and targeted training events for veterinarians, and extension and animal health workers, in providing the relevant services.

Model delivery systems will allow incorporation of outputs from other flagships and national systems as bundled services, for example through integrated livestock business hubs (rapid growth trajectory) or Veterinary Field Units (fragile growth trajectory). These will promote private-sector involvement and offer more business opportunities for women and young people and will be combined with capacity development to strengthen institutional performance. Engagement with all the varied actors in the product deployment chain—will be key to success in this cluster. This part of the work is deemed suitable for bilateral funding and thus limited outputs are related to W1/W2 funds.

Main research outputs

- Gender-responsive business models for animal health service delivery.

Outcomes by 2022

1. Improved access to livestock-related health services and products for female and male livestock keepers in 4 priority countries (2020).

Milestones

- Government, development and private sector actors' use tested business models to deliver products and services to livestock keepers in 4 priority countries (2020).

2.2.1.7 Partnership

The strategy for selecting key partners is based on expertise, complementarity, potential for synergy and partnership record, all framed in the context of the flagship's ToC.

This flagship's core partners are scientists from ILRI, ICARDA and SLU, who have an outstanding track record in bioscience research on tropical animal diseases and livestock systems, an extensive experience of livestock systems in dryland areas and expertise in developing holistic herd health approaches, respectively.

Examples of strategic partnerships include the University of Bern, because of their ability to rapidly type bacterial pathogens and long-track record in working on bacterial virulence factors and anti-bacterial vaccines. The Jenner Institute (University of Oxford) continues to refine a proprietary vaccine platform based on viral vectors, leading to novel methods of vaccination. The University of Edinburgh and the Pirbright Institute are leaders in developing novel immunological assays that support vaccine research. In diagnostic research that provides the evidence for epidemiological studies, the flagship works with the National Animal Health and Diagnostic Investigation Center in Ethiopia, Makerere University in Uganda, and Sokoine University of Agriculture in Tanzania. Partners in India include the Indian Council for Agriculture Research. At country level, the flagship interacts with line ministries and departments of veterinary services to align animal health research with national priorities.

At the global and regional levels, partnerships with programs developed by FAO and AU-IBAR will take on great importance. For example, ILRI and AU-IBAR have developed a position paper on the progressive control of PPR in Africa (AU-IBAR, 2013). Established partnerships with local or national partners representing research and development, will be crucial for the field testing of interventions and with farmers' animal health organizations for the refinement of herd health packages. Examples include the Tigray Agriculture Research Institute in Ethiopia for field testing of interventions, Veterinarians without Borders for adaptive research in Uganda, and Department of Veterinary Services for testing of ITM delivery models in Tanzania. The scaling up of vaccine production will require private-sector partnerships, for example with Hester Biosciences Limited, a company that produces poultry and large animal vaccines and health products. Hester will provide oversight and expertise in the production of a thermo-stabilized PPR vaccine in Mali. Initiatives with GALVmed and the CTTBD in Malawi revolve around production and improvement of the live ECF vaccine for use in Kenya, Tanzania and Uganda.

The flagship is also a partner in regional and global innovation systems and multi-stakeholder platforms that aim to scale up technologies and approaches. ILRI is a member of the Executive Committee of STAR-IDAZ (Strategic Alliances for the Coordination of Research on the Major Infectious Diseases of Animals and Zoonoses), which seeks to strengthen the links between and reduce the duplication of global research efforts, maximize the efficient use of expertise and resources and accelerate coordinated development of control methods at international level. Similar interactions with the World Organization for Animal Health (OIE), where ILRI has observer status at the General Assembly, are critical in harmonizing global, regional and country livestock health efforts. ILRI is also a member of the Global Foot and Mouth Research Alliance (GFRA) and the Global African Swine Fever Research Alliance (GARA).

2.2.1.8 Climate change

Livestock production will be constrained by infectious and vector-borne diseases that emerge following alterations in local or regional climates. In fact, the impact of climate change on pests and diseases is likely to be one of the first to be observed.

Emerging infectious animal diseases can have devastating effects on livestock health when immunologically 'naive' animal populations are infected by 'new' pathogens. Cluster 1 on evaluating animal health constraints and threats, will follow the emergence of diseases and pests, carrying out risk assessments due to climate changes and contributing to improved preparedness, in cooperation with the Livestock and the Environment flagship, A4NH, and others. Cluster 3 on developing diagnostics and vaccines to improve animal disease control programs, will closely follow the climate change-related emergence of infectious diseases such as RVF, and adjust its activities when appropriate.

It is well established that healthy animals produce more meat, milk or eggs and thus reduce GHG emissions per unit of product. This will be quantified by cluster 2 on improving herd health management, including appropriate drug use, working with the Livestock and the Environment flagship to contribute to the reduction of the GHG footprint.

2.2.1.9 Gender

Gender relations affect animal health management and the adoption of animal health protocols and technology (see Annex 3.3). In turn, animal diseases as well as vaccines and protocols affect different dimensions of gender relations.

Gender-integrated research in the Livestock and Fish CRP included participatory and gender epidemiology and assessment of the impact of diseases and technology on gender relations. These have pointed to a number of critical dimensions of gender relations for animal health services and information such as the division of labour and skills, access to and control over resources and knowledge of women (e.g. ability to detect animal health problems).

Gender-integrated research will be undertaken with the Livestock Livelihoods and Agri-Food Systems flagship especially in clusters 1, 2 and 4. Cluster 1 builds on earlier work to allow for the gendered targeting of future interventions and offer a sound basis for gender integration in clusters 2 and 4. In cluster 2, the work on herd health packages requires the integration of gender and social analyses, to respond to the preferences, opportunities and constraints of women, men and young people. The gender-responsive business models in cluster 4 not only seek to reduce women's labour and energy expenditure, but also strengthen gender-equitable control over animals and their benefits, and the participation of women and young people in decision making.

Youth

Young people are often excluded from influence as they often lack resources. However, the animal health sector, provides opportunities to meet the aspirations of young people, beginning with the capacity development agenda in low-income countries, as well as to that specific in the Livestock CRP (see Annex 3.4). Opportunities for young people include:

1. Participation in field monitoring and research activities.
2. With appropriate training, roles as community animal health workers, veterinarians or other extension related positions.
3. Participation in bioscience research as MSc or PhD students.
4. Agribusinesses and IT opportunities such as sale and delivery of pharmaceuticals as well as other animal health services.

2.2.1.10 Capacity development

The flagship pursues 2 tracks for capacity development: One addressing the capacity to undertake research and one the capacity to use and apply research outputs (see Annex 3.2). Capacity development is key in all clusters; each has its own priorities and capacity focus and it is all gender-sensitive. Key elements per cluster include:

In cluster 1, the flagship will build the capacity of farmers and producers to recognize diseases and measure their impact. In addition, research with national partners will require specialized training in relevant research methods in epidemiology and impact measurement.

Cluster 2 requires substantial engagement of livestock producers, community animal health workers and vets to develop herd health packages. This offers exciting opportunities for women and young people as well as men to foster their capacity to innovate. Community animal health workers and vets will be supported to use the new tools and packages made available by research. Innovative learning materials combining adult learning theory and instructional design will be employed.

Capacity development in cluster 3 will focus on fellowships, MSc or PhD projects and with the BecA-ILRI Hub/ABCF. It will support the development of future research leaders in cutting-edge bioscience topics and thus contribute to institutional capacity development of national university partners.

Cluster 4 on delivery models for animal health products and services will train various groups including, farmers, vets, researchers and policymakers. Besides electronic and printed learning materials, this cluster also offers exciting possibilities to use ICTs to deliver products and services. Leadership and entrepreneurship development for women and young people will be complemented through novel business model approaches and includes institutional strengthening through multi-stakeholder approaches.

The flagship's main partners in capacity development are the BecA-ILRI hub as well as local universities and national programs. SLU's cooperation with universities in East Africa and Southeast Asia will contribute to long-term capacities in partner institutions.

2.2.1.11 Intellectual assets and open access management

Robust IA management, as well as open access and research data management and communications, help in uptake and achieving outcomes (sections 1.0.12, 1.0.13 and 1.0.14 and annexes 3.8, 3.9, and 3.10.7). They also contribute to the flagship's effectiveness, learning and accountability. Specific dimensions and concerns of relevance to this flagship are listed here.

For IA management, two important products of the flagship are diagnostic tests and vaccines, both of which are widely disseminated to users through commercial channels. In both cases, program partners are likely to use patent protection and agreements with private partners that may restrict global accessibility. These will be addressed in line with the CGIAR principles. In some countries, wide access to these technologies is determined by national compliance and registration requirements that take time.

Most of the information products of the Livestock and Fish CRP flagship are already open access. This include materials accessible through [CGSpace](#). Some journal articles are limited access and the flagship will reserve funds each year to supplement bilateral projects to pay article open access fees. The longer-term strategy is for these to be fully budgeted into bilateral projects. Genome sequencing information and data is a major product of the program; this is currently made accessible through NCBI and other specialized public repositories. Ensuring that raw data is well-documented and accessible is a continuing challenge that the flagship will tackle through partner open access and data management plans and by allocating funds on an annual basis to ensure proper curation and publishing. Some flagship projects are experimenting with data visualization tools and these will be made open source for wider re-use.

2.2.1.12 Flagship management

Implementation will be led by a FL, supported by a leader for each cluster (CL). The primary roles of this core team is to develop and update the research agenda and impact pathways, monitor the quality and delivery of knowledge outputs, and report as required. Responsibility for implementation and

delivery of research lies with CGIAR-centre or other partner teams. The FL will lead guide priority strategic research and allocation of W1/2 resources as well as any strategic exploration of new research areas; guide development of bilateral projects to ensure alignment to the flagship their ability to contribute to strategic synthesis funded by W1/2; coordinate all reporting; lead cross-flagship initiatives; support and sometimes lead resource mobilisation and lead bi-monthly meetings (face-to-face or virtual). Cluster leaders will have a scientific leadership role, they will also contribute to reporting, together with PIs of aligned projects and Centre focal points. CLs support the FL in developing the flagship strategy, and will guide research design in their clusters and monitor science quality of outputs. They will lead design and science quality of all strategic research supported by W1/2 resources.

The flagship will be led by Ulf Magnusson at SLU; 20% of his time will be supported by W1/2, with 20% administrative support, and an annual flagship meeting. Cluster leaders will be: C1 Barbara Wieland (ILRI), C2 Ulf Magnusson (SLU), C3 Vish Nene (ILRI), C4 Barbara Wieland (ILRI). Cluster leader contributions will not be specifically resourced beyond their agreed participation in cluster outputs.

The SLU flagship leadership is an exciting opportunity which may also present challenges since the SLU systems and contracts have not been designed for the CGIAR, and inputs from a university are not necessarily well-suited to command-and-control implementation and they need to be balanced with academic responsibilities. This arrangement will require regular review and adaptation to succeed.

2.2.2 Flagship Budget Narrative

2.2.2.1 General Information

CRP Lead Centre's Name: ILRI

Centre Location of Flagship Leader: Sweden

2.2.2.2 Summary

Total Flagship budget summary by sources of funding (USD)

Funding Needed	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1 + W2	3,918,425	4,114,346	4,320,063	4,536,067	4,762,870	5,001,013	26,652,787
W3	1,710,090	1,795,594	1,885,374	1,979,643	2,078,625	2,182,556	11,631,884
Bilateral	2,341,669	2,458,752	2,581,690	2,710,774	2,846,313	2,988,629	15,927,830
Other Sources	0	0	0	0	0	0	0
	7,970,184	8,368,692	8,787,127	9,226,484	9,687,808	10,172,198	54,212,493

Funding Secured	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2 (Assumed Secured)	3,918,425	4,114,346	4,320,063	4,536,067	4,762,870	5,001,013	26,652,787
W3	1,710,090	0	0	0	0	0	1,710,090
Bilateral	1,064,300	29,433	0	0	0	0	1,093,733
Other Sources	0	0	0	0	0	0	0
	6,692,815	4,143,779	4,320,063	4,536,067	4,762,870	5,001,013	29,456,607

Funding Gap	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2 (Required from SO)	0	0	0	0	0	0	0
W3 (Required from FC Members)	0	-1,795,595	-1,885,375	-1,979,643	-2,078,625	-2,182,557	-9,921,794
Bilateral (Fundraising)	-1,277,369	-2,429,319	-2,581,690	-2,710,775	-2,846,314	-2,988,629	-14,834,096
Other Sources (Fundraising)	0	0	0	0	0	0	0
	-1,277,368	-4,224,914	-4,467,065	-4,690,418	-4,924,939	-5,171,186	-24,755,890

Livestock CRP: Full Proposal 2017-2022

Total Flagship budget by Natural Classifications (USD)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
Personnel	2,720,747	2,856,784	2,999,624	3,149,605	3,307,085	3,472,439	18,506,287
Travel	434,121	455,827	478,618	502,549	527,676	554,060	2,952,853
Capital Equipment	255,000	267,750	281,137	295,194	309,954	325,451	1,734,487
Other Supplies and Services	1,961,677	2,059,761	2,162,749	2,270,886	2,384,430	2,503,652	13,343,157
CGIAR collaborations	0	0	0	0	0	0	0
Non CGIAR Collaborations	1,506,046	1,581,348	1,660,415	1,743,436	1,830,608	1,922,138	10,243,993
Indirect Cost	1,092,593	1,147,222	1,204,583	1,264,813	1,328,053	1,394,456	7,431,722
	7,970,184	8,368,692	8,787,126	9,226,483	9,687,806	10,172,196	54,212,487

Total Flagship budget by participating partners (signed PPAs) (USD)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
ILRI	7,560,387	7,938,406	8,335,327	8,752,093	9,189,698	9,649,183	51,425,096
SLU	379,081	398,035	417,937	438,834	460,776	483,814	2,578,479
ICARDA	30,715	32,251	33,864	35,557	37,335	39,202	208,927
	7,970,183	8,368,692	8,787,128	9,226,484	9,687,808	10,172,199	54,212,494

The most significant cost driver for the Livestock Health flagship is Personnel costs, at 34% of the total budget and with roughly equal amounts from W1/W2 funding (48%) and bilateral funding (52%). To realize its 4 outcomes, 10 scientist FTEs per year are required. Since the flagship budget has significant funding gaps in bilaterals from 2018 onwards, the required 10 scientist FTEs are only accounted for in 2017. For the remaining years, FTEs covered by W1/W2 budget vary from 4.7-5.1 scientist FTEs per year (29.5 FTEs for the 6 years). Including the costs of support staff (research associates, post-doctoral fellows, instructional design specialist, tick unit manager, technical assistants, animal technician, program management officer, program accountant) the total amount budgeted for staff for W1/W2 over the 6 years is \$12,033M, which equals 52% of the W1/2 budget. Around 40% of staff are internationally recruited staff and 60% nationally recruited staff and staff are currently based in 4 countries. The staff budget also includes needed new hires to build and extend needed capacity in herd health, reducing AMR emergence, vaccine and diagnostic development, evaluate animal health constraints, develop business models for delivery of animal health products and services and capacity development.

The second most important cost driver is supplies and services which is funded largely by W1/W2 resources (81%) while 19% of the total flagship bilateral budget makes up the balance. A large proportion of this supplies and services budget is for consumables for diagnostic testing and to cover laboratory costs.

Management of the Flagship is budgeted at 20% of the Flagship Leader's time with smaller amounts for other staff such as the Program Management Officer, Program Accountant and administrative support staff. Also included are the costs of an annual Flagship planning meeting at \$20,000 per year. Management costs are pro-rated across all the outcomes.

Outcome 1 (Closed yield gaps through improved agronomic and animal husbandry practices) requires \$6,997M or 23% of the overall budget. Of this, \$4.545M is from W1/W2 funds, representing 20% of the total W1/W2 funds allocated to the flagship. All clusters contribute to this outcome, with the most important contributions coming from cluster 1 (disease impact and risks), cluster 2 (herd health packages) and cluster 4 (access to animal health services and products). These clusters have a high proportion of gender and capacity development for this outcome and they comprise \$1.436M (20%

of outcome budget) and \$1.007M (13% of outcome budget). These high proportions provide the necessary enabling environment to move from research outputs to reach the intended 1.6 million livestock keeping households (4 million individuals) and support them realize 15%, on average, increase in productivity through the use of integrated herd health packages in 9 countries. Total staff costs funded through W1/W2 attributed to this outcome is \$2.49M. Key skills of staff contributing to this outcome are expertise in assessing and developing herd health packages, expertise in evaluation of delivery models of animal health products and services, expertise in developing socio-economic impact models.

Less W1/W2 budget is assigned to operational costs with W1/W2 budget for supplies at \$1.488M. Travel, especially national travel related to field work is \$324,365 for W1/W2. Some expenditure is foreseen to introduce ICT in performance monitoring and for improving delivery of animal health services. The amount budgeted from W1/W2 funds however allows only pilot testing and proof of concept (\$69,288), but will increase considerably as significant bilateral projects are expected in this area. Included in the supplies and services budget line are laboratory reagents and utensils, and diagnostic kits.

Raising bilateral funds will be required to hire 4 FTEs to have the necessary human resources to achieve the intended outcomes. Given that this outcome addresses one of the key objectives of this flagship, the current level of bilateral funds are comparably low. However the herd health approach and research related to animal health service delivery are relatively novel and thus secured bilaterals are not as high as they could be. Note that contributions to this flagship will also come from bilateral projects mapped to the livelihoods flagship which are not reflected in this budget

Outcome 2 (Technologies that reduce women's labour and energy expenditure developed and disseminated) has a total budget of \$4.390M, of which 3.306M is W1/W2 funds, or 14% of total W1/W2 funds allocated from the flagship. This will enable more than 2.8 million women in the targeted CRP sites to profit from improved technologies. In W1/W2 funds, staff time budgeted towards this outcome is \$1.82M and supplies and services is \$1.136M. Supplies mainly consists of consumables used for field work for testing herd health interventions, including diagnostic tools and costs to produce training materials.

A considerable amount of these budgets have direct capacity development activities, comprising \$901,208 (20% of the outcome budget). Gender, the other important cross-cutting theme has \$644,604 (15% of the outcome budget).

Outcome 3 (Reduced livestock and fish disease risks associated with intensification and climate change) has the highest budget with \$15.313M (49% of overall budget), of which W1/W2 funds are 12.362M and secured bilaterals 2.951M, which is 54% of total W1/W2 funds and 37% of secured/highly expected bilaterals. Besides cluster 1 (45% of its budget) which develops risk models to identify future health threats, the main contributor to this outcome is Cluster 3 (70% of its total budget). The other two clusters have much lower but important contributions to this outcome (20% and 25% of their respective budgets) and ensure that outputs translate into the intended outcome of 20% reduction in morbidity and mortality of livestock and 25% reduction in disease control costs through early diagnosis of disease. It is estimated that by the end of the project 6.4 million people in livestock keeping households, across 10 countries will be impacted by the work conducted towards this outcome. Such vaccine and diagnostic tool development work can make a significant contribution to reducing or mitigating disease risks, but they are also expensive and require specialized facilities. At ILRI, which operates on a full cost recovery basis, user access fees (\$12,500 annually) are levied on people using the BecA-ILRI Hub and its modern infrastructure. This work also requires access to farm facilities with large and small animals for research purposes. A Tick Unit is required to maintain the life cycle of *Theileria parva* for research purposes. All these need to meet bio-safety and animal care and use standards. The BecA-Hub operates at Biosafety Level (BSL) 1 and 2, the Tick Unit at BSL 2 and there is an enhanced BSL-2 facility at the farm. Farm and Tick Unit costs vary on the services. For

example, a single cow costs about \$500 to purchase and \$20/day to maintain and feed. Cattle experiment numbers are usually 10/group and experiments can last as long as 3 months. A single tick costs \$2 to rear and a single day's production of *T. parva* sporozoites costs about \$2,500. Hence, these costs rapidly accumulate over the course of a year. Another service provides state-of-the art flow-cytometry for immunology research, which costs \$55/hour to run. The basic equipment was purchased by ILRI two years ago at a cost of \$420,000.

The level of consumables support based on historical data reflects an extensive use of molecular biology, immunological techniques, protein expression and purification, DNA sequencing to name a few. An example of reagents needed includes: general laboratory consumables such as disposable micro-tips and gloves and expensive immunological (tissue culture media, fetal calf serum, r-hIL2, TCGF, disposable tissue culture flasks, microtitre trays, sterile pipettes, mAbs for cell fractionation, anti-mouse magnetic beads, antibody reagents, FACS reagents, IFN-g ELISpot, 51chromium and 111indium radio-isotope for CTL assays, syringes, synthetic peptides, vacutainers and other materials required for sampling animals) and molecular biology reagents (enzymes, agarose, buffers, PCR oligonucleotide primers, PCR reagents, random DNA labeling kits, DNA sequencing plasmid expression constructs, reverse transcriptase, SDS-PAGE and immunoblot reagents, SMART cDNA synthesis kits, plasmid mini-prep kits, genomic DNA, RNA and FPLC protein purification). Discounting large ticket items, e.g., synthetic peptide libraries – last purchased at \$300,000 using bilateral funds, average consumables for routine works costs per BecA-ILRI Hub user about \$2,500/month. Part of the reason for this high cost is that consumable items cost on average 10~20% higher than in Europe and the USA.

The expenses outlined are reflected in the budget as follows. Of the \$12,362M W1/W2 funds, \$6.216M are for staff (50%), and \$5.407M for supplies and services (44%). As explained above, the main cost drivers are related to laboratory work. Non-lab work is also needed and non-laboratory related staff costs are \$1.245M (compared to \$4.969M lab-related staff costs), and supplies and services for field work in this outcome are \$650,140.

For 2017 activities towards this outcome, substantial bilateral funds are secured, but the situation is less clear from 2018 onwards and there will be significant funding gaps unless more bilateral funds can be raised.

Outcome 4 (Reduced biological and chemical hazards in the food system) has a total budget of \$3.84M, of which \$2.792M is W1/W2 funding. To reach the intended outcome of 5.6 million people in livestock keeping households experiencing 15% (or actual) reduction in prevalence of zoonotic pathogens and applying rational use of antibiotics in the livestock food system, translating into reduced risk for increase in anti-microbial resistance and improved food quality for 2.7 million consumers in 7 countries, activities will mainly take place in clusters 2 (developing evidence and tools) and 4 (animal health service delivery). Staff time of W1/W2 funds amount to \$1.507M with supplies and services at \$1.02M.

The relative low allocation of W1/W2 funding for this outcome (12% of the total W1/W2 allocated to this flagship) is because there are strong synergies with activities related to the primary outcomes of this flagship (closed yield gap and reduced disease risks). In other words, measures to improve animal health in general reduce the risk of occurrence and transmission of zoonoses to humans and they also reduce the need for excessive use of antibiotics thereby reducing the risk of further emergence of AMR and antimicrobial residues in animal source foods. The relative distribution of the costs related to this outcome are similar to that for outcome 1. Besides staffing, there will be considerable travel costs (\$161,892 from W1/W2 funds) as the activities are field-based at several locations. For supplies and services, ICTs and GPS equipment are needed. In addition, point of care diagnostic kits for known zoonoses may help as indicators to assess reductions in the spread of zoonotic infections (like brucellosis, leptospirosis and others) from livestock to humans. Consumables for established and well

standardized kits (including microtitration plates) for monitoring AMR at farm level are included. This fieldwork on AMR may attract bilateral funds in 2018 and onwards.

2.2.2.3 Additional explanations for certain accounting

For the CGIAR partners, personnel costs are defined as the total remuneration costs of an individual: base salary, fringe benefits and other employment costs. Actual computations on average for fringe benefits and employment costs in relation to base salary would translate to an average multiplier of 97% and 68% for international and national staff respectively. The reason for the high multiplier for international staff is because of the housing allowance, security and education allowance that are not provided to nationally recruited staff. Fringe benefits include: pension, housing allowances, education allowance, security, health insurance, other insurances, catastrophe fund, annual leave and severance pay. Other employment related costs include staff training and development; transportation, recruitment, appointment and repatriation allowances and payroll administration fees.

For SLU, the 51.3% fringe benefits is constituted as a Swedish tax that the employer must set aside for the employees and covers vacation, sick-leave, parental leave, part of the pension, full professional insurance and part of health care costs.

The cost structure of research undertaken during the first phase CRPs has been applied to estimate average research costs for collaborators, consumables, other supplies and services, and travel. The actual cost structure for secured W3 and bilateral projects is first applied, and the average research cost factors are then applied to the remaining portions of the budget that are yet to be secured.

2.2.2.4 Other Sources of Funding for this Project

The program is funded by a mix of W1/2 and W3/bilateral funding. Funding from other sources and significant in-kind contributions from program partners or other collaborators are not anticipated.

Funding from W3 and bilateral sources is almost fully secured for Year 1 under the Base Budget scenario, with a funding gap of \$0.5 million. But considering the project pipeline, it is expected that the gap will be filled for 2017.

Recognizing the high degree of uncertainty with W1/2 funding, both in terms of whether the indicative allocation assigned to the CRP in the CRP2 guidance document will be maintained once the CRP portfolio has been approved, and in terms of whether the projected budget assigned to the CRP in the System Financial Plan each year is actually achieved through donor W1/2 commitments, the program will be prepared to reduce the scope of its activities and outcomes to reflect any W1/2 funding shortfalls. Within this flagship, the W1/2 funded activity on developing herd health packages and the long-term development of vaccines and diagnostic platforms will be reduced or postponed should there be any shortfall. The W1/2 budget for staff with the necessary expertise has been kept to a minimum and thus any shortfall will have immediate effect on the quality of research that can be undertaken.

The program is giving high priority to mobilizing bilateral funding to improve its ability to implement the full program and achieve the outcomes. This is required to:

- Generate replacement funding for current bilateral funded projects as they end and follow-up or initiate new research activities in later years; and
- Offset the uncertainty associated with W1/2 funding.

Given the broad technical coverage of the flagship – from advanced biotechnology to development social/economic research - this flagship has the opportunity to seek bilateral funding from many different

sources. Both traditional (e.g., DFID, USAID, BMZ, SDA, IDRC) non-traditional donors (e.g., NIH, NSF, BBSRC, Rockefeller, Moore Foundation, Ford Foundation) to the CGIAR will be targeted, based on their request for proposals. It is of course very difficult to judge from where bilateral funding or for which of the flagship activities will come in 2-6 years time from now. However, one may refer to the fact that the scientists in this flagship have a strong track-record with respect to their ability to secure external competitive grants, so the likelihood for future bilateral funding is judged as generally good.

The best assessment is that areas for bilateral or W3 funding will appear is in field orientated research and in particular the delivery of animal health products and services. High-end biotechnology research is an area of scientific merit at ILRI and funding for AMR related research is a global emerging issue. The flagship is uniquely placed to do research on the ground in these areas and finally the assessments and evaluation research for delivery of animal health services and products that would be attractive for development oriented donors. Finally and notably, the fact that SLU is a full partner of this flagship opens a set of new sources of bilateral funding; funds available only for main applicants in Sweden or the EU.

Latest technology developments further open new avenues to undertake research in collaboration with development partners. For example increased use of ICT at farm level can support monitoring of performance and /or contribute to early detection of emerging diseases or can be used for remote capacity building. In W1/W2 allocations minimal funds have been allocated for ICT related activities, but research in that area combined with development outcomes, makes it attractive for bilateral donors. Similarly, latest advances in the use of unmanned aerial vehicles (UAVs) as drone-ports open also new avenues for delivery of services and products related to animal health. This can be both ways by delivering products, such as vaccines and/or treatments to remote areas, but can also be used to shorten the time clinical samples from suspected outbreaks reach diagnostic labs. Drones further would support a One Health approach in delivery systems since the same channels and infrastructure can be used to address human and animal health challenges. While this is a new area for the flagship, there is compelling reasoning to engage in this process in collaboration with other CRPs and flagships of the Livestock CRP for bundling of services. It is expected that development donors will have a particular interest in this area and thus they will be approached for funding in consortia consisting of policy makers and NGO development partners.

The importance of women in livestock production, especially in the smallholder sector, has been recognized but there is a scarcity of examples on how women can increase their incomes and thus directly profit from their knowledge and experiences. There is a role of women, esp. young women to get involved in delivery of animal health service delivery, for example as community animal health workers or by establishing small-scale businesses selling inputs for livestock production. The poultry sector and the dairy sector would be ideal to initiate research on how this can be achieved. Given the scalability of outputs of such a project, it is likely to attract interest of donors for whom development outcomes are important.

Emerging threats by experience are attractive for funders and thus work on antimicrobial resistance and risk models which take into account challenges resulting from changing production systems (intensification) and from climate change is expected to generate interest of donors.

The following major projects are priority targets to deliver Flagship outcomes and mobilize the needed bilateral projects, both to address the need for replacement funding as current projects finish and to secure resources for the uplift budget.

Project focus	Total amount (\$)	Start Year
Assessment of livestock production constraints.	5M	2018
Maintaining the vaccine and diagnostic platform technologies in order to develop vaccines and diagnostics against priority diseases.	20M	2019
Mapping the effect of climate change on the distribution of ticks and tick-borne diseases, risk maps for emerging diseases.	5M	2018
Mapping AMR and developing mitigation strategies.	10M	2018
Women in animal health service and product delivery	20M	2018/19
Use novel technologies for animal health service and product delivery (drone-ports)	20M	2019
TOTAL FUNDING GAP	60M	

2.2.2.5 Budgeted Costs for certain Key Activities

	Estimate annual average cost (USD)	Please describe main key activities for the applicable categories below, as described in the guidance for full proposal
Gender	1,477,196	The flagship will fully integrate gender into its activities wherever possible. It is important in cluster 1 activities related to the development of tools to measure impact of disease including socio-economic aspects. Gender will have an even more important role in cluster 2 activities which aim to develop and test herd health packages which address disease control issues and relates those to animal husbandry and welfare. In cluster 4 which aims to improve access of livestock producers to animal health services and products, gender will also play an important role. Without engagement of women in the flagship activities, the intended outcomes to reduce the yield gap, reduce risks from livestock diseases and reduce biological and chemical hazards in the food system, cannot be achieved. Across activities in clusters 1, 2 and 4, about 20% of all budget has a direct or indirect gender link, which emphasizes the role gender has in these activities.
Youth (only for those who have relevant set of activities in this area)	90,000	Youth plays an important role in clusters 2 and 4. The development of herd health packages offers opportunities for youth to actively engage with research and thus appreciate new sides of livestock production. Also they will be specifically targeted in training on how the best combination of herd health packages can be identified in a specific production context.
Capacity development	433,183	Capacity development is a key component in all clusters of the flagship, each with different priorities and each addressing several elements of the CGIAR capacity development framework. It will increase capacity to undertake research in national research institutions, mainly in clusters 1 and 3 through PhD and fellowship programs. It aims to promote innovation capacity of farmers,

	Estimate average annual cost (USD)	Please describe main key activities for the applicable categories below, as described in the guidance for full proposal
		community animal health workers and veterinarians by involving them in R4D activities, mainly in cluster 2 for the development and testing of herd health packages and in cluster 4 in innovation systems for the identification of suitable and acceptable business models that result in better access to animal health products and services for livestock producers in the target countries. This considerable proportion of staff time includes time of project staff and capacity development experts to run training for farmers, veterinarians and community animal health workers, for facilitating innovation platforms and develop training materials, and it includes post-doctoral fellowships which aim to build capacity of future research leaders. Operational costs include mainly training materials, incl. e-learning approaches. It is expected that funds raised for clusters 2 and 4 will have substantial capacity development elements, raising the overall percentage of funds for capacity development.
Impact assessment	0	While this budget is held by the Strategic Investment Fund, several avenues for Impact Assessment suggest themselves. Cluster 1 will provide extensive baseline data on disease occurrence and resulting impact of livestock diseases. As part of the research in cluster 2, activities related to testing herd health packages will monitor all changes in the production system under research to identify the best options and thus will directly deliver inputs for impact assessments. Also through planned knowledge, attitude and practice KAP surveys, which are planned to be repeated at the end of interventions, will provide important impact assessment data. For capacity building activities, especially trainings, ante- and post-training tests will be applied to monitor increase in knowledge and skills. How these impacts play out at a larger scale will be captured through monitoring activities in other flagships, namely the livelihoods flagship. If the flagship is successful in getting more bilateral projects which have a more explicit development component, for example projects mapped to cluster 4, additional specific impact assessment activities will be planned and thus the budget available for Impact Assessment is likely to increase over time.
Intellectual asset management	2,721	A small budget has been set aside for ad hoc IP advice and support for contract development with e.g. private sector partners. This will be supported by in-kind investments of the partners and support from management level.
Open access and data management	79,356	The flagship subscribes to the various tools and platforms used by the Program to maximize the wise accessibility of its research. The Flagship will reserve funds each year to supplement bilateral projects to pay article open access fees. The longer term strategy is for these to be fully budgeted into bilateral projects. Ensuring that raw data is well-documented and accessible is a continuing challenge that the flagship will tackle through partner open access and data management plans and by allocating funds on an annual basis to ensure proper curation and publishing.
Communication	40,811	Communication is key to engage with the various stakeholders related to flagship research activities in order to achieve the intended outcomes. This includes funding to disseminate results and high profile events.

2.2.2.6 Other

2.2.3 Flagship Uplift Budget

2022 additional outcome description	Amount needed (\$)	W1 + W2 (%)	W3 (%)	Bilateral (%)	Other (%)
Closed yield gap - Extended to 4 more priority countries or other locations	5,406,000	0	74	26	0
Reduced women's labour - Extended to 4 more priority countries or other locations	4,054,500	0	0	100	0
Reduced livestock diseases - Extended to 4 more priority countries or other locations	13,515,000	0	7	93	0
Reduced hazards in food system - Extended to 4 more priority countries or other locations	4,054,500	0	49	51	0

2.3. Livestock Feeds and Forages

Box 2.3a Livestock Feeds and Forages Flagship—Summary

The ex-ante impact assessment indicates that the Flagship's research to improve cultivars is among the highest ranked in addressing the CRP's multiple objectives, also in terms of returns on investment. The Flagship makes particularly strong contributions to capacity development and environmental issues.

This flagship:

- Aims to close yield gaps through improved feeding that increases livestock productivity, providing enhanced opportunities for smallholder livestock keepers and producers to meet increased demand for livestock products.
- Builds on CGIAR comparative advantages, including a long tradition of research on feeds and forages and the unique genetic resources held in CGIAR genebanks.
- Exploits new scientific opportunities to produce more and better quality feeds and forages.
- Delivers content-specific feeding strategies that increase overall feed supply and livestock productivity in intensifying systems and provides more reliable feed supply in vulnerable systems.
- Identifies and addresses specific strategies to enhance equity and improve participation of women and young people in the livestock sector.
- Contributes directly to sub-IDOs:
 - Close yield gaps through improved agronomic, agroforestry and animal husbandry practices.
 - More efficient use of inputs.
 - Technologies that reduce women's labour and energy expenditure developed and disseminated.

2.3.1 Flagship Project Narrative

2.3.1.1. Rationale and scope

Why research on animal feeds and forages in developing countries?

Increasing demand for animal-source food offers multiple opportunities for small-scale livestock producers to be part of the supply response, but they can only do so if livestock productivity, for which feed is a key component, can be increased.

Feed is a key limiting factor and often the most expensive input in livestock production (Swanepoel *et al.*, 2010). Integrating feed and forage research with improved animal health and genetics can lead to significant enhancements in livestock production, up to 240% (Herrero *et al.*, 2016). In mixed crop–livestock systems, which often have the potential to intensify, the most important contributors to feed resources are forages, crop residues and rangelands (Herrero *et al.*, 2013), while in pastoral and agro-pastoral systems grazing of rangelands is the principal, often the only, source of feed. Feed shortages, in terms of both quantity and nutritional quality, either seasonally or, in the case of dryland pastoral systems, inter-annually, are widespread, slowing the sector's growth and periodically causing severe losses. Improved feed and forage options (including processing and commercialization), better management of rangeland, and increased cut-and-carry and pasture resources, together with improved feed utilization of crop residues and other agricultural by-products, all have considerable underexploited potential to improve animal productivity, while also contributing to the resilience of agro-ecosystems and environmental sustainability (Smith *et al.*, 2013b; Searchinger *et al.*, 2015; Rao *et al.*, 2015).

Increasing land and water scarcity, driven by the relentless pursuit of food security, often restricts opportunities to increase feed and forage production. Consequently, options to improve feed resources need to be carefully targeted and adapted to each context. This flagship provides feed-

based solutions that respond to challenges in the rapid growth trajectory to increase the quantity and quality of feed biomass, to smooth seasonal variability without over-taxing the natural resource base and harness positive environmental effects, such as contributions to biodiversity, soil fertility and carbon sequestration. Example locations include Kenya, Nicaragua and Vietnam, with mixed crop-livestock systems focusing on small-scale strategic cut-and-carry forage plots and crop residues/by-products in East Africa and Southeast Asia, as well as on pastures in Central America. For fragile growth (Ethiopia, Kenya, Tunisia), the key challenge is to enhance resilience by reducing spatial, seasonal and inter-annual variations in biomass availability, which may cause significant losses of animals. There is considerable opportunity to reverse land degradation and increase water-use efficiency in these systems by exploiting genetic diversity, encouraging higher biomass growth and introducing appropriate management and grazing systems.

Delivering feed and forage options to address these multiple dimensions must address a number of constraints using evidence-based approaches (World Bank, 2012). Included here are technical constraints, such as land scarcity, where improving the quality, quantity and use of food crop residues and by-products is paramount; variable feed inputs (as described above) for which solutions have been shown to include assessing and matching available resources, conservation of feeds and increasing use of biomass. Use of planted forages, or food-feed crops may be constrained by biotic and climatic threats, necessitating the application of new selection and breeding approaches. Institutional and policy constraints are also important and may be addressed by solutions spanning seed and planting material delivery practicalities and policies, public regulations that support private sector investment in feed options and new feed production and marketing opportunities such as irrigated fodder in Ethiopia.

Addressing the grand challenges

This flagship will contribute to several of the grand challenges. Feed and forage research ensures efficiently produced milk and meat will help to combat malnutrition and ensure nutritious and diverse agri-food systems and diets. Feed based options provide opportunities for women and young people, mitigating problems associated with age and labour. Environmental factors, such as competition for land, overdrawn water supplies, soil degradation and climate change, are all affected, positively or negatively by the production and management of feeds and forages.

The CIAT, ICARDA and ILRI genebanks cover most of the world's forage species. The management and conservation of these genetic resources is addressed through the Genebanks CRP, but their utilization through this flagship is an important dimension.

Why should CGIAR invest in this?

CGIAR has a long history of research on animal feeds and tropical and subtropical forages, principally targeting small-scale livestock producers in developing countries. It began with the creation of CIAT in 1967, ILCA in 1974 (continued through ILRI) and ICARDA in 1977. It is an important part of the Livestock and Fish CRP.

No other research group or institute has the resources, facilities, expertise and partnerships in place to deliver what the CGIAR can in this field. Resources include genebanks that, as already indicated, include a diverse and unique collection of most of the world's forage and feed species. Facilities and expertise cover feed and forage analyses, animal nutrition, forage breeding and on-station facilities for the development and rigorous testing of feed and forage options. There are strong links with farming communities for piloting new options using participatory approaches developed by CGIAR researchers. For almost 50 years, CGIAR researchers have enjoyed strong collaborative relationships with researchers in the national programs that are the 'next users' of its research outputs.

Today, advances in animal genetics and health can be combined with exciting new opportunities in feeds and forages to create a holistic approach to increasing livestock productivity while tackling a range of other development and environmental challenges. Above all, CGIAR research on feeds and forages is central to its mission to reduce poverty and improve human nutrition and food security.

The ex-ante impact assessment, identified the research to improve cultivars as among the highest ranked in addressing the CRP's multiple objectives, and also in terms of returns on investment. The flagship makes particularly strong contributions to capacity development and environmental issues (see Annex 3.10.2).

Overall goal

The goal of the flagship is to increase livestock productivity and reduce environmental impacts by identifying, testing and delivering superior feed and forage strategies and options and by designing and implementing livestock value chains with reduced ecological footprints and positive environmental and social (gender- and youth-equitable) implications.

2.3.1.2 Objectives and targets

Research in this flagship will contribute directly to two SLOs—reduced poverty and improved food and nutrition security for health—and indirectly to improved natural resource systems and ecosystem services. The flagship aims to reach one million households by 2022 with improved feeding options and strategies that will increase livestock productivity by over 30% per unit area production. Many of these beneficiaries will be women and young people, who will enjoy higher incomes and increased job opportunities, as well as improved nutrition. Most will be livestock keepers, but non-livestock keepers engaged in feed and forage value chains will also benefit, in both 'rapid inclusive growth' and 'fragile growth' systems. The flagship will also conduct research to help realize the particularly strong opportunities for youth employment within livestock value chains.

Research will contribute directly to three sub-IDs, by achieving the following outcomes:

- Closed yield gaps through improved agronomic, agroforestry and animal husbandry practices.
- More efficient use of inputs, specifically feed options.
- Technologies that reduce women's labour and energy expenditure developed and disseminated, addressed through efficiency gains in forage and feed production, sourcing and processing.

This flagship's objectives are:

- Define the priorities for feed and forage research and development.
- Develop improved feed and forage genetic options.
- Identify and test feed and forage utilization and processing opportunities suitable for use in small-scale production systems undergoing rapid inclusive or fragile growth.
- Take new feed and forage technologies to scale
- Assess the impact of these technologies on animal productivity, farm incomes and the distribution of benefits to producing and consuming families, including women and children.

Flagship outcomes to 2022

- 1.8 million poor households (4 million individuals) efficiently using inputs through optimized feeding strategies, including rations and processing across 11 countries.
- 1.8 million poor households (8.4 million individuals) realizing 30% increase, on average, in productivity through the use of improved feeding options and strategies, in 12 countries.
- Improved feeding practices that reduce women's labour and energy expenditure by 10% developed and disseminated, reaching 2.6 million women in 12 countries.

2.3.1.3 Impact pathway and theory of change

Figures 2.3a and 2.3b present the flagship's ToC and assumptions. The flagship aims to increase livestock productivity among livestock producers and keepers through developing, testing and delivering superior feed and forage strategies. Its strategy is structured to respond to livestock feed challenges in fragile and rapid inclusive growth systems. In fragile growth systems, it focuses on opportunities to improve livelihoods through 'smoothing productivity', so that producers can maintain regular supplies to markets and are less susceptible to seasonal variations. In rapid inclusive growth systems, opportunities centre on reducing the variability of feed supply across seasons and years, in order to achieve better and more stable animal production, enhance household consumption of animal-source food, and build household and community resilience.

The flagship focuses its work on four key areas to support its focus on closing the yield gap, whilst improving resource use efficiency and offering livelihood opportunities within livestock value chains. The first involves the development and use of tools, methods, approaches, technologies and data resources to understand the constraints and opportunities for enhanced feed and forage interventions. The second area of focus involve the development of forage, rangeland and crop cultivar resources; the third focus is on improving the utilization of existing feed resources; whilst the fourth looks at the delivery and uptake options and business models for taking these resources to farmers across diverse environments and link them to markets.

Capacity development is essential to deliver the impact of the technologies developed in this flagship. Women play a crucial role in ensuring household food security, but their contributions to farm work and productivity tend to be undervalued. Identifying and challenging gender differences and tailoring activities and technologies to meet women's needs can contribute to their increased participation in developing improved feeding. Similarly, young people represent a great part of the labour force on farms and their participation can be secured by engaging them in learning new technologies and emerging opportunities as the sector grows and develops. Working with strategic partners that already work with these groups will lead to greater impact of interventions.

While some change pathways are fully incorporated in the flagship, others are routed through other flagships. Feed and forage technologies must be 'bundled' with other technologies, such as improved animal health or genetics to fully capture synergies for closing the yield gap. This will occur through the work undertaken in priority countries and other locations and consolidated in the Livestock Livelihoods and Agri-Food Systems flagship, in particular their work on optimizing livestock systems for productivity and resilience and enabling markets and institutions. Feed and forage technologies also have environmental implications and research on the trade-offs between production objectives and environmental impacts will be delivered through the Livestock and the Environment Flagship.

Flagship outputs are translated to outcomes through changes in capacity and practices of 'next users', such as local, national and international research and development partners, the private sector, policy and decision-makers and in some cases livestock producers; this last group representing 'final users', or beneficiaries. Examples of specific changes that the flagship will influence through collaboration include: Diagnosis of feed constraints and opportunities, and effective prioritization and targeting of feed and forage interventions; availability of new forage, rangeland and crop cultivars, superior to local through 'next users' to farmers; delivery and uptake of feed and forage technologies through proof-of-concept scaling, business model development and value-chain approaches; better utilization of existing and novel feed and forage resources, and application of management strategies to conserve and rehabilitate rangelands and pastures.

These changes rest on some key assumptions: that technologies are considered relevant to researchers and policymakers; that policy, development practitioners and livestock producers prioritize sustainable feed and forage technologies.

Changes across the four domains of 'next users' contribute to closing the yield gap, more efficient use of inputs and technologies that reduce women's labour and energy expenditure being developed and disseminated. This will happen because: private and public sectors partners are able to produce sufficient planting material to respond to demand; livestock keepers are willing to adapt their practices to better utilize feed and forage options; appropriate market incentives exist for different value-chain actors and increased livestock feeding options result in sustainable production systems and lower environmental impact per unit of livestock product.

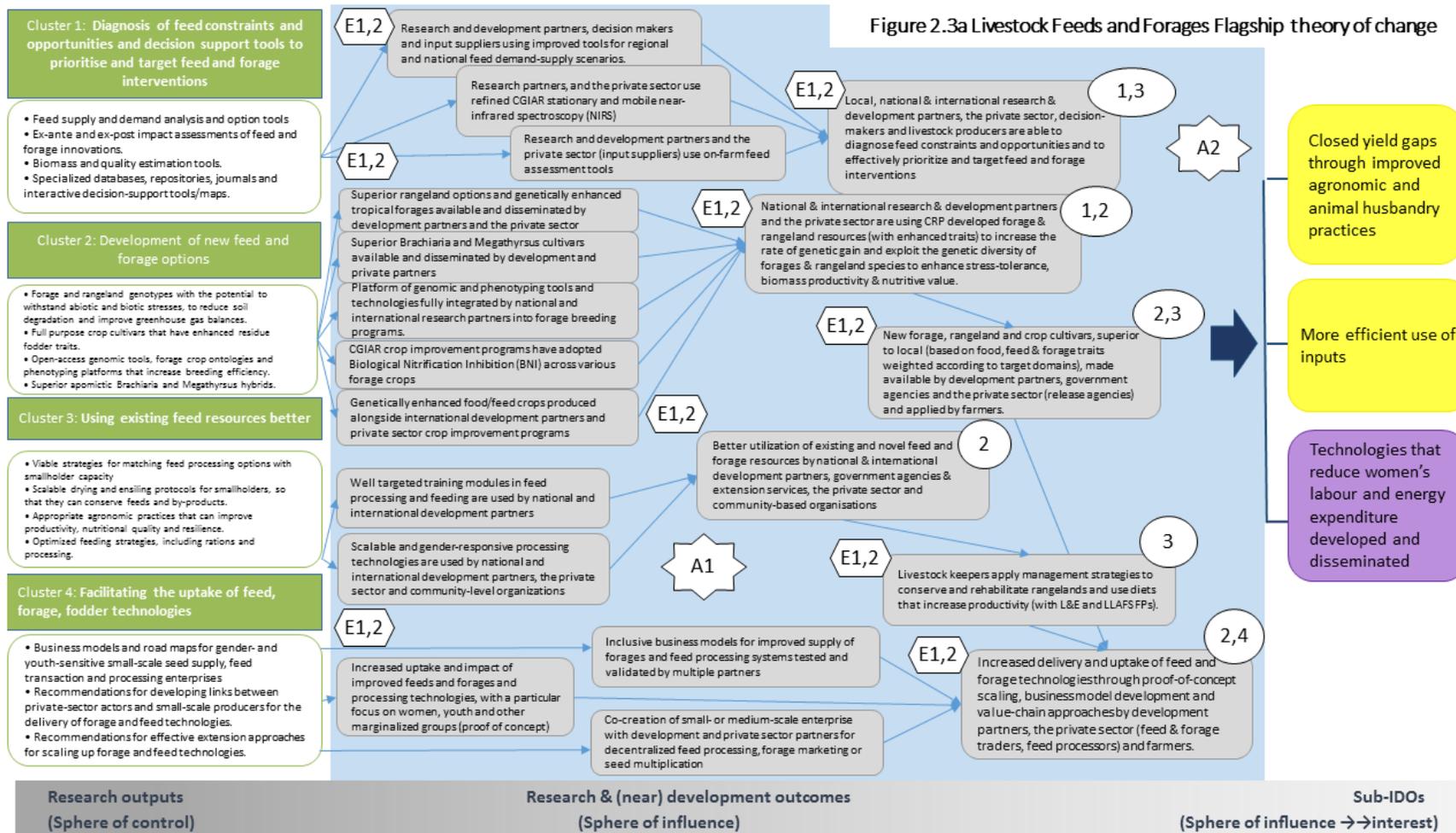


Figure 2.3b Livestock Feeds and Forages Flagship theory of change, assumptions, enabling actions and change domains

A1

Assumptions	
A1	▪Technologies are considered relevant to researchers and policy-makers
	▪Appropriate market incentives exist for different value-chain actors
	▪That there is an enabling policy environment
	▪Policy makers, research and development partners prioritize sustainable feed and forage technologies.
A2	▪Private and public sectors partners are able to produce sufficient planting material to respond to demand
	▪Livestock keepers are willing to adapt their practices to better utilize feed and forage options
	▪Appropriate market incentives exist for different value-chain actors
	▪Policy makers, development partners and livestock producers prioritize sustainable feed and forage technologies.
	▪That there is an enabling policy environment
▪Increased livestock feeding options result in sustainable production systems and lower environmental impact per unit of livestock product.	

E1

Enabling cross-cutting actions	
E1	"Next user" capacity development
E2	Consideration of gender & youth issues in technology, business models & delivery system development and dissemination

1

Domains of Change	
1	Changes in local, national and international research and development systems
2	Changes in markets, enterprises and consumer behaviour
3	Changes in producer systems (producers and communities)
4	Changes in policy and investment systems for scaling

2.3.1.4 Science quality

The flagship builds on research carried out over several decades, by ILRI (and ILCA), ICARDA, CIAT, ICRISAT and latterly by the Livestock and Fish CRP. Much has involved national research and extension services, as well as farmers and the private sector, in the development and testing of innovations. This flagship aims to develop novel feed and forage solutions for both the rapid inclusive growth and fragile growth scenarios. It has a global perspective addressing smallholder constraints in representative locations in Central America (e.g. Nicaragua), East Africa (e.g. Kenya, Ethiopia), North Africa (Tunisia), Asia (e.g. Vietnam, India). It will work with the Livestock Livelihoods and Agri-Food Systems flagship to address target smallholder systems and link with the site integration strategy of the CGIAR.

This will involve incorporating strong expertise on feed and forage options into readily usable approaches for feed intervention prioritization and thus making them available to the livestock development community. The work acknowledges that feed solutions vary by context and that simple approaches to connect solutions to individual contexts are needed. This process has already begun with development of tools such as FEAST, Techfit and SoFT which incorporate decades of expertise with biophysical and other information to address the challenges of matching feeds to different situations and will be taken to conclusion in this Cluster of Activities. Further strands of work in this Cluster will involve capitalizing on advances in phenotyping techniques at a range of scales using NIRS and remote sensing to better match feed solutions to local contexts. Without such analyses, introducing feeds and modifying systems will not be possible.

Significant advances have been made in the selection, evaluation and breeding of forages in the Livestock and Fish CRP addressing both cut-and-carry and pasture systems. Methodologies for the selection of stress-tolerant and highly nutritive forage, rangeland and tree germplasm were developed (Rao 2014). Advances in *Brachiaria* phenotyping and definition of new species with high potential for breeding (Rao, 2014; Cardoso *et al.*, 2013, 2014a, 2014b) and selection for biomass production, nutritive quality and resilience were achieved. CIAT's long-term *Brachiaria* breeding programs resulted in the release of various hybrids adopted on over 500,000 ha so far among small, medium and large producers (Livestock and Fish, 2014). Napier grass germplasm selected from ILRI's genebank was the basis of varieties resistant to smut (a potentially devastating disease in East Africa), developed by KARI. Research on biological nitrification inhibition (BNI) has advanced (Subbarao *et al.*, 2013). Advances have been made in rangeland monitoring technologies and in studying the effects of water salinity and drought on *Artemisia herbalba* (Louhaichi *et al.*, 2010, 2015; Ouled Belgacem and Louhaichi, 2013).

The flagship will use recent developments in genomics (e.g. Abera Desta and Ortiz, 2014) and in the management and analysis of big data (e.g. Berger *et al.*, 2013) to achieve increased efficiency in the development of new forages, linking with the Genetic Gains platform and leading to improved forage cultivars with enhanced productivity and nutritional quality and performance under biotic and abiotic stresses (Rao, 2014; Cardoso *et al.*, 2014a). Dense maps and reference genomes will be constructed for complex polyploid forage species (Farrell *et al.*, 2014; Li *et al.*, 2014), enabling genomic selection (Hayes *et al.*, 2013a), genetic mapping for quantitative traits of interest, and making basic and applied research on apomixis a reality. The application of genomic selection, together with recent advances in field-based high-throughput plant phenotyping (White *et al.*, 2012), to forage selection and breeding pipelines promises to accelerate genetic gain in target genera and support the trend to develop forages better adapted to specific production systems and locations. Optimized nutritional quality assessments will be used to support the development of the 'full-purpose crop' approach—going beyond the primary traits of grain, pod and tuber yields to better match and balance human and animal nutritional needs (Blümmel *et al.*, 2013).

The flagship will use advances in phenotyping—including remote sensing with unmanned aerial vehicles, hyperspectral cameras, digital vegetative charting techniques, and portable NIRS units—for *in situ* prediction of forage nutritional quality, as a basis for accelerating genetic gain in tropical forage systems. Building on work conducted by CIAT and the BecA-ILRI hub, it will develop approaches to BNI in forages—work that adopts an innovative approach to both environmental and economic sustainability. New uses for endophytes, a novelty in tropical forages, and other microbial associations to enhance forage biomass and increase adaptation to biotic and abiotic stress factors will also be explored (Subbarao *et al.*, 2015; Djikeng *et al.*, 2014; Ghimire and Craven, 2013; Ghimire *et al.*, 2009).

The Livestock and Fish CRP saw advances in the development of demand scenarios and domains for selected crops (e.g. maize, sorghum, cowpea) and geographies (Blümmel *et al.*, 2013; Singh *et al.*, 2003), to inform decisions on new full-purpose crop cultivars for farmers, consumers and the feed industry. Proof-of-concept studies have shown that breeding can simultaneously increase crop residue feed quality and water use efficiency. Feeding options that reduce methane emissions livestock have also been identified (Hatew *et al.*, 2015) while the use of cassava peels for animal feeds could turn 50 million tonnes of waste material into a USD 900 million a year feed industry in Africa. The flagship will take these advances forward.

The development of crop improvement strategies that integrate human and livestock nutritional needs with those of specific production systems will allow synergies and increase system efficiencies in a world of shrinking natural resources. In particular, the full purpose crop concept developed with the other AFS CRPs will allow across-crop adaptations that transcend mono-dimensional improvements for primary produce yield and encompass whole plant optimization, thereby improving the quantity and quality of crop residues at source. The rapidly increasing demand for monogastric meat in many countries requires new solutions to feed supply that do not compete for human food. Biological advances in entomology, modification and *de novo* synthesis of organisms and deconstruction of ligno-cellulosic biomass (Blümmel *et al.*, 2014) provide the cutting-edge science needed to underpin the development of such feeds.

In the Livestock and Fish CRP, advances were made in understanding how candidate feed solutions need to connect to the wider value chain system. The CRP experimented with the use of multi-stakeholder platforms to ensure that solutions were demand-driven and adoptable at scale. Cluster 4 of the Feeds and Forages Flagship will apply systems approaches to ensure that research advances in other clusters are relevant and that they reach users at scale. This will include the co-development of informal and formal seed supply systems for specific feeds and forages (Hanson and Peters, 2003) taking into account the different needs and roles of women and men (Galiè, 2014). The work will also build on the participatory approaches to uptake of improved feeds and forages developed in SE Asia by CIAT (Horne and Stur, 1999; Stur and Horne, 2001; Peters *et al.*, 2003). Advances have been made in the development of integrated, inclusive and gender-sensitive systems in targeted value chains under the Livestock and Fish CRP.

Informal and formal seed supply systems will be further co-developed with private- and public-sector partners and through farmer-to-farmer networks, applying new approaches to business model development and gender-sensitive value chain analysis (Lundy *et al.*, 2014). *Ex-ante* and *ex-post* impact assessment, integrating economic, environmental and gender and youth trade-offs, will reveal opportunities and constraints for the adoption and dissemination of feed and forage technologies. Feed production and supply chain analysis will be applied (Lundy *et al.*, 2014), together with feed certification models where appropriate. With development partners, notably GIZ, the flagship will test, validate and apply a proof-of-concept to scale feed and forage technologies, aiming to close yield gap in animal productivity and reach millions of smallholder farmers.

2.3.1.5 Lessons learned and unintended consequences

The Livestock and Fish CRP showed that feed and forage research can have the greatest impact when it is conceived and delivered as combined demand-driven interventions with strategic research. This dual approach will also be employed and enhanced in the proposed Livestock CRP.

Decision-support tools like SoFT, FEAST and Techfit help development agencies identify feeding solutions and take them to scale, matching technologies to target environments and socio-economic contexts. FEAST is widely-used across the livestock research for development community and enhanced with gender-sensitive aspects. The flagship will enhance the FEAST approach and its integration with other tools such as SoFT and Techfit and continue to adapt these tools to be more accessible to wider audiences.

The Livestock and Fish CRP emphasized the link between feed and forage research and integration into systems. For example, initial collaborative proof-of-concept research in Nigeria between three CRPs (Roots, Tubers and Bananas; Humidtropics; and Livestock and Fish) has shown the huge potential to convert the 50 million tonnes of cassava waste in Africa to livestock feed. Further research on appropriate business models will allow us to scale up feed and forage technologies that have the potential to close the yield gap in a sustainable manner.

In the 1990s, CIAT began a long-term *Brachiaria* breeding program focused on classical recurrent selection for superior apomictic hybrid cultivars. During the past 25 years of research, a number of widely adopted new varieties have been developed and levels of genetic resistance to insect pests have been dramatically improved in breeding populations. The inclusion of improved forages in livestock systems has at least doubled carrying capacity. The knowledge and experiences generated during this process, together with new tools developed, allow us to shorten the time to market of improved forages with higher quantity and quality—currently emphasizing *Brachiaria* and *Megathyrsus*.

Previous research at ILRI and in the Dryland Systems CRP led to the development of innovative index-based livestock insurance products, based on normalized difference vegetation index (NDVI), greenness, for forage predictions. However, NDVI does not provide an estimate of forage palatability. The flagship will now explore how palatability maps that link VegMeasure (Louhaichi *et al.*, 2013) with Leaf Snap (Kumar *et al.*, 2012) can be used on mobile phones to provide real-time data on pasture condition.

Unintended consequences that might occur as a result of the work conducted in this flagship revolve around two areas: gender/youth and the environment.

With regard to gender/youth, feed and forage interventions might alter relationships in beneficiaries' households, including the empowering or disempowering of men and women or young people, and/or changes in responsibilities or workloads. This might create conflicts and result in negative consequences for individual family members, including women and young people. For example, it has been documented that in pastoralist communities in Tanzania, improved forages that are fed to single cows by women could contribute to food security during the dry season (Galiè *et al.*, in press). The flagship will include gender- and youth-disaggregated *ex-ante* and *ex-post* analyses to foresee, and avoid, such unintended consequences while extending the knowledge base on what works.

With regard to the environment, the development of highly productive feed and forage technologies could result in further expansion of the area used for animal production. This may lead to further deforestation and other negative consequences for the environment, including the loss of biodiversity

and increased greenhouse gas emissions. To prevent this, strong links will be needed with policymakers who support the sustainable intensification of existing areas and are keen to conserve forests.

2.3.1.6 Clusters of activity

The flagship has four clusters.

- Cluster 1 supports the planning and implementation of feed and forage research and interventions by the other clusters and with the flagship's partners.
- Cluster 2 takes advantage of new genomic and phenotyping technologies and approaches to produce more and better quality feeds and forages.
- Cluster 3 aims to match feed, forage and rangeland supply with demand, both spatially and temporally.
- Cluster 4 ensures that the technologies developed in the flagship and elsewhere are available to end users, especially farmers.

To achieve these ends, the core research agenda comprises five priority outcomes supported by W1/2 investment:

- Platforms to prioritize and target context-specific feed and forage interventions (cluster 1).
- Forage improvement to facilitate sustainable intensification, with an emphasis on the rapid inclusive growth trajectory and on integrating private-sector engagement (cluster 2).
- Full-purpose crop improvement, making use of the synergies in crop–livestock interactions to maximize system efficiency (cluster 2).
- Utilizing existing feed resources better (cluster 3).
- Delivery and scaling up (proof of concept), to ensure that the pathway from discovery to adoption and impact is completed (cluster 4 with the Livestock Livelihoods and Agri-Food Systems flagship).

The forage and feed development and utilization clusters (2 and 3) will relate to clusters 1 and 4 in an iterative and dynamic process of priority setting and scaling up, ensuring strong orientation to users' demands and maximizing impact at scale.

Cluster 1: Diagnosis of feed constraints and opportunities and development of smart approaches for prioritizing and targeting feed and forage interventions

Existing supply of quality livestock feed and forages in target livestock systems varies markedly over space and across seasons. At the same time demand for feed and forages to fulfil production needs for market oriented livestock production is also highly variable both spatially and temporally. This cluster will build on the CRP's evolving understanding of contextual constraints to better livestock feeding built through collaboration across CGIAR centres, NARS and IAR centres during development of participatory tools such as FEAST, Techfit and SoFT. It will also capitalize on new phenotyping capability at both farm (near infra-red spectroscopy) and landscape level (infrared reflectance and x-ray fluorescence spectroscopy) to inform decision making about enhanced feeding strategies at a range of scales including for rangeland systems.

The cluster will refine approaches to intelligent decision making about best-bet feed interventions, capitalizing on expertise in CGIAR centres, building this into decision tools and thus making it available to the livestock development community at scale. Ex-ante and ex-post impact studies will be used to assess the economic, environmental and social impacts of the feeding strategies developed in this flagship.

Main research outputs

- Refined local, national and regional feed supply and demand analysis and option tools
- Research priority setting based on *ex-ante* and *ex-post* impact assessments of feed and forage innovations.
- Biomass and quality estimation tools for assessing feed resources and for mapping and monitoring trends in rangeland condition and vegetation cover.
- Specialized data bases, repositories, journals and interactive decision-support tools/maps for capacity building and forage and tree selection.

Outcomes to 2022

1. Local, national and international research and development partners, the private sector, decision-makers and livestock producers are able to diagnose feed constraints and opportunities and to effectively prioritize and target feed and forage interventions, resulting in: a 10% improvement in utilization of feeds and forages, a 20% increase in animal production using improved feed and forage technologies, a 10% accuracy increase for biomass and quality estimation and at least 250,000 annual visitors to global databases, repositories, interactive tools and maps and the *Tropical Grasslands—Forrajes Tropicales* journal website.

Milestones

- Research and development partners, decision makers and input suppliers use improved approaches for local, regional and national feed supply and demand scenarios in 3 priority countries (2019) and in a further 2 priority countries (2022).
- Research partners and the private sector use refined CGIAR stationary and mobile NIRS hubs in Eastern Africa and Latin America: in 3 priority countries (2019) and in a further 2 priority countries (2022).
- Research and development partners and the private sector (input suppliers) use on-farm feed assessment tools in one priority country (2019) and in a further 3 priority countries (2022).

Cluster 2: Development of new feed and forage options

As demand for livestock products grows and the natural resource base for animal production becomes more constrained, the importance and monetary value of crop residues and forages is increasing rapidly. In response to farmer demands for improved feeds and forages, new technological options will be identified through the selection, evaluation and breeding of full-purpose crops with improved residue fodder traits (Blümmel, 2010; Porqueddu *et al.*, 2016) and forage species with high quality, superior productivity and stable agronomic performance at plant and landscape levels (Rao, 2014; Rao *et al.*, 2015). Work will build on decades of previous work by all partners and give new emphasis to the contribution of improved technology options to adaptation to and mitigation of climate change, and to water and nutrient use efficiency.

Main research outputs

- Forage and rangeland genotypes that have the potential to withstand abiotic and biotic stresses, reduce soil degradation and curb greenhouse gas emissions.
- Key full-purpose crop cultivars that have enhanced residue fodder traits (in collaboration with other CRPs).
- Open-access genomic tools, forage crop ontologies and phenotyping platforms that increase breeding efficiency.
- Superior apomictic *Brachiaria* and *Megathyrsus* hybrids.

Outcomes to 2022

1. National and international research and development partners and the private sector are using CRP developed forage and rangeland resources (with enhanced traits), in 30 countries and reaching producers who plant over 2 million ha, to increase the rate of genetic gain and exploit the genetic diversity of forages and rangeland species to enhance stress-tolerance, biomass productivity and nutritive value.

Milestones

- Superior *Brachiaria* and *Megathyrus* cultivars available and disseminated by private sector partners in Latin America and the Caribbean priority countries and other locations (2019), and in a further 2 priority countries in Central America, East Africa and Southeast Asia and further scaling in South America for forages (2022).
 - Platform of genomic and phenotyping tools and technologies fully integrated by national and international research partners into forage breeding programs in Latin America and the Caribbean priority countries (2019), and in a further 2 priority countries in Central America, East Africa and Southeast Asia and further scaling in South America for forages (2022).
 - Superior rangeland options available and disseminated in North Africa (2019).
 - Genetically-enhanced tropical forages disseminated by development partners and the private sector globally (1 million ha by 2019 and 2 million ha by 2022).
2. New forage, rangeland and crop cultivars, superior to local (based on food, feed and fodder traits weighted according to target domains), made available by development partners, government agencies and the private sector and applied by 100,000 farmers in each of at least 7 priority counties and other locations

Milestones

- New forage, rangeland and crop cultivars, superior to local (based on food, feed and forage traits weighted according to target domains), made available by development partners, government agencies and the private sector and applied by 100,000 farmers in one priority country (2019) and by 100,000 farmers in each of a further 6 priority countries and other locations (2022).

Cluster 3: Using existing feed resources better

Feed shortage and high feed costs can be significantly mitigated by making better use of the resources that are already available leading to reduced feed costs and more efficient production of animal-source food and hence to a reduced environmental footprint. For on-farm feed resources this includes preservation and storage (hay, silage) to balance seasons of plenty and deficit, context specific feed processing targeted to on-farm conditions (productivity level, feed demand, labour, investment ability), smart supplementation, matching of key nutrients to actual animal performance, least cost ration and feed substitution design and biological, chemical and physical upgrading of feed, fodder and forage biomass. For off-farm feed resources mapping of feed resources and demand at a range of scales to encourage and facilitate feed surplus-to-deficit transactions through feed markets engaging a range of public and private value chain actors is needed.

The tools described in cluster 1 will be used to identify the appropriate approaches in different contexts, taking a value chain approach. Many interventions offer opportunities for private-sector engagement in decentralized settings, especially for small and medium-sized enterprises. They will also result in income and employment opportunities, especially for young people and women. For the fragile growth trajectory, improved utilization of rangeland feed resources will be a focus, together with rangeland conservation and rehabilitation measures (with clusters 2 and 3 of the Livestock and

the Environment flagship). New biological, physiological and chemical approaches, often designed and developed for second-generation biofuel technologies, are becoming available and will be explored for the economically effective release of sugars from the 10 - 50 billion tonnes of ligno-cellulosic biomass available annually from crop and rangelands potentially making them available for ruminant and monogastric animals.

The strategic research outcome is the better utilization of existing and novel feed and forage resources, and outputs linked to feed processing, feed surplus/deficit scenarios, ration balancing, forage/feed conservation and preservation, and the upgrading of lignocellulose management of feed and forage resources. Practical outcome will be reduced feed costs, reduced labour/drudgery associated with feed resourcing and feeding, increased production of animal-source food and increased livelihood opportunities around feed.

Main research outputs

- Viable strategies for matching feed processing options with smallholder capacity.
- Scalable drying and ensiling protocols for smallholders, to conserve feeds and by-products.
- Agronomic practices that improve the productivity, nutritional quality and resilience of diverse grass, legume, tree and rangeland technologies across environments.
- Optimized feeding strategies, including rations and processing, to improve animal productivity, including rangelands and monogastric production, reduce feed cost and labour requirements.

Outcomes to 2022

1. Better utilization of existing and novel feed and forage resources through: scalable and gender-responsive processing technologies, management strategies to conserve and rehabilitate rangelands while producing, preserving and storing feed biomass and diet formulation that increases productivity while reducing overall feed and forage costs and environment impacts, by national and international development partners, government agencies and extension services, the private sector and community-based organisations in 3 priority countries.

Milestones

- Well-targeted training modules in feed processing and feeding are used by national and international development partners in at least 1 priority country (2019).
 - Scalable and gender-responsive processing technologies are used by national and international development partners, the private sector and community-level organizations in at least 1 priority country (2019).
2. Livestock producers in 3 priority countries apply management strategies to conserve and rehabilitate rangelands and pastures while ensuring ongoing ability to produce, preserve and store feed biomass and use diets that increase productivity while reducing overall feed and forage costs and environmental impacts (with the environment and livelihoods flagships).

Milestones

- Livestock producers apply management strategies to conserve and rehabilitate rangelands and use diets that increase productivity in 1 priority country (2019) and in a further 2 priority countries (2022).

Cluster 4: Facilitating the delivery and uptake of feed and forage technologies

This Cluster will develop approaches to enhancing the uptake of improved feed options developed in this flagship and elsewhere, including those developed by farmers. This will involve developing a better understanding of the organizational constraints to uptake of new feeding strategies including the supply of germplasm. The Cluster will interleave extensively with the Livestock Livelihoods and Agri-Food Systems flagship and will be the bridge between the development of new feeding strategies (in this cluster) and their adoption at scale through institutional innovation (LLAFS Flagship).

Research in the livestock sector in the past decade involving CGIAR centres and partners has undergone a paradigm shift away from linear supply-push approaches to more holistic actor-oriented and community-pull approaches. This Cluster will build on this understanding to place the new feed options developed elsewhere in the Flagship into an innovation systems context. This will involve identifying the various organization and institutional constraints which limit uptake of new feed options.

For example, seed supply for planted forages and trees is often an impediment to uptake by smallholders. The Cluster will therefore test organizational innovations to overcome the germplasm constraint including working with private sector actors, community seed production groups and the public sector research system. The work will involve development of business plans, value chain interventions and strong collaboration with the development community bringing in their business expertise.

A further barrier to improved feeding concerns arrangements for economical transport and processing of bulky feeds such as crop residues. Again organizational innovations will be explored including community ownership of processing facilities and collaboration with transporters and private processors to develop compacted feeds which are more amenable to economical transport.

Co-development of innovative and inclusive business approaches (Springer-Heinze, 2007; Lundy *et al.*, 2014), in collaboration with the Livestock Livelihoods and Agri-Food Systems flagship will address adoption of the technical and organizational solutions described above, paying particular attention to the needs of women and young people (Kiptot and Franzel, 2011).

The strategic research outcomes are a) increased uptake of existing and novel feed resources and b) more equitable value chains, with better research-to-development interface to facilitate scaling up.

Main research outputs

- Business models and road maps for gender- and youth-sensitive small-scale seed supply, feed transaction and processing enterprises.
- Recommendations for developing links between private-sector actors and small-scale producers for the delivery of forage and feed technologies.
- Recommendations for effective extension approaches for scaling up forage and feed technologies (evaluated for their cost-effectiveness, sustainability, benefits to women and young people and accountability to clients).

Outcomes to 2022

1. Increased delivery and uptake of feed and forage resources through proof-of-concept scaling, business model development and value-chain approaches by development partners, the private sector (feed and forage traders, feed processors) and (1 million by 2022) farmers across diverse environments in priority countries and other locations in Latin America, North and East Africa and South and Southeast Asia.

Milestones

- National and international development partners and other value-chain actors' pilot test at least 4 extension approaches (including at least 1 that improves women's access to information) in at least 1 CRP focus country (2019).

- National and international development partners and other value-chain actors adopt and scale up at least 2 of the tested extension approaches (including at least 1 that improves women's access to information) in 5 priority countries (2022).
- Increased uptake and impact of improved feeds and forages and processing technologies, with a particular focus on women, young people and other marginalized groups (proof of concept) in 3 priority countries (2019) and in a further 2 priority countries (2022).
- Inclusive business models for improved supply of forages and feed processing systems tested and validated by multiple partners across 4 priority countries (2019) and in a further 3 priority countries (2022).
- Co-creation with development and private-sector partners of up to 5000 small- or medium-sized enterprises in decentralized feed processing, forage marketing or seed multiplication, in 4 priority countries (2022).

2.3.1.7 Partnerships

This flagship's partnership strategy is driven by its ToC and the skills, expertise, facilities and capacity needed along discovery-to-delivery pathways, the combined comparative advantage of the flagship's core program partners and any additional capacity that is required, and where it will work.

Comparative advantage in forage technologies is provided by ILRI, CIAT and ICARDA, each with relevant expertise, resources, and genebanks. The choice of partners is largely determined by a) past collaboration, b) technical, managerial and operational capacities of the partner, c) where the partner is located, and d) the stage in the discovery-to-scaling up process. Key cross-CRP partnerships, especially on animal-source food, will be deepened through the full-purpose crops and BNI platforms.

Core flagship partners: CIAT, ICARDA, ILRI and SLU have a strong record of delivery on forage development and integration into smallholder systems, generating economic and environmental benefits. CIAT, ILRI and ICARDA and Tier 2 partner ICRAF have extensive forage and tree collections available to select materials for a wide range of agro-ecologies and livestock production systems. This is complemented by forage breeding at CIAT, for which there are few alternative providers. ILRI has strong links with crop centres to develop full-purpose crops, which represent a unique global opportunity. CIAT and ILRI are linked with the BNI network and climate-smart Brachiaria program. CIAT, ILRI, ICARDA, GIZ and SLU are researching links between feeds and forages, livestock and the environment. WUR has strong expertise on feeds and environmental assessment, while IWMI will bring expertise on water use efficiency and irrigation, which can be game-changing for feed production in drylands. GIZ brings a strong demand orientation and a focus on value chains, business models and scaling up. The BecA-ILRI Hub state-of-the-art biosciences facility includes expertise on feeds and forages.

Advanced research partners: To develop diagnostic and decision-support tools the flagship will collaborate with upstream research and development partners. These will include FAO, CSIRO, and CIRAD, all of whom have databases on tropical feed resources. CSIRO has one of the longest histories of developing decision-support tools in agriculture. The development of new feed and forage options requires access to state-of-the-art knowledge and facilities in genotyping, phenotyping and bioinformatics, so it is important to be linked with cutting-edge research groups such as the UK's Genome Analysis Centre and Institute of Biological and Environmental Research. Access to genetic material beyond the CGIAR will be provided through partnerships with, for example EMBRAPA in Brazil. Work on the de-construction of ligno-cellulosic biomass will involve collaboration with organizations such as Michigan State University. Continued collaboration with regional institutions such as CATIE will allow up- and downstream advances in understanding and managing the livestock–environment interface.

Partners for effective innovation systems: Scaling feed and forage strategies will be done through links with service providers, with organizations such as the National Dairy Development Board and the Indian Council for Agricultural Research in India, and with private-sector feed and seed suppliers. Collaboration with GIZ as a strategic partner will help establish proof of concept to scale different technologies in priority countries and locations. The final piece in the uptake of new feed and forage technologies is strong partnerships with national research programs and universities in priority countries and with development organizations such as SNV and Heifer International. These partnerships will test, validate and support technology innovations and the links will be forged mainly through the Livestock Livelihoods and Agri-Food Systems flagship.

Partners for effective scaling up: GIZ will have a special role in linking with other development partners. Links with private companies such as Dow Agrosociences will allow more rapid scaling up of feed and forage strategies through business-oriented dissemination. In dry areas, the flagship will link with the Opuntia network to expand the reach of its research results. Two new cross-CRP scaling platforms will be anchored in the flagship: The full-purpose crops initiative and the BNI Consortium with JIRCAS and others.

2.3.1.8 Climate change

Feed and forage production is critical both for adaptation to and mitigation of climate change. Recognizing that feed and forage production is the greatest agricultural land use worldwide (Peters *et al.*, 2013), there is considerable potential for widespread impact on climate change goals through these land-based interventions.

The flagship will develop technologies that contribute to adaptation by enhancing stress tolerance and to mitigation through BNI and enhanced carbon sequestration. Additionally, increasing the productivity and quality of forage-based systems will reduce methane emissions per unit of livestock product, as improved metabolisable energy reduces emissions and fewer animals and less land will be needed to produce the same amount or even more of the end product (Hatew *et al.*, 2015).

Improved resource-use efficiency will help mitigate the effects of climate change through reduced use of external inputs, especially those based on fossil fuels. Sustainable intensification of livestock-based systems will lead to either less land being needed to maintain the current level of production or to increased production levels on the same amount of land. Close links with the policy community will be needed to avoid the expansion of feed and forage production into non-agricultural areas, such as forests, and other eco-systems with high conservation value and an important role in mitigation. The climate change impacts of this flagship will be measured through collaboration with the Livestock and the Environment flagship.

2.3.1.9 Gender

Gender is an integral part of the problem analysis and priority setting process across the program (see Annex 3.3). This flagship will translate the gender strategy into concrete activities, including developing gender capacities, developing approaches that enable women to improve their participation in value chains and increasing their access to and control of resources, technologies, and the benefits of their work. Reducing drudgery, in feed chopping for example, is also important.

Typically, but not exclusively, women tend to maintain smaller livestock, such as poultry, pigs and small ruminants, which have different feed demands and costs than larger livestock and thus dictate different preferences for feed. This will be incorporated in the flagship's agenda-setting. Gender-

based crop and variety preferences will be assessed and gender analysis will consider the demand for and uptake of forage solutions, and develop an understanding of gendered forage and feed technology dissemination and uptake pathways. Differences in labour demand and preferences for women in forage and feed production or in sourcing and processing feeds will be researched. Other aspects include intra-household distributional impacts of feeds and forages innovations. This analysis will inform technology development and delivery systems so that both women and men benefit. Policy aspects affecting women's ability to access and use feed resources will be addressed with the Livestock Livelihoods and Agri-Food Systems flagship.

Youth

Opportunities exist to engage young people in the development of new small-scale businesses in feeds and forages. Possibilities include the involvement of young people in technologies that connect farmers to feed and forage supplies, in producing feeds and forages (for example in irrigation schemes) and in feed formulation. Further, young people can be supported to produce and market quality forage seeds, thereby ensuring better year-round feed availability—a major constraint at present. Activities will identify entry points for young people, identify constraints to participation, and developing a youth engagement strategy (see Annex 3.4).

2.3.1.10 Capacity development

Capacity development in the program will build on approaches developed during the Livestock and Fish CRP (see Annex 3.2). This flagship will focus on two elements of the CGIAR capacity development framework:

- Design and delivery of innovative learning materials and approaches through using methods such as new ICT facilities.
- Development of future research leaders through fellowships and institutional strengthening.

Learning approaches, including blended learning for farmers and development practitioners, which is being developed for use in conjunction with decision-support tools (e.g. FEAST/TechFit, SoFT), will be extended, while their efficiency and reach will be improved using novel ICT approaches.

Training of trainers will be addressed through capacity development incorporating approaches such as new instructional design. Big data approaches will be brought into play to support a broad audience ranging from development, research and education institutions, to policymakers, the private sector and farmers/farmer associations. Integrated platforms (FEAST, TechFit and SoFT, NIRS) will further facilitate scaling up. The flagship will continuously train and receive inputs from PhD, MSc and undergraduate students.

Gender research informs capacity development in both an integrated (technical aspects) and strategic (gender aspects) manner. To understand and work in a specific context, it is necessary to work with local partners who are able to collect, analyse and interpret gender data. The Livestock and Fish CRP gender team has finalized an assessment of local gender capacities in each value chain and will develop a tailor-made gender capacity development strategy in 2016 for each current Livestock and Fish site. This will be adapted for any further locations added under the Livestock CRP.

2.3.1.11 Intellectual assets and open access management

Robust IA management, open access and research data management and communications help in uptake and achieving outcomes (sections 1.0.12, 1.0.13 and 1.0.14 and annexes 3.8, 3.19, and 3.10.7). Specific issues relevant to this flagship are listed here.

For IA management, the flagship sometimes works with private-sector organizations to develop and commercialize its technologies. These require negotiation and active legal engagement to safeguard open access while protecting the interests of all partners which will be done in line with CGIAR principles. These are normally time- and location-limited agreements with companies to disseminate products resulting from forage breeding efforts. Such commercial cultivar IP management for bred forages mainly applies in Latin America and differentiated approaches are followed elsewhere. For full-purpose crops, the flagship works closely with other crop CRPs using crop-specific delivery pathways. For its forage genetic resources, the flagship complies fully with the International Treaty on Plant Genetic Resources for Food and Agriculture.

Most information products developed by the Livestock and Fish CRP are already open access. This includes materials accessible through [CGSpace](#) and through the open access *Tropical Forages–Forrajes Tropicales* journal. A weaker element is journal articles, some of which are still limited access. The flagship will reserve funds each year to supplement bilateral projects to pay open access fees for selected articles. The longer-term strategy is to fully budget these costs in bilateral projects.

The flagship produces various online products and tools whose content is currently open access. Partners also manage various feed databases with various degrees of openness. The flagship will work with partners to ensure that these are as open as possible. Ensuring data are well documented and accessible will be tackled through open access and data management plans and by allocating funds to ensure proper curation and publishing, including for quality and design.

2.3.1.12 Flagship management

Implementation will be led by a FL, supported by a leader for each cluster (CL). The primary roles of this core team is to develop and update the research agenda and impact pathways, monitor the quality and delivery of knowledge outputs, and report as required. Responsibility for implementation and delivery of research lies with CGIAR-centre or other partner teams. The FL will lead guide priority strategic research and allocation of W1/2 resources as well as any strategic exploration of new research areas; guide development of bilateral projects to ensure alignment to the flagship their ability to contribute to strategic synthesis funded by W1/2; coordinate all reporting; lead cross-flagship initiatives; support and sometimes lead resource mobilisation and lead bi-monthly meetings (face-to-face or virtual). Cluster leaders will have a scientific leadership role, they will also contribute to reporting, together with PIs of aligned projects and Centre focal points. CLs support the FL in developing the flagship strategy, and will guide research design in their clusters and monitor science quality of outputs. They will lead design and science quality of all strategic research supported by W1/2 resources. Each CL will identify a small group of key scientists across the CRP to develop innovative research design and to review new initiatives.

The flagship will be led by Michael Peters (CIAT); 20% of his time will be supported by W1/2, with 20% administrative support, and an annual flagship meeting. Cluster leaders will be: C1 C. Jones (ILRI), C2 M. Worthington (CIAT), C3 M. Blümmel (ILRI), and C4 U. Rüdiger (ICARDA). Cluster leaders contribution will not be specifically resourced beyond their agreed participation in cluster outputs. A new CIM-supported position in C4 will connect to GIZ and the Livestock Livelihoods and Agri-Food Systems flagship.

2.3.2 Flagship Budget Narrative

2.3.2.1 General Information

CRP Lead Centre's Name: ILRI

Centre Location of Flagship Leader: Colombia

2.3.2.2 Summary

Total Flagship budget summary by sources of funding (USD)

Funding Needed	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1 + W2	2,999,292	3,149,256	3,306,719	3,472,055	3,645,658	3,827,941	20,400,922
W3	0	0	0	0	0	0	0
Bilateral	3,598,708	3,778,643	3,967,575	4,165,954	4,374,252	4,592,965	24,478,099
Other Sources	0	0	0	0	0	0	0
	6,598,000	6,927,899	7,274,294	7,638,009	8,019,910	8,420,906	44,879,018

Funding Secured	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2 (Assumed Secured)	2,999,292	3,149,256	3,306,719	3,472,055	3,645,658	3,827,941	20,400,922
W3	0	0	0	0	0	0	0
Bilateral	3,598,709	840,630	261,658	70,000	0	0	4,770,997
Other Sources	0	0	0	0	0	0	0
	6,598,001	3,989,886	3,568,377	3,542,055	3,645,658	3,827,941	25,171,918

Funding Gap	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2 (Required from SO)	0	0	0	0	0	0	0
W3 (Required from FC Members)	0	0	0	0	0	0	0
Bilateral (Fundraising)	1	-2,938,013	-3,705,918	-4,095,955	-4,374,252	-4,592,965	-19,707,102
Other Sources (Fundraising)	0	0	0	0	0	0	0
	1	-2,938,013	-3,705,918	-4,095,955	-4,374,252	-4,592,965	-19,707,102

Total Flagship budget by Natural Classifications (USD)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
Personnel	2,393,903	2,513,598	2,639,278	2,771,242	2,909,804	3,055,295	16,283,123
Travel	309,331	324,797	341,037	358,089	375,993	394,793	2,104,042
Capital Equipment	100,000	105,000	110,250	115,762	121,550	127,628	680,191
Other Supplies and Services	2,774,103	2,912,808	3,058,448	3,211,371	3,371,939	3,540,536	18,869,207
CGIAR collaborations	0	0	0	0	0	0	0
Non CGIAR Collaborations	235,263	247,026	259,377	272,346	285,963	300,261	1,600,238
Indirect Cost	785,399	824,669	865,903	909,198	954,658	1,002,391	5,342,219
	6,597,999	6,927,898	7,274,293	7,638,008	8,019,907	8,420,904	44,879,009

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Total Flagship budget by participating partners (signed PPAs) (USD)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
ILRI	2,361,845	2,479,937	2,603,934	2,734,131	2,870,838	3,014,380	16,065,068
CIAT	2,728,191	2,864,600	3,007,830	3,158,222	3,316,134	3,481,940	18,556,919
ICARDA	1,457,963	1,530,861	1,607,404	1,687,774	1,772,163	1,860,771	9,916,938
SLU	50,000	52,500	55,125	57,881	60,775	63,814	340,096
	6,597,999	6,927,898	7,274,293	7,638,008	8,019,909	8,420,905	44,879,012

The most significant cost driver is other supplies and services at 42% of the total budget with 37% of this absorbed by various bilateral projects. This line item includes laboratory supplies, equipment related to the running of various laboratories and the cost of developing and maintaining the analytical platforms.

The second most important cost driver relates to personnel costs, at 36% of the total budget. To realize its 3 outcomes by 2022, a total of 162 FTEs are required over the 6 year life of the program. These include senior scientists, scientists, post doctoral researchers, research assistants, technicians, administrative assistants, with about one third being international staff and the balance national staff in 12 locations. This number does not include new hires which would be needed to build capacity in the following areas: Tools developer: 1 Informatician (SoFT tool development); Forage Genetics: 3 PostDocs (ILRI, ICARDA, CIAT for forage genetics); Forage Physiology: 1 Physiologist (CIAT replacement); Forage Utilization: 1 Animal Nutritionist (ILRI or ICARDA); Systems Analysis: 2 Systems Specialists (CIAT, replacements); Capacity Development: 0.5 Capacity Development Specialist (CIAT Central America); Gender: 0.5 Gender Specialist (ILRI Asia); Scaling: 1 Scaling Specialist (CIAT-GIZ-CIM). These new hires will be either replacements or supported by W1/2, Capacity development or bilateral funds.

The third most important cost driver relates to indirect costs which absorb 12% of both the W1/W2 budget and the bilateral budgets.

Management of the Flagship is budgeted at 20% of the Flagship Leader's time with smaller amounts for other staff such as the Program Management Officer, Program Accountant and administrative support staff. Also included are the costs of an annual Flagship planning meeting at \$10,000 per year. Management costs have been pro-rated across all the outcomes.

For Outcome 1 (30% increase in productivity through the use of improved feeding options and strategies, in 12 countries benefitting 1.8M poor households (8.4 million individuals), requires 58% of the W1/W2 allocation and 80 FTEs are required over the life of the program at a cumulative cost of about \$4,500,000. Skill categories include Forage Agronomists, Feed Specialists, Systems Specialists, Economists, Plant Breeders, Plant Geneticists, Biologists, Physiologists, Pathologists, Entomologists, Animal Nutritionists, Gender Specialists, Capacity Development Specialists and 7.5 FTEs of new hires are required to have capacity in these areas.

Lesser amounts of W1/W2 budget are assigned to operational costs (travel, capital equipment and supplies and services) to deliver this outcome. Included under supplies and services are e.g., lab and field operation inputs (e.g., genomics, biotechnology, animal nutrition, planting material), service fees for external laboratories (e.g., bioinformatics, genomics, biotechnology to capitalize on economies of scale), consultant fees for tool development, consultant fees for gender and capacity development. Capital equipment required to deliver this outcome includes mobile NIRS. A travel budget of about \$400,000 is required for field work, demand prioritization (e.g. staff exchange), participation in national and international conferences, staff meetings, and south-south exchange.

Bilateral funding to the value of just over \$2,000,000 supports the achievement of Outcome 1. Of this, approximately 26% is for personnel, representing 14. FTEs over the life of the program. 0.5 FTE will be

hired on bilateral funding in order to have capacity in scaling. The following amounts of the projected bilateral budget are assigned to operational costs: about \$100,000 for travel (to conduct field work, participate in international meetings and conferences) and \$1,000,000 for supplies and services (laboratory and field operation inputs, service fees for external laboratories, consultants' fees for gender, capacity development and economics).

For Outcome 2 (Efficiently using inputs through optimized feeding strategies, including rations and processing across 11 countries and benefitting 1.8M poor households representing 8.4M individuals), will require about 35% of the W1/W2 allocation, including 46 FTEs over the life of the program. Skill categories include Forage Agronomists, Feed Specialists, Systems Specialists, Economists, Physiologists, Animal Nutritionists, Gender Specialists, Capacity Development Specialists and 1.5 FTEs of new hires.

Lesser amounts of W1/W2 budget are assigned to operational costs (travel, capital equipment and supplies and services) to deliver this outcome. Under supplies and services are e.g., laboratory and field operation inputs (e.g., planting material, soils analysis, greenhouse gas analysis), service fees for external laboratories (e.g., bioinformatics, greenhouse gas analysis, soils analysis to capitalize on economies of scale), consultant fees for gender and capacity development. Capital equipment required to deliver this outcome includes mobile greenhouse gas measurement equipment. A travel budget of approximately \$237,000 is required for field work, demand prioritization (e.g. staff exchange), participation in national and international conferences, staff meetings, and south-south exchange.

Bilateral funding of about \$1,300,000 also supports the achievement of Outcome 2. Of this, approximately 26% is budgeted for personnel, representing 8.5 FTEs over six years. 0.25 of a new staff member will be hired under bilateral funding to have capacity in scaling. The following amounts of the projected bilateral budget are assigned to operational costs: \$60,000 for travel to conduct field work, participate in international meetings and conferences and about \$600,000 for supplies and services (laboratory and field operation inputs, service fees for external laboratories, consultants' fees for gender, capacity development and economics).

For Outcome 3 (Improved feeding practices that reduce women's labour and energy expenditure by 30% developed and disseminated, reaching 2.6M women in 12 countries), which requires 7% of the W1/W2 allocation, a total of 9 FTEs are required over the life of the program with the following skill categories - Systems Specialists, Economists, Forage Agronomists, Feed Specialists, Gender Specialists, Capacity Development Specialists and 1 FTE of new hires. Lesser amounts of W1/W2 budget are assigned to operational costs (travel and supplies and services) to deliver this outcome. Under supplies and services are e.g., field operation inputs (e.g., survey materials, consultant fees for gender and capacity development as well as surveys. A travel budget of \$53,000 is required for field work, demand prioritization, participation in national and international conferences, staff meetings, and south-south exchange.

Bilateral funding of \$263,000 also supports the achievement of Outcome 3. Of this, approximately 5% is for personnel, representing 1.7 FTEs, of which 0.25 is a new hire on bilateral funding. The following amounts of the projected bilateral budget are assigned to operational costs: about \$12,000 for travel for field work, participation in international meetings and conferences and approximately \$125,000 for supplies and services (surveys, materials, consultants' fees for support in gender, capacity development and economics).

Potential risks in spending as planned and mitigation of those risks:

- Partners: the Flagship will work intensively with partners as delays or failure by partners affects overall performance. Mitigation: clarity on the terms of reference and contracts as well as close monitoring and evaluation.

- Biophysical risks: climate vulnerability and natural catastrophes might have a negative influence on agronomic field trials and socio-economic studies. Mitigation: use of climate smart technologies; adjustment of trial establishment and evaluation; availability of additional inputs (e.g. irrigation); diversification of locations.
- Staff continuity: key staff may leave and this may result in a loss of key capacities and in a delay of performance of the Flagship. Mitigation: continuous staff succession plans, potential staff databases, networking, continuous staff meetings to evaluate performance and morale.
- Reduced W1/2 funding: a reduction in W1/2 funding might have a negative effect on the delivery of promised outcomes and will affect continuity of long-term research with serious drawbacks. Mitigation: continuous search for bilateral projects to support key research agenda.
- Civil safety: civil unrests or wars might affect the execution of planned activities and result in negative impacts on the delivery of promised outcomes. Mitigation: diversification of research locations.

2.3.2.3 Additional explanations for certain accounting

For the CGIAR partners, personnel costs are defined as the total remuneration costs of an individual: base salary, fringe benefits and other employment costs. Actual computations on average for fringe benefits and employment costs in relation to base salary would translate to an average multiplier of 97% and 68% for international and national staff respectively. The reason for the high multiplier for international staff is because of the housing allowance, security and education allowance that are not provided to nationally recruited staff. Fringe benefits include: pension, housing allowances, education allowance, security, health insurance, other insurances, catastrophe fund, annual leave and severance pay. Other employment related costs include staff training and development; transportation, recruitment, appointment and repatriation allowances and payroll administration fees.

For SLU, the 51.3% fringe benefits is constituted as a Swedish tax that the employer must set aside for the employees and covers vacation, sick-leave, parental leave, part of the pension, full professional insurance and part of health care costs.

The cost structure of research undertaken during the first phase CRPs has been applied to estimate average research costs for collaborators, consumables, other supplies and services, and travel. The actual cost structure for secured W3 and bilateral projects is first applied, and the average research cost factors are then applied to the remaining portions of the budget that are yet to be secured.

2.3.2.4 Other Sources of Funding for this Project

not applicable

2.3.2.5 Budgeted Costs for certain Key Activities

	Estimate annual average cost (USD)	Please describe main key activities for the applicable categories below, as described in the guidance for full proposal
Gender	721,069	Gender considerations form an integral part of the problem analysis and priority setting process in this Flagship. Gender will be systematically and practically included by translating it into concrete activities and relevant indicators that will reflect and feed into the CRP's gender strategy. These activities include developing gender capacities, together with strategies and approaches that enable women to improve their participation in the value chain and to increase their access to and control of resources, technologies, labour power and the benefits of their work, while also improving

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	Estimate annual average cost (USD)	Please describe main key activities for the applicable categories below, as described in the guidance for full proposal
		their nutritional status. One FTE is dedicated to work on gender (0.5 in East Africa, 0.5 in Central America shared with the livelihoods flagship). For other locations, the Flagship works through the livelihoods flagship. Roughly equal proportions of the gender budget are supplied by W1/W2 resources and W3/Bilateral resources.
Youth (only for those who have relevant set of activities in this area)	90,000	Opportunities exist to engage young people in developing new small-scale businesses in animal feeds and forages. The identification and analysis of these opportunities is undertaken with an initial investment of about \$90,000. Possibilities include the involvement of young people in technologies for connecting farmers to feed and forage supplies, in the production of feeds and forages (e.g. irrigation schemes) and in the formulation of feeds. Further, young people can be supported to produce and market quality forage seeds, thereby ensuring availability – a major constraint on the adoption of tropical forages and rangeland species at present. Activities include assessment of priority sites and institutional arrangements, with a view to better identification of entry points for young people; identification of constraints to participation; development of a youth engagement strategy; and implementation.
Capacity development	363,702	These activities focus on two elements of the CGIAR capacity development framework, namely, design and delivery of innovative learning materials and approaches, and the development of future research leaders through fellowships and institutional strengthening. Learning approaches, including blended learning for farmers and development practitioners, which is being developed for use in conjunction with decision-support tools (e.g. FEAST/TechFit, SoFT), will be extended, while their efficiency and reach will be improved by using novel ICT approaches. Training-of-trainers will be addressed through capacity development events that focus on selected CRP sites and by incorporating approaches such as new instructional design. Big data approaches will be brought into play to support a broad audience ranging from development, research and education institutions, to policy makers, the private sector and farmers/farmer associations. Integrated platforms (FEAST, TechFit and SoFT, NIRS) will further facilitate scaling up. The CRP will continuously train and receive inputs from PhD, MSc and undergraduate students and their supervisors. To understand and work in a specific context, it is necessary to work with local partners who are able to collect, analyze and interpret gender data; the Flagship will invest in assessing and strengthening local gender capacities. The Flagship has dedicated 0.5 FTE for capacity development in Central America. For all other locations the Flagship will work through the livelihoods flagship. Roughly one-third of this budget is provided by W1/W2 resources.
Impact assessment	0	The budget for Impact Assessment is held in the Strategic Investment Fund.
Intellectual asset management	2,721	A small budget has been set aside for ad hoc IP advice and support for contract development with e.g. private sector partners. This will

	Estimate annual average cost (USD)	Please describe main key activities for the applicable categories below, as described in the guidance for full proposal
		be supported by in-kind investments of the partners and support from management level.
Open access and data management	62,578	Support is provided for open access journal payments, open access journal hosting/management and data curation and open access support.. Bilateral projects in this flagship are expected to budget for these activities.
Communication	39,678	The budget covers staff time as well as as direct costs to ensure effective communication of its results. Bilateral projects in this flagship are expected to budget for these activities.

2.3.2.6 Other

2.3.3 Flagship Uplift Budget

2022 additional outcome description	Amount needed (\$)	W1 + W2 (%)	W3 (%)	Bilateral (%)	Other (%)
Closed yield gap - Extend the accessibility of global databases, repositories, interactive tools and maps and the Tropical Grasslands-Forrajes Tropicales journal website; increase the reach of outcomes to 30 countries and increase in area (ha) under improved feeds & forages.	13,537,200	0	0	100	0
Efficient use of inputs - Extend the accessibility of global databases, repositories, interactive tools and maps and the Tropical Grasslands-Forrajes Tropicales journal website; increase the reach of outcomes to 30 countries and increase in area (ha) under improved feeds & forages.	8,169,000	0	0	100	0
Reduced women's labour - Extend the accessibility of global databases, repositories, interactive tools and maps and the Tropical Grasslands-Forrajes Tropicales journal website; increase the reach of outcomes to 30 countries and increase in area (ha) under improved feeds & forages.	1,633,800	0	0	100	0

2.4 Livestock and the Environment

Box 2.4a Livestock and the Environment Flagship—Summary

The ex-ante impact assessment indicates that this Flagship's research on greenhouse gas emission is in the highest tercile in addressing the CRP's multiple objectives. The components of the Flagship agenda make particularly strong contributions to capacity development, gender inclusiveness, and environmental objectives

The focus on the importance of livestock for the environment is unique across CGIAR's CRP portfolio.

This flagship:

- Aims to secure the essential role of livestock in ensuring nutritional security and contributing to poverty reduction for a growing population, in the context of ongoing global change, by reducing the environmental footprint of livestock production.
- Aims to ensure that livestock continue to enhance the ecosystem services necessary to sustain productivity and improve resilience to global environmental changes.
- Fills a unique role by contributing evidence to the global debate on livestock and the environment that is specific to the developing world and to poor and vulnerable small-scale producers undergoing either fragile or more rapid market-oriented growth.
- Uses field research to develop and test context-specific solutions that minimize the trade-offs between increasing productivity, enhancing ecosystem services, reducing environmental footprints, and adapting to expected environmental change.
- Works with partners and stakeholders to enhance evidence-based decision-making at household, community and policy levels, informing global debates and models so they better apply to developing country contexts.
- Contributes to sub-IDOs:
 - Land, water and forest degradation (including deforestation) minimized and reversed.
 - Increased resilience of agro-ecosystems and communities, especially those including smallholders.
 - More productive and equitable management of natural resources.
 - Agricultural systems diversified and intensified in ways that protect soils and water.
 - Reduced net greenhouse gas emissions from agriculture, forests and other forms of land use.
 - Technologies that reduce women's labour and energy expenditure developed and disseminated.
 - Improved capacity of women and youth to participate in decision-making.

2.4.1 Flagship Budget Narrative

2.4.1.1 Rationale and scope

Why research on livestock and the environment?

Livestock have a critical place in the debate about the planet's ability to feed itself without destroying the natural resource base that supports agriculture. Livestock production places high demands on natural resources (Foley *et al.*, 2011; Herrero *et al.*, 2013) and often has negative impacts on the environment (FAO, 2006). The resource use efficiency of small-scale livestock production in the developing world is generally low and GHG emission intensity high (Herrero *et al.*, 2013). The expectation, therefore, that most demand-driven increase (Delgado, 2003) in livestock production will take place in developing countries, largely on small-scale farms, (Alexandratos and Bruinsma, 2012) raises concerns that the overall environmental footprint of livestock production will grow considerably, across both rapid and more fragile growth trajectories.

At the same time, small-scale livestock producers in developing countries depend on healthy and resilient landscapes for their livelihoods (Boelee and Khaka, 2011). Global environmental changes, including climate change, other pressures and changes in land use, exert pressure on the natural resource base and ecosystem services, putting livestock production and related livelihoods at risk, especially for those on a fragile growth trajectory.

Small-scale livestock systems offer great opportunities to enhance environmental management and ecosystem services and improve productivity and resilience. Livestock are often the *raison d'être* of key provisioning services (e.g. biodiversity inherent in cereal–legume crop combinations or agroforestry systems), they regulate carbon sequestration in grasslands and manure enhances soil fertility. Livestock provide greater resilience to smallholders in the face of climatic or disease shocks than do crops alone.

To maximize the synergies between livestock and the environment, the environmental footprint of livestock has to be reduced by increasing resource-use efficiency. In intensive systems, combining improved technologies with efficient value chains can reduce GHG emissions per unit of animal-source

food. In extensive systems, improving rangeland and sown pasture management to increase yields, accumulate carbon and improve soil–water productivity is another win–win. The flagship will initially focus on GHG emissions and land degradation; and later on interventions for sustainable water use and enhancing biodiversity.

The feminization of agriculture (FAO, 2011), means the CRP needs to know how gender-based constraints and opportunities, and gender relations and norms, affect the ability of women and men to cope with environmental change and to adopt environmentally friendly practices. Young people also merit particular attention because they have much to offer, and gain, by engaging in the sector.

Widespread adoption of environmental management of livestock requires appropriate governance mechanisms and significant investment, by local actors, national governments and the private sector. Environmental issues and livestock are moving up global and regional donor and political agendas, a trend that may open up new finance streams but also requires accurate evidence on a range of livestock and environmental aspects. A prime example is the opportunities opening up for payments for ecosystem services, especially mitigation of GHG emissions.

Addressing the grand challenges

This flagship addresses the SRF grand challenges of competition for land, soil degradation, overdrawn and polluted water supplies, climate change and diminishing genetic resources. It does this by enhancing the efficiency of natural resource use, reducing the negative impacts of livestock production on ecosystems while enhancing the positive ones, and adapting livestock systems to future climate change. In addition, it directly responds to the ISPC paper on livestock research, especially recommendations to strengthen research on livestock and climate change and to address livestock policy research.

Why should CGIAR invest in this?

The flagship has a key role because it is the only one devoted to avoiding the unintended consequences of improving livestock productivity. It ensures that technology-generating flagships avoid this and that solutions consider future climate change. In Phase I of the CRPs environmental issues surrounding livestock production were fragmented across several CRPs. By consolidating research in this flagship, the CGIAR will achieve significant impact across priority countries and beyond.

Several research organizations focus on advancing strategies for a more sustainable livestock sector in developed countries, but this issue is ignored or only just emerging in many developing countries. By investing in this field, CGIAR will address new requests¹¹ to develop more sustainable livestock sectors. Early engagement is urgent so interventions can take place before degradation is irreversible.

CGIAR is well-equipped to do research on livestock and the environment that will generate both local and global impact. Program partners have strong track records contributing to global analyses on the environmental footprint of livestock systems. The gap is linking local data derived from field tested interventions to global models and debates – where CGIAR is already a key player. The flagship brings a specific focus on small-scale production systems, with on-site capacities to assess environmental footprints and develop strategies that marry socially inclusive and equitable productivity and

¹¹ Colombia, Kenya, Ethiopia and Vietnam are all developing specific low-emissions development strategies for livestock, and CGIAR partners are already engaged with the line ministries and climate change units.

livelihood improvements with improved environmental performance. The flagship's activities could be ground breaking for developing countries.

In the ex-ante impact assessment, the research on greenhouse gas emission figures is in the highest tercile in addressing the CRP's multiple objectives. The components of the flagship agenda make particularly strong contributions to capacity development, gender inclusiveness, and environmental objectives (see Annex 3.10.2).

Overall goal

The overall goal of the flagship is to reduce the environmental footprint of livestock production across both rapid and fragile growth trajectories, while ensuring that livestock systems in East Africa, Nicaragua, Vietnam, Tunisia and Burkina Faso are able to adapt to global environmental changes.

2.4.1.2 Objectives and targets

The flagship has direct strategic relevance to SLO 3, improved natural resource systems and ecosystem services. It will directly contribute to the strategic target of 190 million ha of degraded land restored by 2030. It will also directly contribute to two other planned CGIAR outcomes: a 20% increase in water and nutrient use efficiency; and a 15% reduction in agriculturally-related GHG emissions. Finally, intensifying livestock production is a key pathway to preventing deforestation. The flagship will also contribute to SDG Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation, and halt biodiversity loss.

The flagship directly addresses the following sub-IDOs:

- Land, water and forest degradation (including deforestation) minimized and reversed.
- Increased resilience of agro-ecosystems and communities, especially those including smallholders.
- More productive and equitable management of natural resources.
- Agricultural systems diversified and intensified in ways that protect soils and water.
- Reduced net greenhouse gas emissions from agriculture, forests and other forms of land use.
- Technologies that reduce women's labour and energy expenditure developed and disseminated.
- Improved capacity of women and young people to participate in decision-making.

The flagship's objectives are:

- Identify solutions to environmental management challenges and provide diverse stakeholders, including women and young people, with the knowledge and incentives to change their behaviour and implement the solutions.
- Provide foresight as to how environmental footprints are likely to evolve and feed information back into decision-making processes so as to avoid negative environmental outcomes.
- Foster an enabling policy and institutional environment for the environmental management of livestock production, through research and engagement with key decision-makers.

Flagship outcomes to 2022

- Reduction in land and water degradation of 7.9 million ha which positively impacts 5.1 million direct and indirect beneficiaries across 8 countries.
- Rural communities practice more productive and equitable management of natural resources, with benefits experienced by 2.2 million beneficiaries, representing 14 million ha across 9 countries.

- Livestock production systems diversified and intensified in ways that protect soils and water (representing land area of 7 million ha), with benefits experienced by 2.4 million beneficiaries across 9 countries.
- Agroecosystem resilience increased by 10%, impacting 1.8 million final beneficiaries (representing 9.2 million ha) across 6 countries.
- GHG emission intensities from agro-ecosystems will be reduced by 2% (0.08 Gt CO₂-e yr⁻¹), impacting 7 million indirect beneficiaries across 7 countries.
- Environment management interventions that reduce women's labour and energy expenditure by 10% developed and disseminated (reaching 770,000 women) in 9 countries.
- Improved capacity of 930,000 women and young people to participate in decision-making for environmental management of livestock in 9 countries.

2.4.1.3 Impact pathway and theory of change

Figures 2.4a and 2.4b present the flagship's ToC and assumptions. The flagship aims to reduce the environmental footprint (GHG emissions, water and land degradation) and enhance ecosystem services (carbon sequestration, biodiversity, water quality and quantity, fodder biomass) from livestock systems that are adapted to environmental change. The flagship will help the CRP understand the implications of climate change for the livestock sector and together with CCAFS will provide evidence on the GHG emissions-reducing potential of interventions in the livestock sector. The outputs and outcomes are delivered at different levels for different stakeholders, but together they will produce these higher level impacts.

The flagship responds to key sets of research challenges and opportunities in the two Livestock CRP trajectories. For fragile growth systems, the primary challenges are: high variability of climates and environments, the loss of key ecosystem services, weak institutions for managing natural resources, undeveloped infrastructure and a lack of suitable policy to foster the development of better management. Conversely, the opportunities are to: build resilience to environmental shocks, increase livestock productivity by enhancing sustainable rangeland management and to support policies, institutions and incentive schemes that enhance environmental management. For rapid inclusive growth systems, the main challenge is to ensure that systems that are becoming more commercial and intensive meet the growing demand for livestock products without exhausting the limited natural resource base and with minimal environmental footprint; ample opportunities exist to simultaneously respond to these.

The flagship provides foresight about likely environmental changes, including the two-way interaction between livestock development and the environment, and develops new solutions for environmental management challenges. It also develops evidence on the benefits of engaging women and young people more directly in building resilience and better environmental management. As such it provides the research foundation for advice and recommendations to decision-makers at a variety of levels; support will also be provided to stakeholders to use the flagship research outputs. The flagship intends to bring about changes among both 'next' and 'final users' across the CRP's four domains of change.

To bring about changes in policy and investment systems, the flagship, together with its partners, will produce IPGs. This evidence will be brought to key global fora, such as IPCC and the Global Agenda for Sustainable Livestock, so that these debates better reflect the reality of developing countries. It will thereby seek to influence investment decisions by national governments, donors and other development partners through raising the profile of livestock in the development world. With increased global attention to the imperative for sustainable intensification and the commitment to the SDGs, the flagship aims to capitalize on this commitment at national level, identifying stakeholders in countries already committed.

Many¹² countries are highlighting the livestock sector as key to achieving both climate change mitigation as well as other environmental goals; the flagship has strong links to these governments, and ILRI and CIAT have received specific requests for support. Through further engagement with key decision-makers, the flagship will raise awareness about environmental degradation and global environmental changes as serious constraints to agricultural production with implications for socio-economic welfare. It will also build upon lessons and successes from previous support to the development of NAMAs, applying these to other environmental issues, such as land degradation and manure management. The proliferation of PES schemes for biodiversity, wildlife conservation, and water quality indicates growing interest in developing appropriate economic incentives for required behaviour change to stimulate improved environmental management. In addition, novel partnership models with development partners, such as GIZ and SNV, will be tested and programs co-designed. It is expected that this multi-level evidence-based engagement will lead to the environmental footprint of livestock remaining high on local, national and international agendas and guiding investments.

At local level, the flagship will undertake participatory research that provides proof-of-concept of technical solutions. Analysis of decision-making and possible incentives at multiple levels to adoption, trade-offs and synergies will be included, so that the environmental options are also socially and economically feasible and equitable. In recognition that technical interventions require institutional and policy innovations to regulate and monitor environmental impacts, the flagship will support specific innovations in this area. Additionally, as the flagship seeks to empower women and enhance their decision-making authority with respect to natural resources, each objective will use gender analysis to understand the needs of women and men, but also use GTAs to overcome social norms and power relations. The flagship also seeks to engage youth as agents of change, given their higher levels of education and the pressing need to develop their capacity to manage future environmental change.

Gender and age-sensitive capacity development of individual and institutions is needed to develop knowledge and strengthen capacity for implementation of policies and legal frameworks to ensure long-term sustainability of solutions. Combined with continuous engagement, the flagship will ensure that diverse stakeholders are equipped with the knowledge, skill and motivation to change their behaviour and implement solutions. The engagement will include resource-poor livestock keepers, women and men of different ages, CBOs, NGOs, local and national government agencies. The flagship will build on previous partnership and engagement models, including the innovation platforms and hubs initiated by the Livestock and Fish and system CRPs (see: Duncan *et al.*, 2015; and [Innovation Platform Practice Briefs](#)).

In summary, the underlying assumption is that increased support and investment, guided by strengthened capacities and an actionable evidence-base, will result in the increased and sustained adoption of environmentally-friendly practices and in turn benefit the environment and the people depending on it.

¹² Seventy countries target the livestock sector in the Intended Nationally Determined Contributions submitted to COP 21; most of these are developing countries. See Richards *et al.*, 2015.

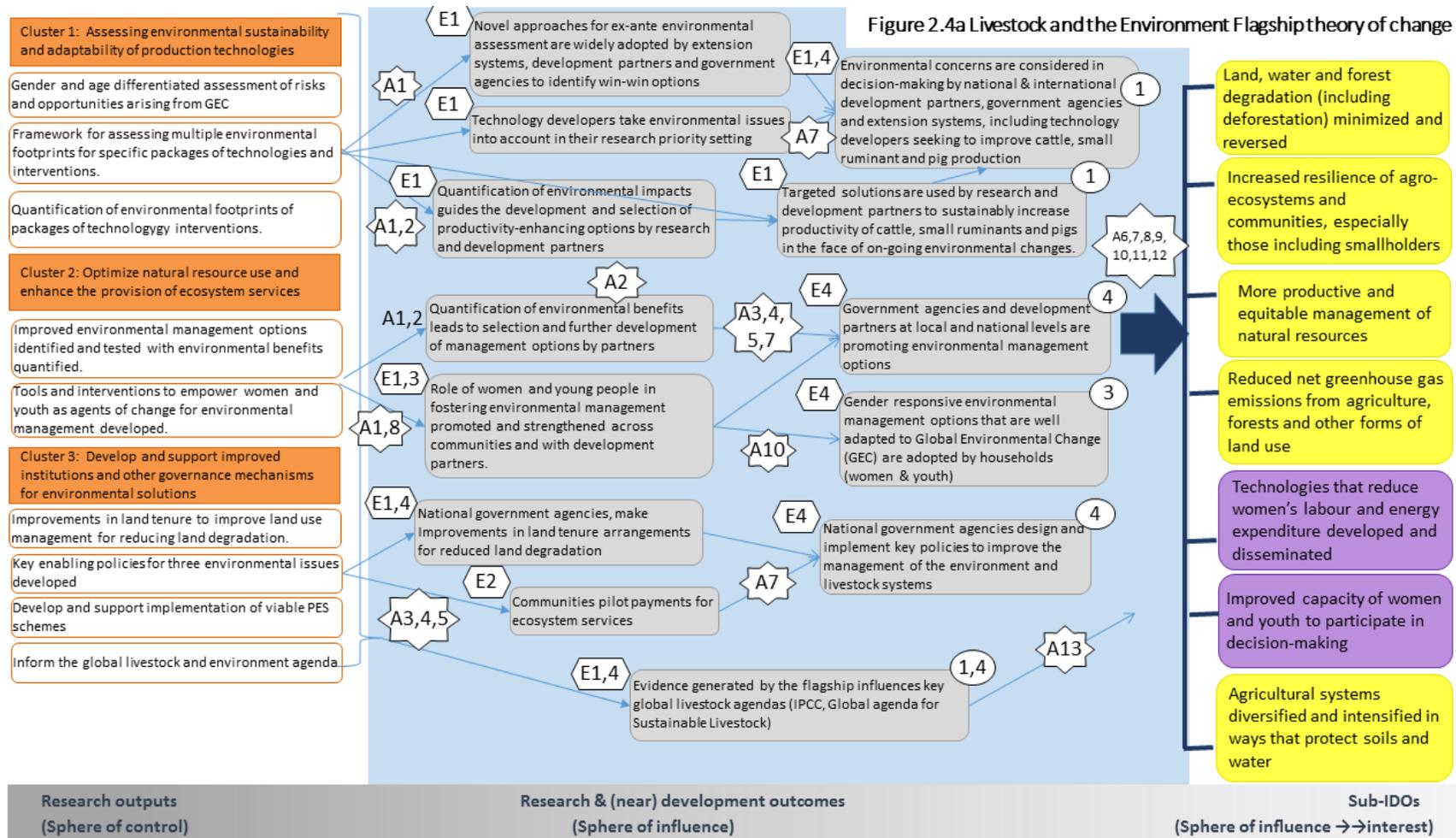
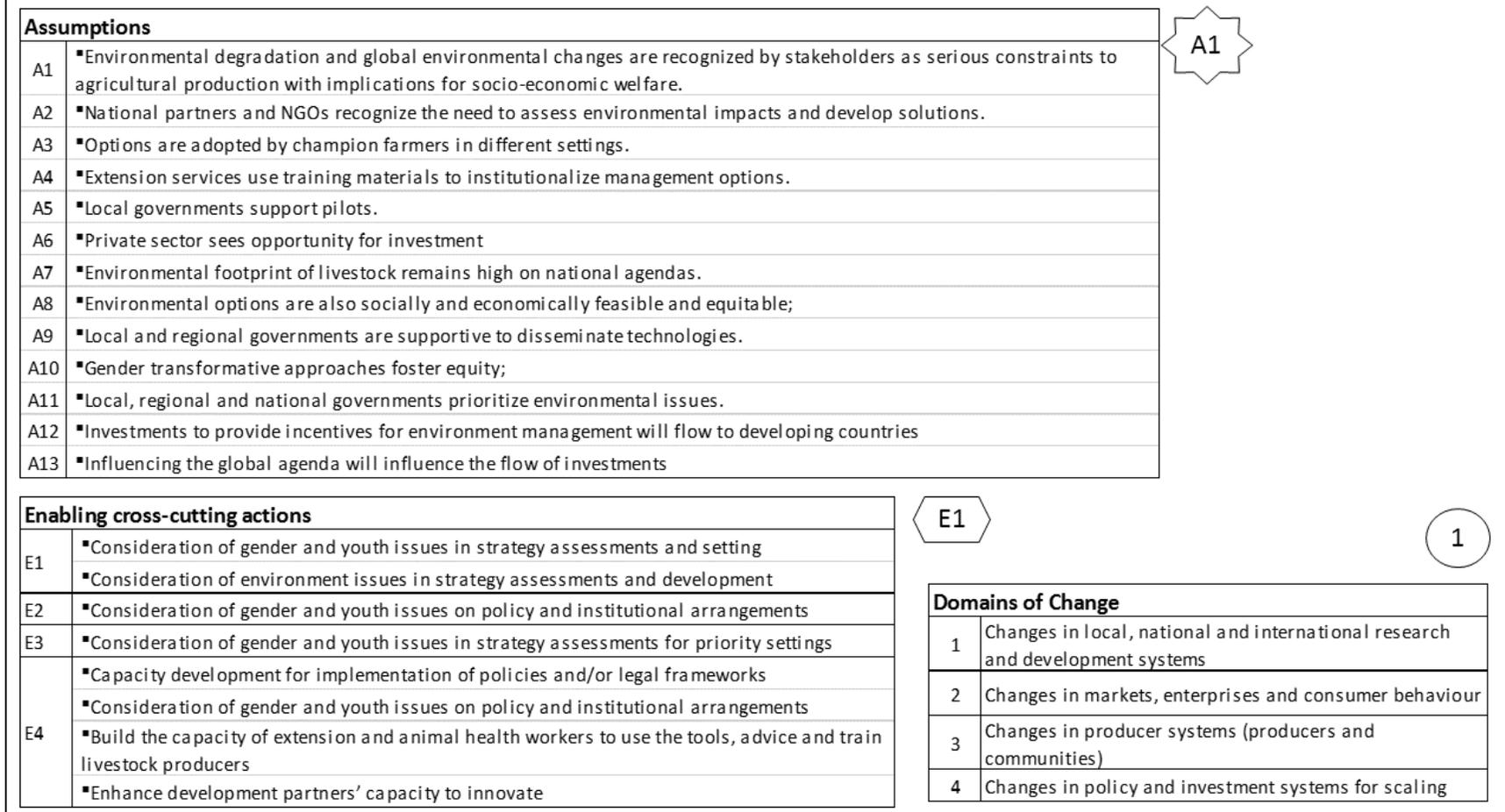


Figure 2.4b Livestock and the Environment Flagship theory of change, assumptions, enabling actions and change domains



2.4.1.4 Science quality

This flagship will develop and pursue four distinct strands of new and innovative research. Through collaboration with the other flagships, these will add value by bringing a specific environmental focus and tradeoff analysis. This flagship will focus on the species and systems prioritized by the technology flagships as a matter of design, and also work with the value chains previously prioritized in the Livestock and Fish CRP.

First, in collaboration with national and international partners, the flagship will initiate, guide and support the collection of 'on-the-ground' data on the environmental impact of livestock production, including support for the environmental analyses of GHG emissions, water quality and quantity, and rangeland health. This will remedy the current dependence on data from livestock systems in developed countries to provide the basis for evidence-based decision-making. Using the example of GHG emissions, primarily an issue for ruminants, a review of the literature reveals an almost complete absence of empirical data for livestock emissions in African production system; yet the existing evidence suggests that significant differences exist, based on differences in diets. McCrabb and Hunter (1999) reviewed enteric CH₄ production in Northern Australian (*Bos indicus*) cattle, and highlighted the differences in emissions between cattle fed diets composed of tropical (C4) forages and cattle fed a diet composed predominantly of temperate species. This led them to question the validity for tropical production systems of algorithms developed for ruminants consuming a 'European' diet. Similarly, other authors observed that cattle consuming tropical forages produced higher amounts of CH₄ than those consuming a temperate species diet, a finding that has been widely quoted in the development of emissions factors for tropical livestock (Kurihara, *et al.*, 1999).

To establish accurate baseline livestock GHG emissions, two elements are required. First, to know with some precision the numbers of ruminant livestock and the conditions under which they are kept, throughout the developing world. Second, to know what feeds, and in what quantities, animals are fed. Detailed estimates of livestock numbers and characterisation of the systems in which they are raised already exist for many parts of the world and will be improved upon by the Livestock Livelihoods and Agri-Food Systems flagship. However, there is very limited knowledge of feeding practices, without which it is impossible to determine enteric CH₄ emissions. The Livestock Feeds and Forages flagship will help filling this gap. A further gap in essential knowledge is that nearly all measurements made of livestock enteric methane emissions have been carried out in animals fed at maintenance levels or above. Many African livestock have intakes below maintenance for part of the year (as evidenced by live weight losses). The effects of sub-maintenance diets on enteric CH₄ emissions are not well understood: there is limited evidence that, in animals fed below maintenance, methane emissions per unit intake will actually increase, possibly due to increased rumen retention time and the intra-ruminal recycling of nutrients. To address these gaps, research at a newly built, state-of-the-art environmental laboratory at the ILRI Nairobi campus (Mazingira centre) is designed to undertake actual measures of emissions from animals fed a range of diets, as well as their manure. Early evidence suggests, for example, that supplementing the protein levels in diets reduces the N released in the excreta (Korir *et al.*, 2016).

Second, the flagship will use a systems approach to investigate the multi-faceted nature of livestock systems and to identify synergies and trade-offs between (i) different interventions including feed and food crops, (ii) environmental impacts across water, soil health, GHGs and biodiversity and (iii) environmental impact and other goals, especially increased productivity. Synergies and trade-offs are found across all livestock species production systems, and in all locations. Systems research evaluates the positive and negative feedbacks among system components and the complex interactions involved in system dynamics. By engaging in focused analysis systems research allows for more sophisticated targeting of options suited to specific contexts, mapped to the objectives of target users.

Systems analysis carried out in an action research mode, which the CGIAR has so far not successfully implemented widely, can also lead to better stakeholder engagement, innovation, scaling up and scaling out. Systems research can also inform policy dialogue to ensure that policies take account of potential synergies and trade-offs among system components, leading to better development outcomes. Formalizing the systems approach with end users will allow decision-makers to make evidence-based decisions when evaluating different development alternatives and setting priorities (Robinson *et al.*, 2015).

Third, locally relevant research findings will be used to inform the development of policies and institutions geared to stronger environmental management of livestock systems, across all the target countries. Environmental management of agricultural production as a whole, although developed and implemented in other parts of the world, is a new concept for many of the countries where CGIAR works. For example, experience from CIAT's support to the NAMA plan in Colombia demonstrated that, although there was political will to include livestock production as a target sector, scientific evidence was required to actually develop the targets and mechanisms to make this a reality. This work started only in early 2015 yet, as a result of good interaction between the stakeholders, the NAMA concept has already been defined and registered with the United Nations Framework Convention on Climate Change (UNFCCC) for both [Colombia](#) and [Costa Rica](#). Both NAMAs are defined and are currently seeking financial support for implementation. CIAT's role was to provide scientific means to the process of estimation and quantification of GHGs by testing the different mitigation options identified in terms of GHG reductions and productivity. In the experience of ILRI in northern Kenya, research on how specific institutions and gaps in coordination constrained the appropriate management of common grazing areas suggests that local governance arrangements commonly have weak links with national policy and regulatory frameworks, such that the actual capacity to govern is undermined. The flagship will encourage South-South learning in this area in particular, for example to support NAMA development in East Africa, and to share experiences from Central Asia and North Africa in large-scale rangeland improvement.

Fourth, the flagship will use gender-transformative approaches to reach out to women so as to give them more control over resource flows and benefits and to promote them as agents who will drive behaviour change towards more proactive environmental management. This is novel. The evidence suggests that women often bear a greater burden than men as a result of environmental decline, with studies showing that this can result in the intensification of women's workloads or the loss of critical assets. Yet few projects have actually used gender-transformative approaches to empower women and hence increase their decision-making capacity with respect to environmental management.

Scientists working on this flagship bring a range of skills and expertise in such areas as systems research and *ex-ante* impact assessment; estimating and measuring GHG emissions from livestock systems; restoring rangelands; fostering improved local and national governance arrangements for natural resource management in extensive systems; interpreting the impacts of climate change for livestock systems; and developing solutions for sustainable water use. They also have strong links to other sources of scientific advice, including the global modelling community at CSIRO, IIASA and PIK (with CCAFS); the WLE network of researchers committed to sustainable water use and reducing land degradation; and land governance experts, through the International Land Coalition and the International Union for the Conservation of Nature (IUCN).

Proof of the quality of the research produced by the flagship will partly be the uptake of its results by high-level global agendas, such as the IPCC. The flagship will produce one scientific publication targeted at specific environment and livestock issues each year.

2.4.1.5 Lessons learned and unintended consequences

The flagship builds on past research on: Improved understanding of the differential contributions of livestock systems to environmental impacts, especially GHG emissions (Herrero *et al.*, 2013); research assessing rangeland vegetation under global environmental change and using livestock grazing to improve rangeland productivity (Louhaichi, 2013); evidence of the benefits of livestock for ecosystem services (Silvestri *et al.*, 2012); research on multi-stakeholder engagement to improve the ownership of interventions (Kristjanson *et al.*, 2009; Nefzaoui *et al.*, 2013); research suggesting IPCC emission estimates using OECD country data could be off (both too low and too high) by factors of between 4 and 10 for African livestock (preliminary figures from ILRI's Mazingira Centre); experience in developing NAMAs for livestock in Latin American and Africa; research on water resources for resilient agro-ecological landscapes (Rockstrom *et al.*, 2014); and research to improve the water use efficiency of livestock (Descheemaker *et al.*, 2010).

The flagship also takes account of lessons from Phase 1 CRPs. First, Livestock and Fish CRP work on *ex-ante* environmental assessments shows there is a high potential to reduce the environmental footprint of livestock by improving productivity, which also reduces GHG emissions per unit of livestock product, as CCAFS research shows. Second, work by CCAFS demonstrated that stakeholder engagement, which is critical to improved environmental management, must begin at the outset of a project. Third, both the Livestock and Fish and the systems CRPs demonstrated that solutions are highly context-specific and that careful design and targeting of interventions is needed. Moreover, to address the environmental impacts of livestock production, trade-offs between multiple objectives are inevitable and require holistic systems approaches. Fourth, CCAFS research shows that environmental management will not improve unless institutional and policy issues are addressed at all levels, from local to international. Fifth, CCAFS and Livestock and Fish research on silvo-pastoral systems in Latin America points to the need to assess gender relations in order to strengthen the capacity of livestock producers to mitigate the impacts of climate change (Gumucio *et al.*, 2015). Last, spreading research on livestock and the environment across six CRPs in Phase 1 resulted in a fragmented agenda. This influenced the decision to consolidate this research in a single flagship in the Livestock CRP.

To a large extent, this flagship was conceived to counter any potential unintended consequences of the CRP's work in genetics, health and feeds. Unchecked livestock development, driven by technical productivity-enhancing solutions and short-term food security objectives, has the potential to increase animal numbers, increase competition for food crops, further degrade the natural resource base and contribute to climate change. Short-term production, income and food security gains are threatened by long-term degradation of the very base on which production relies. This flagship therefore pays specific attention to livestock x environment interactions. By assessing the potential impacts of productivity-enhancing technologies and feeding this information into decision-making, the flagship aims to put in place corrective actions in livestock sector development, to avoid unlimited natural resource extraction. It also aims to develop and scale up practices that improve resource use efficiency, especially with respect to land and water. At the same time, issues in different contexts will be synthesized into generalizable lessons for national, regional and international agendas.

One risk of lifting the environmental agenda out and advocating to adjust the traditional livestock agenda in favour of sustainability is that evidence generated will be used out of context. Some may focus on negative impacts only, without paying attention to the positive. The flagship will work closely with the Livestock Livelihoods and Agri-Food Systems flagship to ensure that environmental issues are fully embedded in context-specific trade-off analyses.

2.4.1.6 Clusters of activity

This flagship has three clusters. Cluster 1 assesses the two-way interactions between the environment and the productivity-improving technologies from the other flagships. Cluster 2 identifies and tests technical solutions to reduce the environmental footprint of livestock production, improve natural resource use efficiency and enhance ecosystem services. Options will also be assessed for their robustness in relation to future environmental change. Cluster 3 explores how best to implement combinations of environmental management solutions developed with attention to the institutional and policy innovations needed to regulate and monitor environmental impacts and provide incentives for behaviour change. Governance dimensions of environmental management are often neglected, are a new issue for many of the countries where the CRP works, and need a different research strategy.

Taken together, the clusters will deliver the outputs and outcomes for different stakeholders needed to achieve the goal of improved environmental management of livestock production systems.

Building on research in the Livestock and Fish CRP this flagship will work in both fragile growth and rapid growth trajectories covering environmental dimensions of water, soil, biodiversity and climate change. To focus, the flagship will initially (years 1-3) concentrate on reducing the impact of livestock on GHG emissions and fostering solutions to reverse land degradation; from 2019 it will include interventions for sustainable water use and enhancing biodiversity. All three clusters interact to combine assessment of productivity enhancing technologies on all these environmental dimensions (cluster 1), to test environmental solutions (cluster 2) and address policies and institutional arrangements (cluster 3). Research will initially focus on systems and value chains in East Africa, Nicaragua and Vietnam, to be followed by Burkina Faso, Tunisia, India, and Central Asia. Collaborative research with CCAFS may be undertaken in Mali and Colombia, as new bilateral opportunities open up.

The flagship will work with CCAFS and WLE, who target the same IDOs. It will build on research deliverables and partnerships developed in both of those CRPs, as well as the Drylands and Humidtropics, particularly in Ethiopia, Kenya, Vietnam, Nicaragua and Burkina Faso. It will lead research on livestock environment interactions within the CGIAR.

Cluster 1: Assess the environmental sustainability and adaptability of livestock production technologies

This cluster supports technology users and developers by assessing the environmental sustainability, and adaptability of productivity-enhancing technologies designed in the CRP's three flagships on genetics, health and feeds and forages.

The livestock sector is challenged by global environmental, economic and social change, especially the increasing demand for livestock products. Both changes have implications for natural resource availability and use, which affect the sustainability of innovative production technologies. Using *in-situ* observations and remotely sensed data, the status and trends of the natural resource base will be assessed. Modelling techniques (e.g. process-based crop and rangeland modelling) and similarity analysis will be applied to assess the potential impact of scenarios of environmental change, especially climate change, on feed availability and suitability of livestock species and breeds. Climate change scenarios developed with CCAFS flagship 1 and statistical models will be applied to project impacts on pest and disease pressure. Results will inform the technology flagships, and be communicated to the wider public in national, regional and global fora. Working with CCAFS, this flagship will help the technology flagships to understand the required adaptation to accommodate the impacts of climate change and still achieve production gains. For the LLAFS flagship, the challenge is greater, as the need to adapt to climate change, specifically greater climate risk, will affect household livelihood strategies.

This flagship will collaborate with LLAFS flagship cluster 4 on resilience and risk management. W1/2 funds will be used for these analyses in all of the priority countries.

The environmental sustainability (effects on water, soil, biodiversity, and the climate system) of the technologies devised in the feeds and forages, animal health and animal genetics flagships will be assessed in all focus systems and value chains using W1/2 funds. It will describe implications for people of different ages and gender, investigate how gender norms influence the uptake and impacts of interventions, and the implications for women's labour. So-called double or triple wins are expected, such as: improvements in feeds resulting in significant increases in animal production that decrease the methane emission intensity of livestock products; forages with increased BNI further reducing GHG emissions; carbon sequestration co-benefits from soil and land restoration. Results from environmental assessments will serve as inputs to trade-off analyses in the Livestock Livelihoods and Agri-Food Systems flagship. Rapid *ex-ante* assessments of technologies and interventions will be used to quantify potential gender-differentiated environmental impacts where possible and to flag issues that need further investigation. These assessments aim to influence the research agenda in the technology flagships and other AFS CRPs, as well as intervention delivery in research sites.

Through awareness raising and capacity development, promising approaches will be mainstreamed among extension systems, development partners and government agencies, to equip them with the necessary tools and skills to assess potential environmental issues when developing solutions. Rapid assessments will be complemented with in-depth research into selected issues, systems and sites involving field-level data collection and remote sensing, with the further development and validation of models. A suite of models at a variety of scales will be employed and combined to understand complex environment x livestock interactions.

In summary, this cluster evaluates whether technologies and interventions are a) robust or adaptable in the face of global environmental change, and b) do not increase the environmental footprint of livestock production. The work will have a strong local and regional focus in the CRP priority countries and beyond to inform higher-level priorities through engagement in governance mechanisms (cluster 3).

Main research outputs

- Gender- and age-differentiated assessment of risks and opportunities in livestock systems arising from global environmental change.
- Framework for assessing multiple environmental footprints for specific packages of production technologies and interventions.
- Quantification of environmental footprints of packages of technology interventions by measurements, on-the-ground surveys, remote sensing and *ex-ante* modelling.

Outcomes to 2022

1. Environmental concerns are considered in decision making across at least 10 priority countries and other locations, by national and international development partners, government agencies and extension systems, including technology developers seeking to improve cattle, small ruminant and pig production.

Milestones

- Novel approaches for *ex-ante* environmental assessment are widely adopted by extension systems, development partners and government agencies in six priority countries to identify win-win options (2019).
- Technology developers take environmental issues into account in their research priority setting, in 6 CRP priority countries (2019).

- Targeted solutions are used by research and development partners, across at least 10 priority countries and other locations, to increase the productivity of cattle, small ruminants and pigs in the face of ongoing environmental changes (2022).
2. Targeted solutions are used by research and development partners, across at least 10 priority countries and other locations, to increase the productivity of cattle, small ruminants and pigs in the face of ongoing environmental changes.

Milestones

- Quantification of environmental impacts guides the development and selection of productivity-enhancing options by research and development partners in 6 priority countries (2019).

Cluster 2: Optimize natural resource use and enhance the provision of ecosystem services

This cluster will explore, design, test and disseminate innovative livestock management solutions that optimize the use of natural resources for reduced environmental footprints and enhanced ecosystem services. Specifically, the cluster will develop options to reduce land degradation and GHG emissions in the first instance, in the priority countries Kenya, Ethiopia, Tanzania, Nicaragua and Vietnam.

Subsequently, work will work on improving the efficiency of water use in the same countries, adding in Burkina Faso and Tunisia. In the extensive systems of Kenya, Ethiopia, Tanzania and Burkina Faso, after 2019, the flagship will focus on research to enhance biodiversity in livestock systems. Interventions will be tailored to the local context and the specific livestock systems in focus systems and value chains. It will work with local communities especially women and young people to develop and pilot new sets of interventions, addressing equity and inclusiveness. The flagship will develop and promote tools and interventions to empower women and young people as agents of change for livestock-environment management. Successful results will be scaled up and out, with support at higher levels from engagement with ministry staff, NGOs, and universities.

Building on research in various CRPs in Phase 1, initial emphasis will be given to the land degradation and climate change issues. In rangeland systems, promising options include improved vegetation and grazing management, while in mixed systems recuperation of soil and soil health through improved forage cultivation are being explored. This flagship will further pursue this work, consolidate lessons learned and develop a collaborative agenda. As livestock systems are the dominant sources of agricultural GHG emissions in developing countries, a considerable amount of work has already been done in the Livestock and Fish CRP and CCAFS. The options to reduce GHG emission will be further researched, tested and refined and include: closing the nutrient cycles in livestock–crop–feed systems (e.g. improved manure and fertilizer management); closer integration of crop–livestock interactions; improved feed baskets; and optimized farm land use. The impact of these options will be quantified *in situ* and through state-of-the-art lab analyses at the Mazingira centre. To gain access to international climate financing, countries need quality data on how interventions will reduce emissions from the livestock sector. In the first three years, these two issues will receive support from W1/2 funds.

Two issues that received little attention in the CRP Phase 1 portfolio in relation to livestock are water and biodiversity. The increased demand for livestock products is expected to increase pressure on the already scarce water resources available for agriculture. With WLE and WUR, the flagship will develop research on sustainable water use at basin and landscape scale, in terms of both quality and quantity, using W1/2 in the first three years. Concepts, methods and approaches will be developed, to generate context-specific livestock management options that optimize water use efficiency in livestock

production systems, using both W1/2 and bilateral funds in the second three years. There are also considerable biodiversity-related costs and benefits to livestock keeping. They are, however, poorly researched, leading to a dearth of evidence-based recommendations on appropriate management of livestock x biodiversity interactions. The cluster will review and synthesize available knowledge on the costs and benefits of biodiversity in livestock systems, including competition between forage and food crops, predation by wildlife, the more productive 'living' soils associated with livestock, ecotourism, and so on. This will be followed by the identification of options for alleviating or mitigating the burden and for optimizing the benefits. This agenda will accelerate with W1/2 support after 2019.

Main research outputs

- Improved environmental management options to reduce GHG emissions, reduce land degradation, improve sustainable water use and enhance biodiversity identified and tested, and environmental costs and benefits quantified. These options will be applicable for one or more livestock production systems in priority countries and beyond.
- Tools and interventions developed to empower women and young people as agents of change for environmental management.

Outcomes to 2022

1. Government agencies and development partners at local and national levels across at least 10 priority countries and other locations are promoting environmental management options.

Milestones

- Quantification of environmental benefits leads to selection and further development of management options by partners in 6 priority countries (2019).
 - Role of women and young people in fostering environmental management promoted and strengthened across 6 CRP priority country communities and with development partners (2019).
2. Gender-responsive environmental management options that are well adapted to global environmental changes are adopted by households (including women and young people) across at least 10 priority countries and other locations.

Milestones

- Role of women and young people in fostering environmental management promoted and strengthened across 6 CRP priority country communities and with development partners (2019).

Cluster 3: Develop and support improved institutions and other governance mechanisms for environmental solutions

Developing sound technical solutions to optimize the environmental impacts of livestock production are necessary but insufficient to achieve the required widespread impact at scale on livestock production systems. The policy and institutional issues needed to provide both local and national incentives for widespread adoption of environmental management merit a research focus of their own, as noted by both PIM and CCAFS. Governance mechanisms to manage the environmental impact of livestock production have so far received insufficient attention in developing countries. With global attention now firmly focused on the environmental impacts of livestock production in these countries, the time is ripe to develop policies and institutions that can support strong environmental management of livestock production systems, together with the technical solutions identified above. Such innovations cover land tenure systems and arrangements for the governance of common lands in Kenya, Ethiopia, Tanzania and Burkina Faso; tools and methods to monitor environmental benefits across all focus systems and value chains; and support for payments for ecosystem services,

particularly GHG emissions, more efficient and equitable water use, and biodiversity enhancements. It is notable that many countries included the livestock sector as a mitigation or adaptation priority in their climate change action plans submitted to COP 21.

This cluster will focus on the priority environmental dimensions identified above (cluster 2). Each requires specific local and higher level governance mechanisms. E.g. in extensive livestock systems mobility can only be ensured if competing land claims are resolved; but often a lack of coordination across local and national institutions prohibits this. In priority countries the flagship will identify institutional and governance needs and pilot successful innovations taken from elsewhere or developed during Phase I. Widespread adoption of environmental management in the livestock sector will also require significant investment, not only by local actors but also by national governments and the private sector. This agenda will be rolled out slowly with W1/2 support in years 1 and 2, accelerating from 2018 with increased W1/2 support to ensure the impact of the results. Evidence from cluster 2 will support transparent monitoring and reporting systems, so countries can account for the environmental benefits and attract support from international and private-sector investors in 'greening' the livestock sector.

The uptake of this flagship's evidence will also influence global agendas (such as that of the IPCC), which are instrumental in getting the livestock sector included in climate financing deals. The cluster will use gender-transformative approaches to empower women and young people to support and benefit from this agenda. The well-educated rising generation is well suited to provide new capacities and skills required for environmental management.

Main research outputs

- Recommendations for land tenure arrangements that enhance land management and reduce land degradation.
- Policy advice on three environmental issues: mitigation of GHGs, management of livestock impact on water quality, and enhancing the positive impact of livestock production on biodiversity.
- Development of viable payments for ecosystem services for biodiversity, water quality and GHG mitigation, with support for their implementation.
- Informed global livestock and environment agenda that shapes and refines the debates about a) the impact of livestock production on the environment, b) opportunities to optimize this impact and c) how best to adapt the livestock sector to global environmental change.

Outcomes to 2022

1. National government agencies across at least 5 priority countries design and implement key policies to improve the environmental management of livestock systems.

Milestones

- National government agencies, make Improvements in land tenure arrangements for reduced land degradation in 4 priority countries (2019).
 - Communities pilot payments for ecosystem services in 3 priority countries (2022).
2. Evidence generated by the flagship influences key global livestock agendas (IPCC, Global agenda for Sustainable Livestock).

Milestones

- Publications aimed at targeted global agendas developed and disseminated (2019).

2.4.1.7 Partnerships

The core knowledge needed by this flagship resides in scientists from ILRI, CIAT and ICARDA together with Tier 2 partner IWMI. Apart from expertise on livestock–environment interactions in a diversity of systems and regions, these scientists provide access to state-of-the-art equipment such as labs, portable equipment for soil, water and GHG measurements, and facilities such as the Mazingira centre in Nairobi. Through PhD fellowship and co-supervision of master students, the scientific expertise of SLU and other universities will be also be harnessed.

These core partners will link with a variety of actors at different levels, building on the good relations established over the years by CGIAR centres and Phase 1 CRPs. Partnerships with international universities and advanced research institutes are sought for their state-of-the-art contribution to (and adaptation of) methods in clusters 1 and 2. They are selected on the basis of their track-record, knowledge and expertise and include the CSIRO and the Potsdam Institute for Climate Impact Research (PIK). The flagship will further engage with international research consortia, such as the Global Farm Platform, Global Research Alliance, IUCN and International Rangeland Congress. The flagship will also collaborate with CCAFS and WLE, borrowing concepts and tools, and feeding back country specific solutions for livestock systems. Cluster 3 also links to flagship 5 of PIM, on governance of natural resources. External partner roles are specific to their expertise. For example CSIRO brings modelling skills, and international research consortia help provide indications of international priorities and data gaps.

In the priority countries, collaboration is already established with local universities and the national research systems. This collaboration will continue to bring in-depth knowledge of local conditions and provide inputs on intervention priorities and the feasibility and acceptability of technological and institutional interventions. As such, it is instrumental in the design of locally appropriate solutions. NGOs and development partners, such as Solidaridad and GIZ, will facilitate engagement with local farmer organizations and link the CRP to their broad on-the-ground networks. Private-sector partners, including input suppliers such as Dow AgroSciences, will adapt technologies for the market, develop business models and commercialize technologies. In the area of capacity development, partnerships with local universities will be expanded to extension services and local training institutes, such as the county-level agricultural training centres in Kenya. In addition, the CRP needs to work on governance and local policy formulation. National research institutes provide links to decision makers at national level (relevant line ministries, e.g. the Ministry of Livestock Development and Fisheries in Ethiopia), who in turn will provide guidance on the type and timing of evidence required to help in policy formulation and implementation. Decision-makers at local level (e.g. county governors) will be important for advising on local governance arrangements and facilitating the initial uptake of technologies and management schemes.

In order to expand the flagship's influence beyond the target countries and influence awareness and policies at global level, links with global partners (such as IFAD and FAO) and alliances (GRA) will be strengthened. The flagship will target two of the UN conventions: on climate change and to combat desertification, with both publications and side events during their annual COP meetings.

2.4.1.8 Climate change

The global climate is changing and can be expected to continue to do so for the foreseeable future (IPCC, 2014). As with all environmental changes, there is a two-way interaction between livestock and climate change. Because most livestock production systems, and especially the low-input systems that dominate the developing world, are highly sensitive to climate variability and change, it is crucial to

adapt them to this challenge. At the same time, livestock contribute to climate change, accounting for an estimated 18% of anthropogenic global GHGs (Gerber *et al.*, 2013).

The livestock sector thus faces the formidable combined challenge of adapting to climatic change, producing sufficient quantity and quality of food for the growing population, and reining in climate change. Keating *et al.*, (2014) argue that changes in the agricultural sector are essential to meet this challenge. They propose an approach that crosses the science and policy domains, complementing actions to increase food production with interventions that sustain the productive capacity of the agri-food system. This flagship aims to contribute livestock-specific solutions to this agenda.

It fully embraces the twin challenges of climatic change and variability. It contributes to the adaptation agenda by assessing the livestock-relevant impacts of different scenarios of climate change. This will enable the accurate targeting of actions to support adaptation. It will also test the robustness of technical interventions in the face of projected climate change. Its work also contributes to the mitigation agenda, by quantifying the potential changes in GHG emissions and GHG-emission intensities induced by productivity-enhancing technologies devised in the CRP's technical flagships on health, genetics and feed. It will also develop and promote interventions that are specifically designed to reduce GHG emissions, such as improved manure management, optimized fertiliser applications, and carbon sequestration.

2.4.1.9 Gender

Women are critical for the environmental management of livestock systems for two reasons. First, women and men livestock keepers have different vulnerabilities and capacities related to environmental change and the management of natural resources (McKune *et al.*, 2015). E.g., women and men control different species of livestock, and have different resource needs and expertise, leading to different environmental impacts. Second, women can potentially become key agents of change in promoting better environmental management if it is presented in ways that respond to their needs, empowers them practically and socially, and guarantees benefits from improved environmental management.

Unpacking how gender norms influence the differential resilience of women and men of different ages to global environmental change, and their capacities for environmental management (see Annex 3.3) will inform the design and implementation of solutions to improve the environmental impact of livestock production and livestock systems' adaptation to ongoing environmental change. Generally, women have had neither access to decision-making institutions nor much influence over policy. Work on governance will pay specific attention to this so this transformative agenda translates into the empowerment of women to become community leaders in environmental management.

Youth

The flagship will also focus on opportunities and advocacy for young people in environmental management. The latter is especially critical, as they will bear the burden of long-term environmental changes. Realizing the potentials that agriculture can offer to young people requires that they be engaged, and listened to. Environmental interventions could become a growth opportunity, as they are a new area for which improved practices and technologies, and advice and services in implementing them, could be much in demand. Rising education levels that many young people are attaining, along with their greater engagement in environmental issues through social media, mean that they could become leaders in this area; but only if their access to and control over resources, such as land and finance, are improved (see Annex 3.4).

2.4.1.10 Capacity development

The flagship recognizes a special need for capacity development, as the concepts and interventions for implementing environmental management in livestock production systems are not yet well established in many of the CRP's target countries (see Annex 3.2).

To design a strategic capacity development agenda, the flagship will carry out a needs assessment (within the CRP, partner organizations, farming communities and other stakeholder groups). This will help refine an agenda that is expected to include:

- Design of training materials and approaches for the environmental impact assessment frameworks and methods developed in cluster 1 and the interventions developed under cluster 2. Care will be taken to develop gender-sensitive approaches.
- Activities to validate the assumption that women and young people can act as agents of change, a critical element in the flagship's ToC.

In addition, capacity development activities will be instrumental in reaching:

- The managers and staff of national agencies, who will need the knowledge and confidence to innovate in the environmental management of livestock systems.
- The national and global research community, to increase their capacity to use research outputs.

In order to influence policy changes, the flagship will test different partnership models, including seconding staff to line ministries, joining consultative forums, for example on climate-smart agriculture, and offering fellowships or study opportunities to national partner staff.

In terms of developing future research capacity, the flagship will support a number of fellowships (MSc and PhD), some of them through the Mazingira centre.

2.4.1.11 Intellectual assets and open access management

Robust IA management, as well as open access and research data management and communications, help in uptake and achieving outcomes (sections 1.12, 1.13 and 1.14 and annexes 3.8, 3.9, and 3.10.7). They also contribute to the flagship's effectiveness, learning and accountability. Specific dimensions and concerns of relevance to this flagship are listed here.

For this flagship, no major IA management issues have been identified. The flagship makes use of many third party open access datasets, via partners and collaborators. Most of the information products of the various Phase 1 activities relevant to this flagship are already open access. This includes materials accessible through [CGSpace](#) and elsewhere. Some journal articles are limited access and the flagship will reserve funds each year to supplement bilateral projects to pay access fees for these. The longer-term strategy is for these to be fully budgeted into bilateral projects. Funds have been budgeted to support effective curation of data generated. An open-access database gives access to [tools used by the flagship](#).

2.4.1.12 Flagship management

Implementation will be led by a FL, supported by a leader for each cluster (CL). The primary roles of this core team is to develop and update the research agenda and impact pathways, monitor the quality and delivery of knowledge outputs, and report as required. Responsibility for implementation and delivery of research lies with CGIAR-centre or other partner teams. The FL will lead guide priority

strategic research and allocation of W1/2 resources as well as any strategic exploration of new research areas; guide development of bilateral projects to ensure alignment to the flagship their ability to contribute to strategic synthesis funded by W1/2; coordinate all reporting; lead cross-flagship initiatives; support and sometimes lead resource mobilisation and lead bi-monthly meetings (face-to-face or virtual). Cluster leaders will have a scientific leadership role, and will not be directly involved in reporting, which will be done directly between PI's, Centre focal points and the FL. CLs support the FL in developing the flagship strategy, and will guide research design in their clusters and monitor science quality of outputs. They will lead design and science quality of all strategic research supported by W1/2 resources. Since all environment clusters have integrating roles across the CRP, CL's will lead cross-flagship interactions. Each CL will identify a small group of key scientists across the CRP to develop innovative research design and to review new initiatives.

The flagship will be led by Polly Ericksen (ILRI); 20% of her time will be supported by W1/2, with 20% administrative support, and an annual flagship meeting. An Notenbaert (CIAT) will lead cluster 1. Cluster 2 is organized in 3 activity sets: GHG emissions activities will be led by Lutz Merbold (ILRI). Mounir Louhachi (ICARDA) will lead activities on rangeland restoration. Mats Lannerstad (ILRI) will lead activities on sustainable water solutions. Cluster 3 will be led by Lance Robinson (ILRI).

2.4.2 Flagship Budget Narrative

2.4.2.1 General Information

CRP Lead Centre's Name: ILRI

Centre Location of Flagship Leader: Kenya

2.4.2.2 Summary

Total Flagship budget summary by sources of funding (USD)

Funding Needed	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2	2,225,806	2,354,778	2,510,393	2,655,996	2,788,796	2,928,236	15,464,007
W3	0	0	0	0	0	0	0
Bilateral	3,080,152	3,234,159	3,395,867	3,565,661	3,743,944	3,931,141	20,950,925
Other Sources	0	0	0	0	0	0	0
	5,305,958	5,588,937	5,906,260	6,221,657	6,532,740	6,859,377	36,414,929

Funding Secured	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2 (Assumed Secured)	2,225,806	2,354,778	2,510,393	2,655,996	2,788,796	2,928,236	15,464,007
W3	0	0	0	0	0	0	0
Bilateral	3,080,151	2,346,154	905,075	0	0	0	6,331,381
Other Sources	0	0	0	0	0	0	0
	5,305,957	4,700,932	3,415,468	2,655,996	2,788,796	2,928,236	21,795,385

Funding Gap	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2 (Required from SO)	0	0	0	0	0	0	0
W3 (Required from FC Members)	0	0	0	0	0	0	0
Bilateral (Fundraising)	-1	-888,005	-2,490,792	-3,565,661	-3,743,944	-3,931,141	-14,619,545
Other Sources (Fundraising)	0	0	0	0	0	0	0
	0	-888,005	-2,490,792	-3,565,661	-3,743,944	-3,931,141	-14,619,543

Total Flagship budget by Natural Classifications (USD)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
Personnel	1,912,411	2,023,961	2,159,282	2,285,339	2,399,606	2,519,587	13,300,188
Travel	314,183	329,892	346,387	363,706	381,892	400,986	2,137,049
Capital Equipment	20,000	21,000	22,050	23,152	24,310	25,525	136,038
Other Supplies and Services	1,686,917	1,771,262	1,859,826	1,952,817	2,050,458	2,152,981	11,474,262
CGIAR collaborations	0	0	0	0	0	0	0
Non CGIAR Collaborations	702,006	737,106	773,961	812,659	853,292	895,957	4,774,985
Indirect Cost	670,439	705,714	744,753	783,981	823,180	864,339	4,592,408
	5,305,956	5,588,935	5,906,259	6,221,654	6,532,738	6,859,375	36,414,917

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Total Flagship budget by participating partners (signed PPAs) (USD)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
ILRI	3,984,451	4,183,673	4,392,857	4,612,500	4,843,125	5,085,281	27,101,890
ICARDA	355,801	373,592	392,272	411,885	432,480	454,104	2,420,135
SLU	45,705	47,990	50,390	52,909	55,555	58,333	310,884
CIAT	920,000	983,680	1,070,740	1,144,361	1,201,580	1,261,658	6,582,022
	5,305,957	5,588,935	5,906,259	6,221,655	6,532,739	6,859,376	36,414,921

The most significant cost driver for the Livestock and the Environment flagship is personnel costs that represent 36% of the total budget. To realize its 7 outcomes by 2022, a total of 90 FTEs are required over the 6 year life of the program or an average of 15 FTE per year. These include research scientists, capacity development staff, administrative staff, and research technicians, with 70% being international staff and the balance national staff, and spread across four locations. This number also includes 3 new hires for work related to gender and engagement with stakeholders (1 FTE), and part of a capacity development person (shared with other Flagships), and for rangeland management.

The second most important cost driver is supplies and services, 52% of which is supported by bilateral funding with W1/W12 making up the balance.

The third most important cost driver is indirect costs which represents 13% of both the W1/W2 and bilateral budgets.

Management of the Flagship is budgeted at 20% of the Flagship Leader's time with smaller amounts for other staff such as the Program Management Officer, Program Accountant and administrative support staff. Also included are the costs of an annual flagship planning meeting at \$20,000 per year. Management costs consume just under \$120,000 per annum and are pro-rated across all the outcomes.

Outcome 1 (Livestock production systems diversified and intensified in ways that protect soils and water), representing a land area of 7 million hectares and benefits experienced by 2.4 million beneficiaries across 9 countries requires approximately 15% of the W1/W2 allocation. Four FTEs with skills in climate change scenario development and interpretation, spatial analysis, and environmental impact assessments are required over the life of the program to deliver this outcome. No new hires are required. Bilateral funding of about \$4.2M also supports the achievement of this outcome and of this, approximately 30% is budgeted for personnel, representing a total of 10 FTEs over the life of the program. No new staff will be hired on bilateral funding. Lesser amounts of W1/W2 budget are assigned to operational costs (travel, capital equipment and supplies and services) to deliver this outcome.

Included under supplies and services is funding to conduct environmental assessments and hold workshops with stakeholders, as well as budget to hire a consultant to develop the sustainable water management framework. Capital investments required to deliver this includes \$20,000 for computers and soil sampling equipment. A travel budget of approximately \$140,000 is included for centre staff to travel to workshops and to conduct environmental assessment field work. The following amounts of the projected bilateral budget are assigned to operational costs associated with this outcome: \$250,000 for travel (most of this is within countries where the bilateral projects are located) and funds for staff to conduct field work; there is a small amount of within-Africa travel for scientific staff);

\$1.33M for supplies and services (research coordination, administrative support and publication costs) while the non-CGIAR collaborators receive approximately \$600,000.

Outcome 2 (Rural communities practice more productive and equitable management of natural resources), with benefits experienced by 2.2 million beneficiaries and representing 14 million hectares across 9 countries absorbs about another 15% of the W1/W2 allocation and this largely funds the 4 FTEs required over the life of the program who have the skills in developing environmental management options, gender and social differentiation analysis, and policy engagement. The new gender expert will spend part of his/her time on this outcome. Again, bilateral funding of approximately \$4.2M also supports the achievement of Outcome 2 with roughly 30% supporting personnel that represent a total of 10 FTEs over the life of the program. A half-time FTE will be hired with bilateral funding to develop capacity on rangeland governance in Tanzania. Lesser amounts of W1/W2 budget are assigned to operational costs (travel, capital equipment and supplies and services) to deliver this outcome. Included under supplies and services is money for workshops with stakeholders. As for Outcome 1, a travel budget of approximately \$140,000 is included for centre staff to travel to workshops and for field work.

The following amounts of the projected bilateral budget are assigned to operational costs: approximately \$240,000 for travel largely within the countries where the bilateral projects are located and to provide funds for staff to conduct field work; there is also a small amount of within-Africa travel for scientific staff; approximately \$1.3M for supplies and services (research coordination, administrative support and publication costs) while the Flagship's non-CGIAR collaborators receive about \$500,000.

To achieve Outcome 3 (GHG emission intensities from agro-ecosystems reduced by 10%) that impacts 7 million indirect beneficiaries across 7 countries, about 18% of the W1/W2 allocation is required, mostly for the skilled staff required. Six FTEs are required over the life of the program to ensure skills in developing and piloting interventions to decrease GHG emissions, measurement of GHG emissions, and policy engagement. Bilateral funding of \$5M also supports the achievement of Outcome 3. Of this, approximately 30% is budgeted for personnel, representing a total of 11 FTEs over the life of the program. No new staff will be hired. Lesser amounts of W1/W2 budget are assigned to this outcome's operational costs (travel, capital equipment and supplies and services). Included in the supplies and services line item is funding for workshops with stakeholders. A travel budget of about \$170,000 is included for centre staff to travel to workshops and for field work. The following amounts of the projected bilateral budget are assigned to operational costs: \$300,000 for travel with most of this travel being in-country and for meetings and field work); \$1.3M for supplies and services (research coordination, administrative support, and publications costs). The Flagship's non-CGIAR collaborators receive about \$530,000.

Outcome 4, (a 15% reduction in land and water degradation) that represents 7.9 million hectares and positively impacts 5.1 million direct and indirect beneficiaries across 8 countries requires 16% of the W1/W2 allocation supporting a total of 4 FTEs with skills in developing and piloting interventions to reduce land and water degradation, analysis and improvement of rangeland governance, and policy engagement. Bilateral funding of \$4.5M also supports the achievement of Outcome 4. Again, approximately 30% is budgeted for personnel, representing a total of 10 FTEs over the life of the program. A rangeland expert will be hired in Tanzania with 50% of time allocated to this outcome and the balance to the complementary Outcome 5). Lesser amounts of W1/W2 budget are assigned to

operational costs (travel, capital equipment and supplies and services) to deliver this outcome. Included under supplies and services is money for workshops with stakeholders, and to hire a consultant to assist with the work on sustainable water management. Capital equipment required to deliver this outcome amounts to \$20,000 for computers and water sampling equipment. A travel budget of about \$150,000 is included for centre staff to travel to workshops and for field work. The following amounts of the projected bilateral budget are assigned to operational costs: \$ 264,000 for travel (most of this travel is within country for meetings and field work), \$1.4M for supplies and services (research coordination, administrative support, and publications costs) and \$570,000 to non-CGIAR collaborators.

Outcome 5 (Agro-ecosystem resilience increased by 10%), impacting 1.8 million final beneficiaries over 9.2 million hectares across 6 countries requires about 13% of the W1/W2 allocation and a total of 4 FTEs with capacity in developing and piloting interventions to reduce land and water degradation, analysis and improvement of rangeland governance, and policy engagement. Thirty-five per cent of the bilateral funding of \$3.35M aligned with this outcome supports 7 FTEs over the life of the program, including half of a new rangeland expert in Tanzania. Lesser amounts of W1/W2 budget are assigned to operational costs (travel, capital equipment and supplies and services) to deliver this outcome. Included in the supplies and services line item is money for workshops with stakeholders. A travel budget of approximately \$114,000 is included for centre staff to travel to workshops and for field work. Bilateral funding contributes another \$198,000 for travel, mostly within country for meetings and field work; approximately \$1.06M for supplies and services (research coordination, administrative support, and publications costs and about\$440,000 for non-CGIAR collaborators.

Outcome 6 (Environment management interventions that reduce women's labour and energy expenditure by 2% developed and disseminated) reaches 770,000 women in 9 countries and requires about 12% of the W1/W2 allocation, including 4 FTEs over the life of the program at a cumulative cost of \$700,000. Skill categories include developing and piloting interventions to reduce land and water degradation, analysis and improvement of rangeland governance, and policy engagement. Half the new Gender expert will be covered from this budget. Bilateral funding of \$3.35M also supports the achievement of Outcome 6. Of this, approximately 30% is budgeted for personnel, representing a total of 5 FTEs over the life of the program. Lesser amounts of W1/W2 budget are assigned to operational costs (travel, capital equipment and supplies and services) to deliver this outcome. Included in the supplies and services line item is money for workshops with stakeholders. A travel budget of about \$198,000 is included for centre staff to travel to workshops and for field work. The following amounts of the projected bilateral budget are assigned to operational costs: \$198,000 for travel mainly within country for meetings and field work; \$1.06M for supplies and services (research coordination, administrative support, and publications costs and \$442,000 for non-CGIAR collaborators.

Outcome 7 (Improved capacity of 930,000 women and young people to participate in decision-making for environmental management of livestock in 9 countries) requires 12% (\$1.80M) of the W1/W2 allocation and 4 FTEs are required over the life of the program at a cumulative cost of \$700,000. Skill categories include developing and piloting interventions to reduce land and water degradation, analysis and improvement of rangeland governance, and policy engagement. Bilateral funding of about \$3.35M is aligned with the achievement of Outcome 7. Of this, approximately 30% is budgeted for personnel, representing a total of 5 FTEs over the life of the program. Lesser amounts of W1/W2 budget are assigned to operational costs (travel, capital equipment and supplies and services) to

deliver this outcome. Included under supplies and services is money for workshops with stakeholders. A travel budget of \$198,000 is included for centre staff to travel to workshops and for field work. The following amounts of the projected bilateral budget are assigned to operational costs: \$198,000 for mostly within-country travel for meetings and field work), \$1.06M for supplies and services (research coordination, administrative support, and publications and \$442,000 for non-CGIAR collaborators.

2.4.2.3 Additional explanations for certain accounting

For the CGIAR partners, personnel costs are defined as the total remuneration costs of an individual: base salary, fringe benefits and other employment costs. Actual computations on average for fringe benefits and employment costs in relation to base salary would translate to an average multiplier of 97% and 68% for international and national staff respectively. The reason for the high multiplier for international staff is because of the housing allowance, security and education allowance that are not provided to nationally recruited staff. Fringe benefits include: pension, housing allowances, education allowance, security, health insurance, other insurances, catastrophe fund, annual leave and severance pay. Other employment related costs include staff training and development; transportation, recruitment, appointment and repatriation allowances and payroll administration fees.

For SLU, the 51.3% fringe benefits is constituted as a Swedish tax that the employer must set aside for the employees and covers vacation, sick-leave, parental leave, part of the pension, full professional insurance and part of health care costs.

The cost structure of research undertaken during the first phase CRPs has been applied to estimate average research costs for collaborators, consumables, other supplies and services, and travel. The actual cost structure for secured W3 and bilateral projects is first applied, and the average research cost factors are then applied to the remaining portions of the budget that are yet to be secured.

2.4.2.4 Other Sources of Funding for this Project

The program is funded by a mix of W1/2 and W3/bilateral funding. Funding from other sources and significant in-kind contributions from program partners or other collaborators are not anticipated. Funding from W3 and bilateral sources is fully secured for Year 1 under the Base Budget scenario. Recognizing the high degree of uncertainty with W1/2 funding, both in terms of whether the indicative allocation assigned to the CRP in the CRP2 guidance document will be maintained once the CRP portfolio has been approved, and in terms of whether the projected budget assigned to the CRP in the System Financial Plan each year is actually achieved through donor W1/2 commitments, the program will be prepared to reduce the scope of its activities and outcomes to reflect any W1/2 funding shortfalls.

Within this flagship, the W1/2-funded activity specifically on Sustainable Water Management will be reduced or postponed if there is a shortfall.

The program is giving high priority to mobilizing bilateral funding to improve its ability to implement the full program and achieve the outcomes. This is required to:

- Generate replacement funding for current bilateral funded projects as they end and follow-up or initiate new research activities in later years; and
- Offset the uncertainty associated with W1/2 funding.

The following major projects are priority targets to deliver Flagship outcomes and mobilize the needed bilateral projects, both to address the need for replacement funding as current projects finish and to secure resources for the uplift budget.

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Project focus	Total amount (\$)	Start Year
Design and Implement Sustainable Water Management	6 M	2020
Implement and scale up rangeland management and restoration	4.2 M	2019
Support countries to develop Low Emissions Strategies for Livestock Production	6 M	2019
Enhance biodiversity from Livestock Systems	4M	2020
Include gender equity in Environmental Management of Livestock	4 M	2019
Enhance local governance of NRM	5M	2020
TOTAL FUNDING GAP	29M	

2.4.2.5 Budgeted Costs for certain Key Activities

	Estimate annual average cost (USD)	Please describe main key activities for the applicable categories below, as described in the guidance for full proposal
Gender	1,699,696	The activities to be undertaken are: 1. Description and analysis of how gender and other social norms influence the uptake and impacts of technical interventions for environmental management, and the implications for women’s labour. 2. Gender-differentiated analysis of risks and opportunities. 3. Development of tools and interventions for environmental management of livestock systems that empower women, ensure environmental management is equitable. 4. Ensuring that institutional mechanisms to enable environmental management also address gender equity. The budget pays for a full-time gender expert, plus other senior staff including two experts in the social and policy dimensions of environmental management.
Youth (only for those who have relevant set of activities in this area)	90,000	\$90,000 kickstarts investment in this area. The Flagship will focus on ensuring that youth are engaged in environmental management and, as for women, engaging youth as possible agents of change through empowering them and building their awareness of environmental issues. The senior staff working with the gender expert will be employed here and much of the funding directed to capacity development activities also ensures that youth are engaged.
Capacity development	400,691	This budget ensures capacity is developed across all 7 outcomes and 3 clusters of activities. Specifically, the capacity of national stakeholders to implement environmental management and monitor outputs is key to achieving Flagship outputs and outcomes. Thus it pays for capacity to develop staff as well as a number of targeted trainings. It will also sponsor several M.Sc. and PhD students each year.
Impact assessment	0	While this budget is held in the Strategic Investment Fund and managed by the CRP Management Unit, the Flagship recommends two main Impact Assessments be undertaken in the life of the program: 1. A review of successes in compiling better estimates of GHG emissions from livestock systems in Africa and Latin America and 2. Evaluation of taking rangeland management (both technical interventions and governance arrangements) to scale.

	Estimate annual average cost (USD)	Please describe main key activities for the applicable categories below, as described in the guidance for full proposal
Intellectual asset management	2,366	A small budget has been set aside for ad hoc IP advice and support for contract development. This will be supported by in-kind investments of the partners and support from management level.
Open access and data management	43,375	The flagship subscribes to the various tools and platforms used by the Program to maximize the wide accessibility of its research. The Flagship will reserve funds each year to supplement bilateral projects to pay article open access fees. The longer term strategy is for these to be fully budgeted into bilateral projects. Ensuring that raw data is well-documented and accessible is a continuing challenge that the flagship will tackle through partner open access and data management plans and by allocating funds on an annual basis to ensure proper curation and publishing.
Communication	69,991	Communication is key to engage with the various stakeholders related to flagship research activities in order to achieve the intended outcomes. This includes funding to disseminate results and high profile events. Bilateral projects in this flagship are expected to budget for these activities..

2.4.2.6 Other

not applicable

2.4.3 Flagship Uplift Budget

2022 additional outcome description	Amount needed (\$)	W1 + W2 (%)	W3 (%)	Bilateral (%)	Other (%)
Protect soil & water - Outcomes achieved in more communities in those same countries to reach an additional 10 M people	2,856,000	0	0	100	0
Management of natural resources - Outcomes achieved in more communities in those same countries to reach an additional 500K people	2,856,000	0	0	100	0
GHG emissions - Outcomes achieved in additional locations in the same countries to reach an additional 2 M people and an additional 1% reduction in emissions	3,808,000	0	0	100	0
Land & water degradation - Outcomes achieved in additional locations in same countries to reach an additional 2 M people	3,808,000	0	0	100	0
Agroecosystem resilience - Outcomes achieved in additional locations in same countries to reach an additional 500K people	1,904,000	0	0	100	0
Reduced women's labour - Options explored with more women in same locations to double the impact	1,904,000	0	0	100	0
Decision-making women & young people - Interventions explored with more women and youth in same locations to double the impact.	1,904,000	0	0	100	0

2.5 Livestock Livelihoods and Agri-Food Systems

Box 2.5a Livestock Livelihoods and Agri-Food Systems Flagship— Summary

The ex-ante impact assessment indicates that Flagship's research on optimization, markets and policies feature high in addressing the CRP's multiple objectives and in generating return on investment. The components of the Flagship agenda make particularly strong contributions to capacity development and gender inclusiveness.

This flagship:

- Delivers outcomes that address rural livelihoods, nutrition, gender and livestock agri-food system performance, with livestock-mediated livelihoods and well-being as its core aim.
- Provides the integrative mechanisms for technologies and strategies from the CRP's technology and environment flagships to be piloted and implemented among target livestock keepers and communities.
- Ensures that priority setting and gender are mainstreamed across the CRP.
- Leads CRP policy analysis as basis for advocacy to promote livestock growth opportunities for the poor.
- Identifies evidence-based best practices to facilitate scaling by partners of innovations addressing the unique opportunities afforded by livestock systems.
- Provides key linkages to the PIM CRP for foresight, gender, market development and scaling, and to A4NH CRP for human nutrition and food safety.
- Contributes directly to sub-IDOs:
 - Increased access to diverse nutrient-rich foods.
 - Reduced market barriers.
 - Increased livelihood opportunities.
 - Increased household capacity to cope with shocks.
 - Gender-equitable control of productive assets and resources.
 - Improved capacity of women and youth to participate in decision-making.
 - Conducive agricultural policy environment.

2.5.1 Flagship Project Narrative

2.5.1.1 Rationale and scope

Why research on livestock and livelihoods in developing countries?

Rapidly-growing demand for livestock products is an opportunity for small-scale livestock keepers and associated enterprises in developing countries. While some demand will be met from industrial-scale production, most supply is likely to come from smallholder and agro-pastoral systems (Herrero *et al.*, 2014). Over 70 million smallholder dairy farmers in India produce more milk than all North America combined (Hemme *et al.*, 2015). In Vietnam, small- to medium-sized pig producers supply 95% of all pork consumed, and projections show this will continue (Lapar *et al.*, 2012). In drylands, subsistence producers are becoming more commercially oriented (Catley and Aklilu, 2013). Smallholders remain dominant because of their competitiveness compared to large producers in low-wage settings, particularly for ruminant production (Hemme *et al.*, 2014; Sharma *et al.*, 2003). Increasing the supply response capacity from these systems is key to meet increasing domestic demand.

Livestock contribute some 40% of agriculture GDP in developing countries and over half a billion of the world's poor depend on livestock as part of their livelihoods. Livestock and their products play essential roles, contributing most household income in many countries (Staal *et al.*, 2009). Livestock assets are a way to save and insure against risk (Moll *et al.*, 2007). These assets are typically invested in other enterprises, multiplying livelihood opportunities and often used for children's education, contributing to a generational escape from poverty. Women typically keep and market small stock, usually their most important income source, so they can feed their families. Livestock value chains provide employment opportunities for input suppliers, service providers and traders. The link between livestock and livelihoods, whether for increased market orientation in a rapid inclusive growth trajectory or to strengthen resilience in a fragile growth trajectory, is a vital one. It is the focus of this flagship.

Small-scale livestock keepers and producers face enormous challenges to exploit the growing markets. Livestock productivity is low in developing countries, with yield gaps up to 300% (Herrero *et al.*, 2015). Farmers often lack access to the knowledge, inputs and services to increase productivity and

profitability. Multiple risks, including disease, climate and market shocks can limit their ability and willingness to innovate. Gender disparities hold women back while young people's involvement in livestock enterprises is constrained by access to capital (land, financial) and cultural norms.

The few successful efforts to link small-scale producers to formal markets are limited to specific markets and products such as dairy hubs or contract production of poultry. Informal markets thus continue to dominate but are subject to inefficiency and market risk, and are challenged by consumers wanting better quality and safe products. Market developments often exclude women, youth and other marginalized groups as well as those with smaller volumes to sell.

Low productivity of livestock limits the direct and indirect contributions of animal-source food to food and nutritional security, especially among the poor. This is further exacerbated in poor-performing markets by reduced affordability and accessibility of such foods, small amounts of which are critical for the health of the most vulnerable.

Addressing the grand challenges

The flagship addresses malnutrition, particularly among women of maternal age and children, through approaches that increase consumption of high-value animal-source food. The evidence regarding the contribution of improved livestock productivity to improved nutrition is scarce, but this is an important knowledge gap that the CRP needs to address. Working with A4NH, it will address food safety in livestock product supply chains in Africa and Asia. Options for young people in livestock production and supply chains will be explored. Production system optimization and gender-transformative approaches will address labour demands and, combined with integrated technology approaches targeting intensifying systems, will reduce competition for land and improve production efficiency. It will indirectly address the risks posed by climate change, by developing solutions to increase resilience, such as livestock insurance (Chantararat *et al.*, 2013).

Why should the CGIAR invest in this?

Livestock production and market systems are complex and the interactive effects of animal health, feed and genetics on productivity require integrated approaches. Complex socio-economic, risk, resource and gender role factors often limit technology uptake while lack of infrastructure constrains cold chains required for technical inputs and perishable products.

These multi-faceted dimensions demand approaches that address complexity in a systematic fashion: analysing interactions among socio-economic, gender and resource factors, accurately setting priorities and targeting key actors and beneficiaries, integrating technologies, facilitating scalable institutional mechanisms for services and markets, and contributing to enabling policy environments. CGIAR has presence on the ground as well as expertise and solid local partnerships to deliver this.

Its breadth and depth of livestock-related experience and knowledge is a comparative advantage and includes a strong focus on poor producers and consumers, a holistic systems approach combining biosciences and socio-economics, and a long-established participatory approach that places farmers and other beneficiaries at the centre. Recently the CGIAR has advanced in value chain and gender transformative approaches, linking agriculture and nutrition, addressing threats and opportunities of climate change, including private-sector partners to drive scaling up, and moving from pilot testing to impact at scale.

The ex-ante impact assessment, indicates that this flagship's research on optimization, markets and policies figures high in addressing the CRP's multiple objectives and in generating return on investment. The components of the flagship agenda make particularly strong contributions to capacity development and gender inclusiveness (see Annex 3.10.2).

Overall goal

The goal of the flagship is to maximize livestock-mediated livelihoods and resilience to risk among women and men smallholder and pastoral producers and their communities. This will be achieved by targeting and prioritizing, integrating and piloting technological and institutional innovations, by integrating this work with that of the other flagships, and by partnering with implementers, investors and advocates of livestock research and development.

2.5.1.2 Objectives and targets

Because of its integrative role within the CRP in supporting the testing and delivery of a wide range of technologies and strategies, and because of the central role of gender in this work, the flagship's contributions to sub-IDOs is wide and serves as a multiplying factor to the technology flagships. The flagship will contribute directly to sub-IDOs on increased access to diverse nutrient-rich foods, reduced market barriers, increased livelihood opportunities, increased household capacity to cope with shocks, gender-equitable control of productive assets and resources, improved capacity of women and youth to participate in decision-making, and a conducive agricultural policy environment.

As described above, the unique characteristics of the livestock sector make integration especially important. They include the inter-related technical determinants of productivity, the impacts on and of environment, and the multiplicity of livestock roles in all dimensions of livelihoods. This flagship will play the central integrating role across the CRP in strategic priority setting and systems analysis, in gender mainstreaming, in addressing human nutrition, and in integrating and testing the technology flagship products among target beneficiaries and communities, including the testing of innovative institutional arrangements. The flagship builds on the approaches and lessons of the Livestock and Fish CRP and plays a central role in the CRP to facilitate scaling up of the CRP's outputs by partners to achieve impact, as illustrated in Boxes 2.5b and 2.5c.

The flagship's objectives are:

- Set research priorities for the Livestock CRP, within the context of a dynamic, global livestock sector and conduct policy analysis to guide inclusive and sustainable investments by both public and private actors.
- Improve livestock technology development and adoption by ensuring that gender-based analysis informs research priority setting across the CRP and that delivery and scaling are equitable.
- Identify, test and facilitate livestock-mediated pathways to improve nutrition in rural households and their communities.
- Improve the livelihoods of smallholder livestock keepers and their ability to cope with shocks, through integrated technologies and institutional innovations.
- Improve the performance of animal-source food systems and promote pro-poor livestock development through institutional innovation and policy advocacy.

The approaches used to achieve these objectives will differ by and be calibrated to the two main livestock trajectories that are the focus of the CRP. For inclusive rapid growth systems, the emphasis will be on integrated system optimization for livelihoods through increased productivity, and on improved market performance to enable access to inputs, technology and growing output markets. For fragile growth systems, the emphasis will be on integrated solutions to ensure resilience, while also exploring opportunities of greater livestock-mediated livelihood options. In all cases, context-specific and appropriate interventions will be tested that address gender, social equity and human

nutrition. Targeting and prioritization through foresight and systems analysis will guide interventions in each context.

Flagship outcomes to 2022

- Innovative institutional options that improve resilience tested and adopted by national and international research and development partners, increasing the resilience of 700,000 rural livestock-keeping households (3.5 million individuals) in 3 countries.
- 900,000 livestock keeping households (representing 4.4 million individuals, including women) increase their supply of livestock to the market by 15%, on average, in 7 countries.
- 15% Increase, on average in total household income from livestock-related activities, including 25% increase, on average, in proportion controlled by women, for 950,000 households (and 4.6 million individuals) in 9 countries.
- 6 million poor people (men and women), in 4 countries, with increase in access to more affordable, safe and nutrient rich animal-source food.
- Gender equity relative to their level of effort (i.e. labour) at household level in the use of, and control of income generated by, livestock related productive assets and resources, impacting 575,000 women across 4 countries.
- Improved capacity of 2 million women and young people to participate in livestock related decision-making in 5 countries.
- Laws, rules and regulations within and across 4 countries at local, country and regional level explicitly include pro-poor livestock mediated development, reaching 4 million livestock keepers and other value-chain actors.

Box 2.5b Uganda - integrated approach to value chain transformation in a rapid inclusive growth system

In 2011–2012, the Livestock and Fish CRP identified development of smallholder pig value chains in Uganda as a promising pathway to improve both livestock keepers' livelihoods, as well as the income of other actors along the value chain.

Designed as an integrated approach to transform the whole value chain, initial activities included a situational analysis of the pig sector, as well as participatory site selection with partners. By combining CRP resources with bilateral project funds, ILRI and its partners conducted gender-responsive value chain assessments in specific locations, working with the National Livestock Resources Research Institute, and public universities. Based on these assessments, 'best-bet' interventions, in areas including health and biosecurity, vaccines, feeds, business development, capacity development, slaughtering, and food safety were identified and pilot tested, in close collaboration with local government partners and on-the-ground development partners (including local governments, Kampala City Council Authority, VEDCO, Pig Production and Marketing Ltd., Iowa State University and SNV).

The Program now works with 8,000 pig farmers and 500 pig value chain actors in five districts. A national-level multi-stakeholder platform was set up to identify systemic issues in the pig value chain, connect actors, engage policy-makers and support the sector find long term and sustainable solutions for inclusive and profitable pig value chains in Uganda. Updates and research outputs are online: <http://livestockfish.cgiar.org/focus/uganda>

This approach of focusing and integrating efforts around a particular value chain in selected sites, building long-term relationships with partners, complementing on-the-ground gender-responsive pilot testing of interventions with high quality modeling work and upstream technology research, addressing systemic issues at a higher level and using evidence to adjust interventions when required, is a promising way to reach impact at scale (see Livestock and Fish CRP external evaluation report: <http://hdl.handle.net/10568/52246>).

Box 2.5c Tunisia - Integrated systems research to increase farm productivity and reduce vulnerability in a dryland fragile growth system

In 2013, the Dryland Systems CRP targeted the transect Beni Kedache to Sidi Bouzid in Tunisia to increase livestock and crop productivity while improving natural resource management. The area is mainly agropastoral livelihood systems, dominated by sheep, and operating in a fragile environment (aridity index between 0.07-0.2).

Research began with a systems analysis and other assessments to identify constraints and opportunities around water scarcity, rangeland degradation, poor rangeland tenure and poor performance of the two key value chains sheep meat and olives. Water productivity of sheep and goat meat production and seasonal nutritional status and deficiencies of grazing sheep, goat and dromedaries along with feeding practices were assessed, emerging animal health threats such as *theileriosis* and toxoplasmosis were identified, rangeland degradation was mapped, forage plant biodiversity and potential in animal disease treatment was surveyed, value chain analyses of sheep meat and olives identified main stakeholders and marketing channels, and the cost-benefits of water harvesting techniques were calculated.

At the same time, cost-effective and environment-friendly interventions addressing the constraints are being developed involving more than 1500 farmers. These include trials to improve seed productivity and seed system establishment of some key rangeland species, establishing a community-based forage nursery, promoting sustainable pasture management concepts at community level, working on a national pastoral code approach, introducing community-based flock and crop management, off-grid solar-powered solution for on farm-milk cooling, and increasing water use efficiency of feed production. Innovation platforms targeting sheep and olive value chains brought together the Arid Regions Institute with local NGOs and IFAD in a learning alliance. To increase the profitability of products of origin, requests to label two local products as PGI's (Protected Geographical Indication), i.e. Olive oil (variety Zarrazy) and Barbarine sheep meat were submitted to the registration authorities. The proposed CRP Livestock will build on this work to intensify the development and scaling of livestock technologies in a systems context while continuing and complementing environmental impact assessments and development of resource management practices. Additional information is online: <http://mel.cgiar.org/repo>.

2.5.1.3 Impact pathway and theory of change

Figures 2.5a and 2.5b present the flagship's ToC and assumptions. The aim of the flagship is to maximize livestock-mediated livelihoods and resilience to shocks among smallholder and pastoral producers and their communities. This flagship is also the CRP's 'integration and delivery' mechanism to enable the CRP teams to jointly move from research outputs and local or near-term development outcomes to achieving long lasting impact. This will be achieved through five linked clusters of activity, each responding to specific challenges and opportunities within the rapid inclusive and fragile livestock growth trajectories.

The flagship will emphasize work on system optimization for the fragile growth trajectory, while exploring interventions to reduce risks to shocks. In the CRP priority countries and other locations, the flagship will integrate the work of the other flagships and continue with the value chains work pioneered in the Livestock and Fish CRP; and expand integrated approaches to selected system sites focused on improving resilience and nutrition. For the rapid inclusive systems, the flagship will focus on integrated productivity improvement and enhancing access to markets and services. Priority setting, gender and nutrition activities will cross-cut both trajectories, but adapted to each. Together, these approaches will lead to demonstrated, demand-led and science-based, scalable interventions for impact, while producing IPGs through cross-site, commodity and context comparisons. This responds to one of the recommendations made the external evaluation of the Livestock and Fish CRP, for stronger convergence, lesson learning and systematic generation of IPGs.

The flagship's work on systems analysis for priority setting and investment will ensure that the CRP's research remains demand driven, directed towards interventions that optimize impact and minimize trade-offs among objectives, and will facilitate investment for scaling up by partners and decision-makers to achieve impact at scale. Another stream of work will focus on streamlining gender and social equity, to ensure that CRP interventions are based on the accurately identified needs, preferences and

potential of women, youth and other marginalized groups. These two streams of work, together, contribute to achieving gender-equitable control of assets and resources and improved capacity of women and youth to participate in decision-making. The flagship will also focus on developing tools and evidence for designing strategies that lead to increased access to diverse nutrient-rich foods.

Interlinked research on optimizing livestock systems for productivity and resilience and on enabling policies, markets and institutions will bring together a range of technical and institutional innovations to improve productivity, resilience and livelihoods, as well as market access and overall system and value-chain performance. This work will focus on on-farm productivity, combining the technologies from the animal health, feed and forages and genetics flagships into packages of interventions that have increased relevance to women and men livestock keepers and their communities. The integrated packages will translate to increased household income and capacity to cope with shocks, reduced market barriers and a conducive policy environment.

A critical element to facilitating change will be to work through partners; the flagship will continue partnering with its target primary users of knowledge products, particularly actors in livestock research and development (as detailed in the Partnership section), facilitating capacity development, lesson learning, and testing proven best-bet interventions to subsequently scale up research outcomes. Linked communication and policy advocacy efforts, again through partners, will ensure greater attention to livestock development and investment, and movement towards pro-poor policies. Additional enabling actions that will contribute to lasting development outcomes include influencing investors and major donors to increase their efforts on livestock R4D. The Livestock CRP partners have a proven record in influencing policy making in East Africa on raw milk marketing, as well as shaping the direction of major dairy development projects from implementing a fixed one-size-fits-all model to a flexible mechanism that is more inclusive.

Initial changes described above will happen because: national and international research partners will make decisions based on scientific evidence, including consideration of gender equity; there exist innovative options for positive nutrition impact that do not negatively impact other dimensions of livelihoods (e.g. gender equity); livestock keepers are able and willing to adopt productive, gender-responsive and -inclusive technologies; technologies are available, accessible and affordable in specific target contexts; systems are currently sub-optimal and there's room for win-win interventions; market structures are adequately efficient to respond to changes in investment, policy and information; and public and private actors are able and willing to invest in new institutional arrangements.

Similarly, changes that contribute to lasting development outcomes will occur because: gender-transformative approaches will translate into lasting inter- and intra-household benefits for poor households; newly adopted gender and other social norms will support equitable access to resources and equitable participation in decision-making; more efficient market structures will be put in place; demand for livestock and livestock products is adequate; and household resource allocations will be based on evidence and equity concerns.

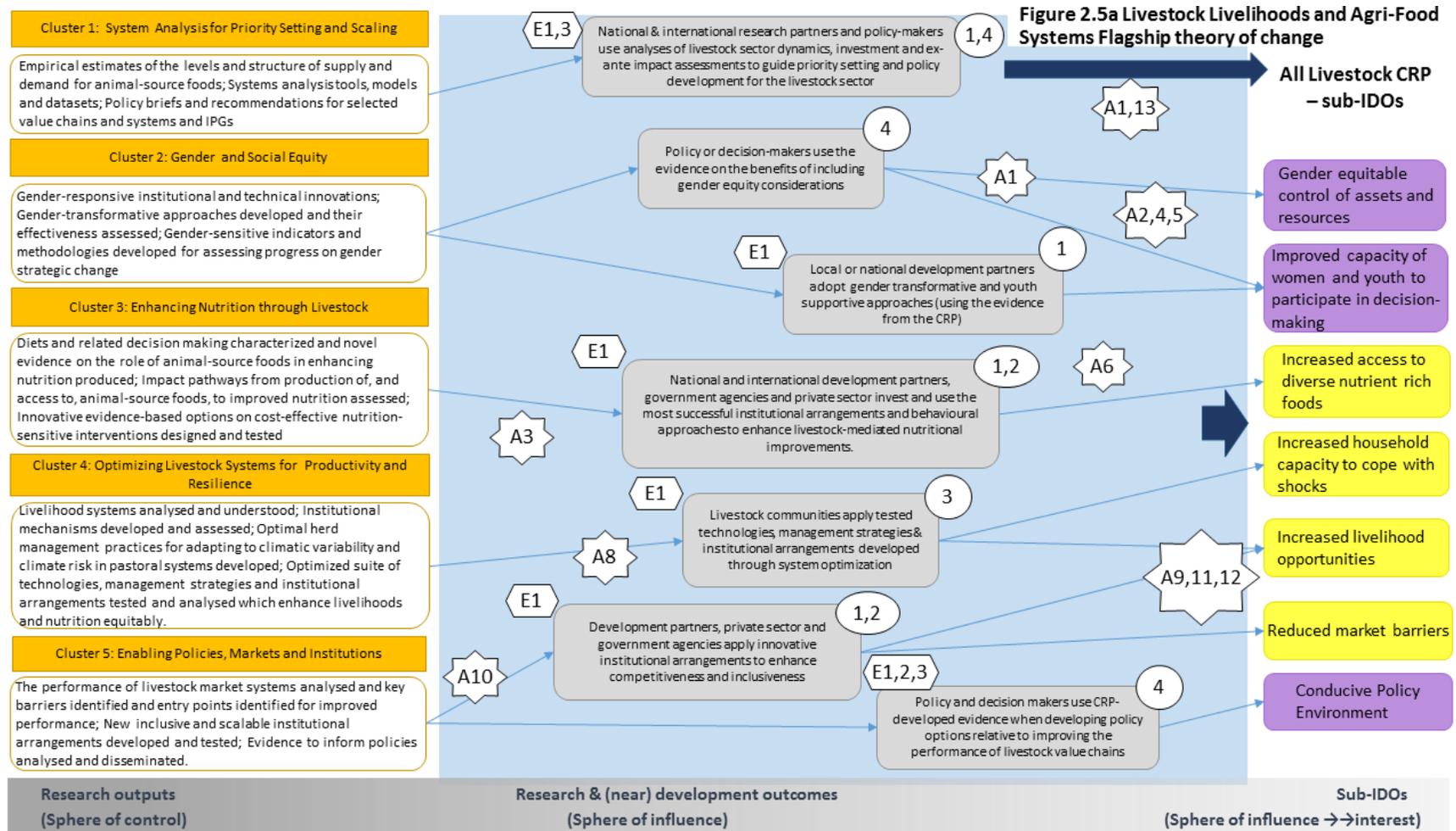
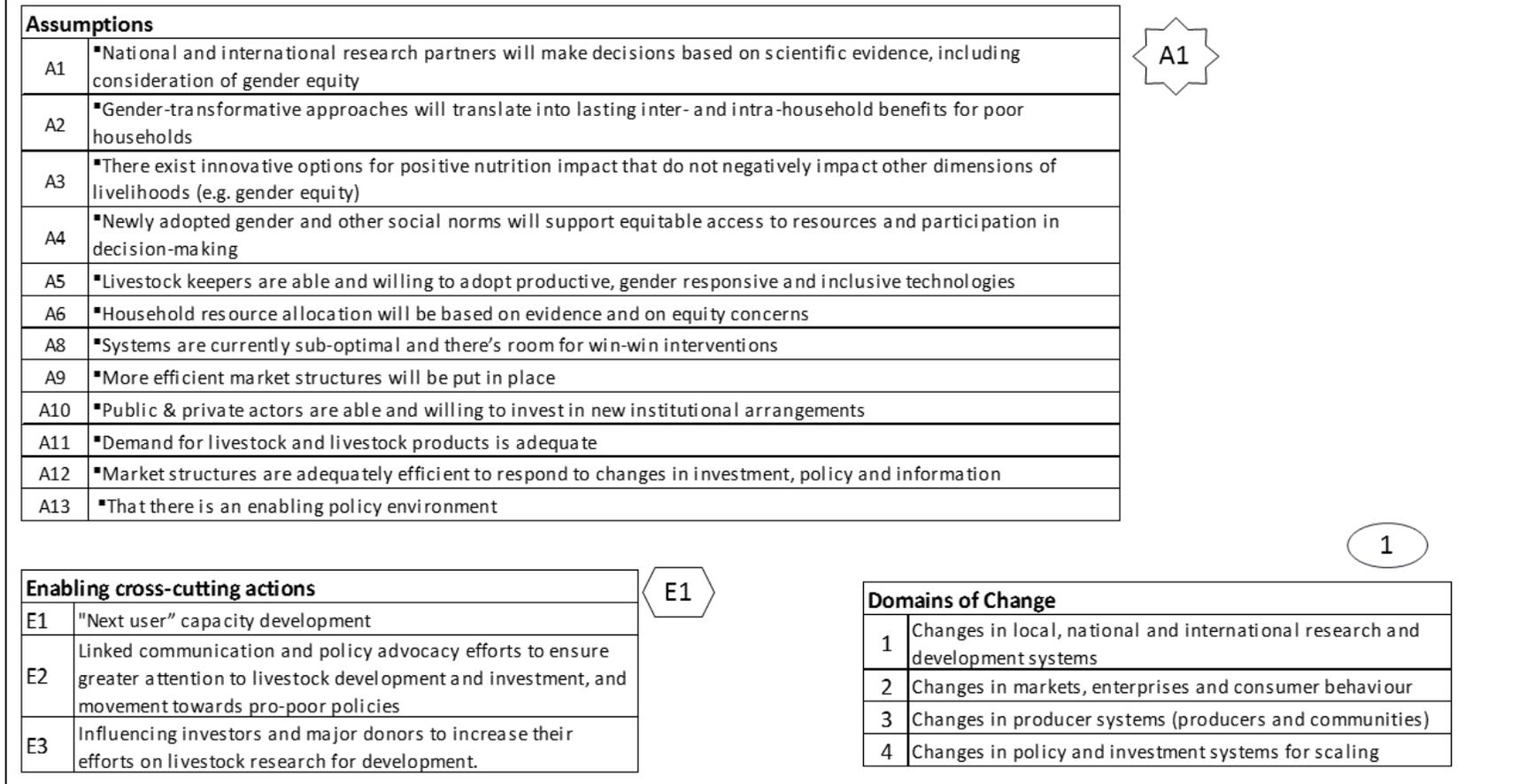


Figure 2.5b Livestock Livelihoods and Agri-Food Systems Flagship theory of change, assumptions and change domains



2.5.1.4 Science quality

The flagship will develop innovative ways of generating data on beneficiary populations that inform investments based on priority setting, spatial targeting and impact assessment. Estimates of the numbers of poor livestock keepers by system (Robinson *et al.*, 2011) will be updated using new datasets and approaches that will include the distribution of poor consumers, livestock keepers and other sector actors and incorporating household data sets. This will provide detailed information on the roles of livestock in livelihoods, often gender-disaggregated, with geographical layers on demography, socio-economics, livestock distributions and systems, and agro-ecology. Combining this with current and potential productivity estimates, using methods being developed with CSIRO and ULB under the LiveGAPS initiative (Herrero *et al.*, 2015), will yield new estimates of potential impacts of different suites of interventions at a range of spatial scales. For the first time, a systematic approach linking populations to potential for poverty reduction, improved nutrition, livestock-related productivity improvements and reduction of externalities (such as health risks and environmental impacts) will be developed to estimate the expected and gender differentiated impact of interventions taken to scale. Such findings will inform policy deliberations, investment in livestock research and development, and advocacy.

The flagship will explore livestock sector trends under different scenarios, improving on current forecasts of demand and production (Robinson and Pozzi, 2011) using partial equilibrium models to link population and systems data to herd and flock models, and to global drivers of change. This will be facilitated by further developing the livestock module in the IMPACT model in collaboration with IFPRI, CSIRO, PIM and FAO.

The flagship team has a proven track record in livestock-sector mapping and foresight analysis, having led the field in mapping livestock distributions and production systems applied to analyses of poverty, health, nutrition and the environment. Team members led the development of the livestock module of IMPACT (Msangi *et al.*, 2014) and contributed to yield gap analytical approaches (Herrero *et al.*, 2015). They have worked on compilation and analysis of multiple household datasets, (e.g. Frelat *et al.*, 2016), and explored the potential of these data for gender-differentiated targeting with KIT.

The flagship will build on research on gender-transformative approaches undertaken in the Livestock and Fish CRP. Although part of the conceptual framework of gender and development work for decades (Young, 1993; Kabeer, 1994), putting them into practice remains a key challenge. In Tanzania and Nicaragua, Livestock and Fish developed some promising approaches that target young people and women by addressing gender norms through social media. It also explored gender norms affecting participation of farmers in the pig value chain in Uganda. And in Tanzania it supported participatory empowerment pathways (Galiè and Kantor, 2016; Galiè *et al.*, forthcoming). The successful experience of Livestock and Fish in integrating gender in the technology flagships will also inform further studies on how gender dynamics affect and are affected by technology development. These include: gender-responsive advisory services (Farnworth and Colverson, 2015), innovation platforms (Mulema and Mazur, 2015; Mulema, 2013), and institutional mechanisms (KIT *et al.*, 2012); gendered species and breed preferences (Waithanji *et al.*, 2015); social and gendered factors affecting vaccine adoption (Waithanji *et al.*, 2015); women's decision making in livestock-producing households; and the links between empowerment and nutrition (Njuki *et al.*, 2015; Galiè *et al.*, in press). The Livestock and Fish CRP's work with KIT led a successful 2-year collaboration among gender scientists particularly around gender integration and this will be developed further in the Livestock CRP.

A relatively new area, is enhancing human nutrition. Knowledge gaps that will be addressed include understanding opportunities to better use various animal-source food and other livestock-mediated pathways to enhance rural household nutrition, as part of a whole diet approach. Innovative research on consumption and nutrition will be developed by adapting methods from other disciplines to analyse the drivers of animal-source-food consumption and intra-household allocation of these foods. It will explore innovative ways to deliver interventions, relevant to both livestock-owning households and poor non-livestock-owning households. This research will include strategic interventions targeting waste reduction and adapted nutrition social and behaviour change communication. The agenda will reflect synergies with solutions developed by the other clusters in priority systems and value chains. Nutritional implications resulting from options currently being implemented by the Livestock and Fish CRP are currently being explored, particularly in Tanzania (milk value chain), and in Uganda (pork value chain) and will inform upcoming work, for example, in the dairy and beef value chains in Kenya. The critical mass working on nutrition will be strengthened by building on collaborative relationships already established with topic leaders, national partners and other CRPs.

Central to integrating technical interventions at the producer level is work on optimizing livestock systems for productivity and resilience. One area with significant knowledge gaps that will be addressed with new tools is the unique role of livestock assets in promoting resilience through contribution to the accumulation of other livelihood assets, including as a mechanism for moving out of livestock and agriculture altogether. Such analysis requires dynamic observations of farmers' livelihoods and how they adapt them to changing circumstances (Alary *et al.*, 2014). Building on data from the Livestock and Fish CRP a comprehensive understanding of this issue, within the framework of poverty analysis in the target areas will be developed. Enhancing resilience in climate-vulnerable settings will include fine-tuning index-based livestock insurance programs (Chantararat *et al.*, 2013) and their adaptation to new settings provided by both public and private entities. In addition to climate risks, livestock keepers in the developing world also face production, marketing, institutional and physical risks. Optimization of resource allocations, with due consideration of the production and marketing challenges (Alary *et al.*, 2011; Siegmund-Schulze *et al.*, 2013), will be essential in increasing the performance and resilience of the sector. Innovative benchmarking, modelling and programming techniques (Frija *et al.*, 2015; Frija *et al.*, 2011; Varghese *et al.*, 2013; Vera Castillo *et al.*, 2014) will be used for comprehensive assessments of system performance, scenarios of production systems dynamics and trade-offs related to the use of biomass. Although this area has been investigated since about 2011, a lot of questions remain about appropriate techniques and strategies for allocating biomass between crop and livestock systems, especially related to conservation agriculture.

To achieve the intended outcomes and impact at scale, enabling policies, markets and institutions are required. To ensure improved access to services, technology and markets requires a conducive regulatory and investment environment. Partners in the CRP are engaged in projects on various commodities for which assessments have been conducted and context-specific interventions are now being developed and tested. While the Livestock and Fish CRP has deliberately tested packages of interventions in specific locations (as opposed to testing individual interventions in different contexts), it has been less successful in overlaying an experimental design that includes the institutional approaches to be tested. Indeed, there is a lack of evidence on the approaches that would be most effective and efficient in improving livestock keepers' livelihoods, while also increasing the supply of animal-source food in different contexts. Mechanisms to facilitate smallholder livestock keepers' access to inputs and services, will be tested, including farmers' collective versus private entrepreneurs versus franchised systems. Extension and advisory approaches in focus systems and value chains, including options to 'bundle' extension with the delivery of inputs and other services will be evaluated.

2.5.1.5 Lessons learned and unintended consequences

The livestock and fish CRP experimented with several configurations of flagships to engender cross site learning and lessons, with limited success. This flagship builds on lessons of what did not work, and aims for more integrated and intentional learning and scaling approaches.

This flagship also builds on systems work in previous CRPs, where ILRI led the strategic research theme on systems analysis. Results from these initiatives include global maps of livestock distributions (Robinson *et al.*, 2014) and production systems (Robinson *et al.*, 2011; Gilbert *et al.*, 2015), estimates of agricultural populations and numbers of poor livestock keepers (Robinson *et al.*, 2011), maps of disease and related risks (Gilbert *et al.*, 2014; Horby *et al.*, 2013; Boeckel *et al.*, 2012; Robinson *et al.*, 2015; Boeckel *et al.*, 2015), economic analyses of livestock interventions (Shaw *et al.*, 2014; 2015) and environmental impacts of livestock (Thornton and Herrero, 2014; 2015; Zhou *et al.*, 2014). Beyond these, there is a growing dataset of standardized household survey data (from IMPACT-Lite and other survey instruments) forming the basis for the systems analysis work described below (van Wijk, 2014; van Wijk *et al.*, 2014). Work on priority setting and investment builds on these results to explore possible synergies and trade-offs (unintended consequences) including gender implications of different livestock interventions under a range of scenarios.

Research on gender-transformative approaches builds on research assessing the links between the transformation of gender norms and empowerment pathways (Galiè and Kantor, 2016; Galiè *et al.*, forthcoming); addressing gender norms through social media; and exploring gender norms affecting farmers' participation in value chains. The flagship will also build on gender-integrated research undertaken by the Livestock and Fish CRP, including gender responsive advisory services; gendered species and breed preferences; social and gendered factors affecting vaccine adoption; women's decision-making in livestock-producing households; and the links between empowerment and nutrition (see science quality).

The flagship will build on work of the Livestock and Fish CRP that assessed: the contribution of animal-source-food consumption on child nutrition in priority value chains (Tanzania and Uganda), drivers of animal-source food consumption (Kenya) and how women's empowerment affects child nutritional status (Tanzania).

This CRP will draw on the growing body of knowledge on the causes, consequences and management of different risks faced by the livestock sector in the developing world (Bailey *et al.*, 1999; Hazell, 1999; Steinfeld *et al.*, 2006). Production risks and vulnerability emanate from uncertainties associated with the ownership of land, water, the unpredictable nature of disease and pest dynamics, weather patterns (Kassie *et al.*, 2013). Marketing risks arise from poor access to markets and the perishability of livestock produce, and producers' responsiveness to the requirements of commercial livestock markets. Farmers in developing regions are well aware of most of these risks and have appropriate coping mechanisms for which comprehensive frameworks (Mahul and Stutley, 2010; Chantarat *et al.*, 2013) have been developed. The flagship will use these approaches as part of its work on risk, especially for the fragile growth trajectory.

All program partners have long experience in value chain development in the livestock sector which will be improved to address the methodological frameworks for measuring and monitoring value chain performance (working with PIM), and thus the potential for creating IPGs. These include tools for monitoring and learning from multi-stakeholder platforms, such as innovation platforms (Swaans *et al.*, 2014) and the flexible hub approach (Rao *et al.*, 2015; Twine *et al.*, 2015) and the tools for developing the capacity to facilitate such platforms, such as "blended learning" (Dror *et al.*, 2015). This flagship will continue working on models of collective action and tools to evaluate producer

organizations' progress towards sustainability (Baltenweck 2014a and 2014b, Kassie *et al.*, 2008) and resilience. Studies that elicited consumer preferences will be broadened to include all animal-source-food and other products (Kassie *et al.*, 2009; Kassie *et al.*, 2010; Kassie *et al.*, 2011; Terfa *et al.*, 2012; Terfa *et al.*, 2013). Current successful policy work on the upgrading and legalization of the raw milk trade in East Africa and India (Kaitibie *et al.*, 2010), and on informal pig value chains in Vietnam will be extended.

2.5.1.6 Clusters of activity

Cluster 1: Systems analysis for priority setting and investment

A major challenge for this CRP is to identify research priorities that reflect the complexity of the livestock sector and embrace livestock's diverse roles. Foresight, targeting and systems analysis will be used to assess potential priorities and entry points. Understanding synergies and trade-offs of different interventions for different livestock sector evolution scenarios will be deepened, in both intensifying and fragile systems informing the other AFS CRPs.

This cluster will define priorities and policies for livestock research and investment at multiple levels, within the context of a dynamic, global livestock sector, and facilitate their strategic use within the CRP and the CGIAR system and among livestock decision-makers and investors more broadly.

Foresight analysis will explore future scenarios in terms of drivers of change, such as climate change, economic growth, urbanisation, changing consumption patterns, trade, policies and land-use competition, and how these may impact on the livestock sector. The flagship will take a multi-scale approach, working with PIM and particularly the Global Futures and Strategic Foresight program, combining broad analyses with household and community-based foresight assessments in priority locations. Such a systems approach is imperative for the livestock sector is to make strong contributions to each of the three SLOs.

Systems analysis for priority setting will investigate the most appropriate methodologies and criteria, including gender, social equity and nutrition, to set livestock research priorities at different levels and for different contexts. Relevant datasets at a range of scales, (e.g. household and landscape level) and analytical tools (e.g. yield gap analysis) will be systematically assembled to determine where specific livestock technologies and interventions can be optimized for livelihoods, gender equity, resilience, public health, the environment and food security. As an example, Shaw *et al.*, 2014 combines, livestock and production system mapping, with vector risk mapping, herd models and economic analysis to estimate economic benefits, *ex ante*, that would accrue from an intervention. This approach will be systematized and applied to combinations of interventions (animal health, genetics and feeding) to prioritise investments and interventions and to estimate potential impacts of research by the CRP.

Based on foresight and systems analysis, policy analysis will explore the effects of existing policies under different scenarios of change, and of livestock sector and related policy investments and interventions on livestock's contribution to sub-IDOs, IDOs and ultimately the SLOs.

Main research outputs

- Empirical estimates of the levels and structure of **supply and demand** for animal-source food, obtained by combining market and household survey data with production estimates.
- Systems analysis tools, models and datasets, which will contribute to informing evidence-based priority setting and investment across the CGIAR and among governments, donors and other partners.
- Policy briefs and recommendations for selected value chains and systems in which the CRP works and global public goods in the form of high-level publications.

Outcomes to 2022

1. National and international research partners and policymakers use analyses of livestock-sector dynamics, investment and *ex-ante* impact assessments to guide priority setting, investment and policy development for the livestock sector in six priority countries.

Milestones

- National and international research partners use analyses of livestock sector dynamics, investment and *ex-ante* impact assessments to guide priority setting for the livestock sector in 3 priority countries (2020).

Cluster 2: Gender and social equity

Gender dynamics and relations affect the relevance and effectiveness of livestock innovations, as well as the equity of their impact. This cluster will lead the gender agenda of the CRP, ensuring that gender-responsive technological and institutional packages are developed and promoted. This involves conducting strategic gender research, also the work in the technical flagships; the coordination and synthesis of both strategic and integrated research; capacity development of both gender and technical scientists, and of research and development partners; and gender analysis to inform priority setting (with cluster 1), and ensuring that all research and development outcomes are gender equitable.

The cluster will systematically study gender relations by integrating gender into baseline studies, research tools, implementation strategies, and monitoring, evaluation and learning tools. It will aggregate, synthesize and provide guidance to gender-integrated research across the CRP flagships, as well as leading strategic gender research. Because of this double role, this cluster contributes to outputs produced by other flagships on gender integration, and produces its own strategic and synthesis outputs. Section 1.4 provides more detail on the gender research agenda and overall research questions. Annex 3.3 discusses how gender analysis has informed priority setting as well as how gender work will be organized and implemented. The gender strategy developed in the Livestock and Fish CRP will be updated for this CRP.

Age is both an intersection of gender analysis as well as a social category in its own right. Young people as a social category were not prominent in the Livestock and Fish CRP, nor has the participation or non-participation of young people in the livestock sector been analysed as a potential problem. Recognizing this, the CRP will prioritize development of a strategy on youth (see Annex 3.4).

Main research outputs

- Packages of gender-responsive institutional and technical innovations that are known to enhance productivity and equity.
- Gender-transformative approaches developed to address the root causes of gender discrimination, and their effectiveness assessed.
- Gender-sensitive indicators and methodologies developed for assessing progress on gender strategic change (e.g. transformation of gender norms or empowerment).

Outcomes to 2022

1. Policy- or decision-makers in 4 priority countries use the evidence on the benefits of including gender equity considerations

Milestones

- Policy- or decision makers in 2 priority countries use evidence on the benefits of including gender equity considerations (2020).
2. Local or national development partners in four priority countries adopt gender-transformative and youth-supportive approaches (using the evidence from the CRP).

Milestones

- Gender-transformative approaches that also support young people have been developed and tested and their impact assessed in 4 priority countries (2020).

Cluster 3: Enhanced nutrition through livestock

Despite progress in recent years, malnutrition continues to be a significant concern in many developing countries, particularly for young children and women of reproductive age. It has significant implications for the growth and cognitive development of children, contributing to poor health and educational outcomes, as well as implications for the labour productivity of adults. In addition, the CRP recognizes that the linkages between livestock production and marketing, gender and potential impacts on nutrition is a critical area where knowledge gaps exist that need to be addressed. Supplementation strategies have had limited effectiveness. Food fortification strategies have increased the levels of specific nutrients. However, in settings where concomitant micronutrient deficiencies exist, the need for food-based strategies, especially the consumption of nutrient-dense foods (such as animal-source food, pulses, fruits and vegetables) and dietary diversification through home-based gardens, has been emphasized (Müller and Krawinkel, 2005). While evidence of the effectiveness of these interventions is still much needed (Ruel *et al.*, 2013), the consumption of small amounts of meat and milk by children has been shown to increase not only physical but also cognitive and social development (Neumann *et al.*, 2003). Women's empowerment has been shown to be a key determinant of intra-household food allocation and resulting nutritional outcomes (Malapit and Quisumbing, 2015).

This cluster will: (1) characterize diets (particularly for smallholder households), analyse household consumption patterns of animal-source food, assess their contribution to filling the nutrient gap experienced for vulnerable populations (including aspects of intra-household food allocation) and identify the main drivers of animal-source-food choice and household barriers to consumption; and (2) identify the most suitable value chains and system modalities to enhance nutrition and test cost-effective nutrition-sensitive livestock-related interventions. The latter will be facilitated through livestock interventions implemented in other clusters and flagships, to which nutrition components will be added. These components will help identify and exploit the specific pathways to improved nutrition for the most successful animal production or market-based interventions. Examples of strategies are product waste reduction, improved animal-source-food delivery systems and behaviour change communication. The aim is to have a positive impact on the nutrition of poor producers and their communities. At the same time, understanding of livestock-mediated pathways to nutrition and health and how women's knowledge, practices and decision-making power relate to food consumption and health will be extended. All the work in this cluster will be closely linked to A4NH.

Main research outputs

- Diets and related decision-making characterized in target communities and novel evidence on the role of animal-source food in enhancing nutrition produced.
- Impact pathways from production of, and access to, animal-source food, to improved nutrition in rural households assessed within the target interventions (with clusters 2, 4 and 5).

- Innovative evidence-based options on cost-effective nutrition-sensitive interventions that can improve availability, affordability, access and utilisation of animal-source food to poor producers and consumers designed and tested, with a focus on pregnant and lactating women, children under five years, and the elderly (with A4NH in the context of full diets).

Outcomes to 2022

1. National and international development partners, government agencies and the private sector invest in and use the most successful approaches to enhancing livestock-mediated nutritional impact, including institutional arrangements and behavioural approaches, in 4 priority countries.

Milestones

- National and international development partners, government agencies and the private sector test innovative options for nutritional impact, including cost-effective institutional arrangements and behavioural approaches, within communities in 2 priority countries (2020).

Cluster 4: Optimizing¹⁵ livestock systems for productivity and resilience

This cluster seeks to improve the livelihoods of smallholder and pastoral livestock keepers and their ability to cope with shocks by increasing farm and system-level livestock productivity, targeting income opportunities for women, men and young people. This will be achieved by developing and testing integrated improved livestock production technologies from the technology and environment flagships along with institutional innovations to facilitate uptake and access to services, leading to optimization of mixed production and pastoral systems in selected target countries. The cluster will also exploit the untapped potential for increasing whole farm productivity through improved crop–tree–livestock interactions in mixed systems and through herd and grazing management in pastoral systems.

An overarching question is how to optimize these production systems considering: (i) the multiple economic and social functions that livestock provide, (ii) competition for land, labour, capital and water resources, and (iii) household priorities, including the role of women and young people in decision-making. Coordination in large development-oriented bilateral projects with cluster 5, where the focus is on inclusive access to markets, as well as on enabling policy, institutional and regulatory environments, will support broad uptake of technological packages through effective access to public and private goods and services. Coordination with cluster 1 and with cluster 1 in the Livestock and the Environment flagship will ensure that animal productivity gains are assessed on their environmentally sustainable and compatibility with both economic incentives and social concerns, thus balancing important trade-offs.

Main research outputs

- Livelihood systems analysed and understood in terms of the roles of livestock incomes and assets, productivity, resilience, nutrition, gender and social relations.
- Institutional mechanisms, equally accessible to women and young household members, developed and assessed which are able to replace or supplement livestock as insurance and a store of wealth in vulnerable systems, leading to improved livestock productivity and asset accumulation (such as Index-Based Livestock Insurance, IBLI).

¹⁵ Optimization is not a static concept and opportunities will evolve based on technologies, resources, and other factors.

- Optimal herd management practices for adapting to climatic variability and climate risk in pastoral systems developed and underpinned by acceptable trade-offs between productivity improvement, economic and social considerations and environmental impacts.
- Optimized suite of technologies, management strategies, and institutional arrangements tested and analysed which enhance livelihoods and nutrition equitably for women, men and young people from livestock-mediated on-farm and off-farm economic opportunities in various settings.

Outcomes to 2022

1. Livestock communities across 4 priority countries apply tested technologies, management strategies and institutional arrangements that have been developed through system optimization, taking the multiple functions of livestock into account.

Milestones

- Livestock communities across 2 priority countries apply tested technologies, management strategies and institutional arrangements developed through system optimization (2019).

Cluster 5: Enabling policies, markets and institutions

This cluster will build evidence on mechanisms for improved performance and inclusiveness in livestock-related value chains and contribute to a policy environment favourable to their development. Inclusiveness encompasses various dimensions of resource availability, gender, youth and marginalised categories. Research here builds on the existing livestock value chains in the Livestock and Fish CRP and selected locations from the systems CRPs.

Partnering with large development-oriented bilateral projects, it will deliver a cohesive agenda in focus systems and value chains and synthesize robust lessons into IPGs. Specifically, it will design, test and implement innovative institutional arrangements for greater and inclusive smallholder supply of livestock and animal-source food products to markets and increased access to inputs and services, including business models for improving the performance of livestock systems, with emphasis on collective action of different kinds as well as access to markets and services, and for improving innovation capacity. . Working closely with research and development partners, it will start from secured bilateral projects in priority countries and value chains, particularly dairy, small ruminants and pigs in East Africa and Southeast Asia. It will build on methodological frameworks to measure the performance of livestock and animal-source food product value chains along multiple dimensions, including gender, youth and other equity dimensions. To realize development outcomes and potential from animal-source food production systems and value chains, the cluster will work on more effective policy environments that facilitate innovation and growth. Links with the PIM CRP will support methodology development and application as well as cross value chain and site comparison and learning. This cluster will conduct policy analysis in priority countries to guide decision-making on policy options for improved livelihoods and resilience through livestock development.

Main research outputs

- The performance of livestock market systems for products, inputs and services analysed and key barriers identified, value addition and equity issues understood, and entry points identified for improved performance.
- New inclusive and scalable institutional arrangements developed and tested, that address key needs for a) enhanced product market and value chain performance, b) improved delivery of livestock inputs and services, and c) increased resilience for livestock keepers and their communities (such as through IBLI).

- Evidence to inform policies analysed and disseminated, with a view to enhancing livestock contributions to food and nutrition security and livelihoods and addressing the constraints faced by women and young people as well as men.

Outcomes to 2022

1. Development partners, private sector and government agencies across 6 priority countries apply innovative institutional arrangements to enhance competitiveness and inclusiveness.

Milestones

- Development partners, private sector and government agencies in 3 priority countries apply innovative institutional arrangements to enhance competitiveness and inclusiveness (2020)
2. Policy and decision-makers in 4 priority countries use CRP-developed evidence when developing policy options relative to improving the performance of livestock value chains

Milestones

- Policy and decision makers in 2 priority countries use CRP-developed evidence when developing policy options relative to improving the performance of livestock value chains (2020).

2.5.1.7 Partnerships

The flagship will work with a diverse partners to deliver its agenda, building on existing and developing new arrangements. Partners bring expertise in science, development implementation, capacity development, and advocacy and communication and include specialized research groups, universities; development agencies, national and international NGOs; public-sector bodies; private-sector companies and entrepreneurs; farmers groups; and civil society organizations, such as women's groups. Although some links already exist with the private sector (e.g. for the development and marketing of index-based insurance, and with input suppliers in value chains), new relationships with supply companies, processors and the food sector will be important.

Core flagship partners are ILRI, ICARDA and CIAT. ILRI leads the flagship, coordinates work in priority countries and provides scientific coordination for clusters 1, 2, 3 and 5, ICARDA coordinates cluster 4 and work in Ethiopia and CIAT contributes to cluster 5 and coordinates work in Nicaragua. ILRI's skills and knowledge relating to the livestock sector cover foresight and priority setting, policy and value chain analysis, gender and livelihoods and integrated action research for livestock livelihoods. ICARDA brings skills in integrated small ruminant development; CIAT has tropical forage expertise from different regions.

Strategic partners harness scientific comparative advantage at the regional and global levels. These include KIT on gender research building on experiences learned in the Livestock and Fish CRP. For human nutrition, the flagship will work with Emory University's Rollins School of Public Health, analysing relationships between livestock rearing and nutritional status. For targeting and foresight analysis partners include ULB, FAO, CSIRO, and IIASA. The University of Natural Resources and Life Sciences (Austria) working with ICARDA in Ethiopia, brings bio-economic modelling and the design of effective extension service delivery systems. IFPRI, IIASA and ILRI constitute an active, well-established livestock data and analytics community of practice.

At **national and local level**, the flagship will continue to partner national systems and universities such as SUA on dairy business hubs (Tanzania), Makerere University in Uganda on pig value chain upgrading,

University of Nairobi (Kenya) on livestock marking and Centre of Agricultural Policy (Vietnam) on economic modelling. In Ethiopia research is implemented with the Ethiopian Institute of Agricultural Research (EIAR) and the regional agricultural research institutes. In all locations, work with partner universities integrates post-graduate fellows into the research program

Partners for effective innovation systems in program sites are essential to achieve target sub-IDOs. These partners bring adaptive research, fieldwork, testing business models and national scaling skills and include NGOs like Heifer International, TechnoServe, Land O'Lakes. Country and local level partners include producers' organisations working on specific value chains and apex organisations (e.g. the Kenya Dairy Farmers Federation, or government counterparts in Kenya for IBLI roll-out). In Ethiopia, the team and ILRI's LIVES project team are members of the Working Groups on livestock production systems in the highlands and in pastoral areas of the Technical Committee on Livestock.

Globally, partners for effective scaling feature as part of regional and global innovation systems and multi-stakeholder platforms that integrate research results into broader initiatives and influence global policy. These partners include Dairy Asia, the Global Agenda for Sustainable Livestock and the inter-agency donor group on pro-poor livestock research and development.

Because of its systems orientation, this flagship will link with both the agri-food system CRPs and global integrative CRPs. The former focuses on the contribution of livestock to target farming systems of agri-food systems CRPs. Strong links, many mentioned above, will be developed with PIM on foresight and policy generally, as well as value chains, gender and scaling up, and with A4NH on nutrition and on the health benefits or risks of livestock interventions, as well as food safety in livestock value chains. Work with CCAFS will include foresight for climate issues as well as integrated farm-level technologies and strategies related to climate change.

2.5.1.8 Climate change

Working closely with the Livestock and the Environment flagship and with CCAFS, this flagship will carry out the trade-off analyses needed to ensure that its intervention packages are optimal in terms of their contributions to emissions without, as far as possible, having a negative impact on other sub-IDOs. It is here also that proposed combinations of technologies and interventions will be evaluated to assess their suitability for (or capacity to adapt to) anticipated climate change and variability at local levels. Particular attention will be paid to the gender and other social and economic dimensions of adapting to climate change. The flagship will analyze the additional risks that adapting to climate change brings to households, and test possible incentives that could encourage behaviour change.

Climate change will be one of the important factors driving the Livestock sector's future development, so the flagship will continue to include it in its scenarios work, exploring how livestock production systems are likely to change and will need to adapt to changing climates (Thornton and Herrero, 2014; 2015). As an example, it will work with the Livestock and the Environment and Genetics flagships to explore which areas may become more or less suited to different livestock species and breeds. The flagship will work closely with cluster 1 of the Livestock and the Environment flagship when evaluating proposed combinations of technologies and interventions to assess their suitability for (or capacity to adapt to) anticipated changing climates, to ensure tools, data and approaches in trade-off analysis are harmonized.

2.5.1.9 Gender

Gender is embedded into each flagship cluster as well as having a home in cluster 2 (see Annex 3.3). For research priority setting (cluster 1), gender is included the tools, systems analysis and targeting,

building on previous research (van Wijk *et al.*, 2014; Pfeifer *et al.*, 2015). Strategic gender research in this cluster will explore inclusion of gender dynamics at household or community levels for modelling and scaling work. Cluster 2 research builds on strategic research undertaken in the Livestock and Fish CRP on meanings of livestock ownership (Galiè *et al.*, 2015; Waithanji *et al.*, 2015; Galiè and Kantor, 2016) and bridging the gender gap in livestock ownership (Njuki and Sanginga, 2013), among others. It also synthesizes, guides and informs gender research across the CRP.

Cluster 3 explores women's key roles in household food and nutrition security and the nexus of women's empowerment with nutritional status of household members vis-à-vis livestock development (Njuki *et al.*, 2015; Galiè *et al.*, in press). In cluster 4 gendered constraints and opportunities in controlling resources and the potential offered by livestock to enhance the livelihood base of women in particular, will be addressed. Cluster 5 focuses on gender and value chain development (Basu *et al.*, in press) and creating policy frameworks that enhance equitable participation in value chains.

Youth

Work in this flagship will coordinate the research on inclusion of young people in institutional arrangements in systems and value chains. It recognises that young people face specific constraints, in terms of access to land, capital and knowledge. They are also agents of change, given their ability to innovate and use new tools like ICT and mobile technologies, as well as their eagerness to improve their livelihoods. Research will explore delivery of packages of interventions, such as school programs, agri-business enterprise development, and capacity development as well as opportunities for young people remaining in or exiting the sector, especially in the fragile trajectory.

2.5.1.10 Capacity development

Capacity development will build on the strong legacy of the Livestock and Fish CRP. The five clusters will engage in capacity needs assessment and intervention strategies to identify gaps between existing and required competencies of both research and development partners (see Annex 3.2).

In cluster 5, for example, to better focus these efforts, the flagship will assess local and national development partners as part of intervention piloting. Innovative learning materials development and delivery will be carried out in all clusters. Thus cluster 3 has a large component on the design of and delivery of behavioural communication materials to improve diets and nutrition. All clusters will also engage in more traditional capacity development activities, by supporting fellowships and embedding students in research. These efforts will be implemented with universities from the priority countries and partner universities from the North.

Enhancing capacities to innovate will be implemented in four clusters. In clusters 4 and 5, the focus will be on understanding how change comes about in sites where new institutional arrangements will be promoted, by applying monitoring and learning systems that embed research activity in ongoing processes of change. Gender-sensitive approaches in capacity development will be followed in three clusters, including when developing and testing technological and institutional innovations in clusters 4 and 5. Institutional strengthening will take place in at least three clusters, including cluster 5 where multi-stakeholder dialogues are facilitated, and in cluster 1, to develop the capacity of policymakers to use CRP outputs. Finally, at least two clusters will directly develop CRP and Centres' partnering capacities. Cluster 5 will identify the most appropriate partnership models for specific contexts, including public-private partnerships. At least two clusters will also work on organizational development, including cluster 4, which will support delivery mechanisms for rural advisory services at selected sites in priority countries.

2.5.1.11 Intellectual assets and open access management

Robust IA management, open access and research data management and communications help in uptake and achieving outcomes (sections 1.0.12, 1.0.13 and 1.0.14 and annexes 3.8, 3.9, and 3.10.7). Specific issues relevant to this flagship are listed here.

For IA management, this flagship is custodian of much data of different types from different partners and projects. It is also a major generator of assets such as know-how, models, protocols and know-how that are applied in different projects. These are made accessible online and via publications and databases. Due to the local focus of this mainly socio-economic information and data, strong emphasis is on local availability with secondary global audiences.

Most of the information products of the Livestock and Fish flagship are already open access. This include materials accessible through [CGSpace](#). Some journal articles are limited access and the flagship will reserve funds each year to supplement bilateral projects to pay article open access fees. The longer-term strategy is for these to be fully budgeted into bilateral projects. The flagship's tools and models are mostly accessible online, while consistent use of the Open Data Kit for data collection facilitates systematic recording and storage for re-use and access. A significant challenge is to ensure that more qualitative data, from focus groups for example, is documented and reported and to be sure that all the various questionnaires and survey designs are accessible. Projects in the flagship make use of various documentation and communication platforms to support this. The flagship has allocated funds on an annual basis to ensure proper curation and publishing, including inputs to research quality and design.

2.5.1.12 Flagship management

Implementation will be led by a FL, supported by a leader for each cluster (CL). The primary roles of this core team is to develop and update the research agenda and impact pathways, monitor the quality and delivery of knowledge outputs, and report as required. Responsibility for implementation and delivery of research lies with CGIAR-centre or other partner teams. The FL will lead guide priority strategic research and allocation of W1/2 resources as well as any strategic exploration of new research areas; guide development of bilateral projects to ensure alignment to the flagship their ability to contribute to strategic synthesis funded by W1/2; coordinate all reporting; lead cross-flagship initiatives; support and sometimes lead resource mobilisation and lead bi-monthly meetings (face-to-face or virtual). Cluster leaders will have a scientific leadership role, they will also contribute to reporting, together with PIs of aligned projects and Centre focal points. CLs support the FL in developing the flagship strategy, and will guide research design in their clusters and monitor science quality of outputs. They will lead design and science quality of all strategic research supported by W1/2 resources. Since all clusters have integrating roles across the CRP, CL's will lead cross-flagship interactions. Each CL will identify a small group of key scientists across the CRP to develop innovative research design and to review new initiatives.

The flagship will be led by Stephen Staal (ILRI); 20% of his time will be supported by W1/2, with 20% administrative support, and an annual flagship meeting. Cluster leaders will be: Tim Robinson (ILRI) for cluster 1, Alessandra Galie (ILRI) for cluster 2, Paula Dominguez-Salas (ILRI/RVC) for cluster 3, Barbara Rischkowsky (ICARDA) for cluster 4, and Isabelle Baltenweck (ILRI) for cluster 5. Cluster leader contributions will not be specifically resourced beyond their agreed participation in cluster outputs.

2.5.2 Flagship Budget Narrative

2.5.2.1 General Information

CRP Lead Centre's Name: ILRI

Centre Location of Flagship Leader: Kenya

2.5.2.2 Summary

Funding Needed	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2	2,321,058	2,434,517	2,553,649	2,678,737	2,810,079	2,947,989	15,746,031
W3	0	0	0	0	0	0	0
Bilateral	5,813,657	6,104,340	6,409,557	6,730,035	7,066,537	7,419,864	39,543,992
Other Sources	0	0	0	0	0	0	0
	8,134,715	8,538,857	8,963,206	9,408,772	9,876,616	10,367,853	55,290,019

Funding Secured	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2 (Assumed Secured)	2,321,059	2,434,517	2,553,649	2,678,737	2,810,080	2,947,990	15,746,032
W3	0	0	0	0	0	0	0
Bilateral	5,813,659	4,545,332	1,649,998	125,000	0	0	12,133,989
Other Sources	0	0	0	0	0	0	0
	8,134,718	6,979,849	4,203,647	2,803,737	2,810,080	2,947,990	27,880,021

Funding Gap	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
W1+W2 (Required from SO)	0	0	0	0	0	0	0
W3 (Required from FC Members)	0	0	0	0	0	0	0
Bilateral (Fundraising)	1	-1,559,008	-4,759,559	-6,605,035	-7,066,537	-7,419,864	-27,410,003
Other Sources (Fundraising)	0	0	0	0	0	0	0
	1	-1,559,008	-4,759,559	-6,605,035	-7,066,537	-7,419,864	-27,410,003

Total Flagship budget by Natural Classifications (USD)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
Personnel	3,025,407	3,176,677	3,335,511	3,502,286	3,677,401	3,861,271	20,578,555
Travel	427,807	449,197	471,657	495,240	520,002	546,002	2,909,909
Capital Equipment	0	0	0	0	0	0	0
Other Supplies and Services	1,786,827	1,876,168	1,969,976	2,068,475	2,171,899	2,280,494	12,153,841
CGIAR collaborations	0	0	0	0	0	0	0
Non CGIAR Collaborations	1,837,381	1,927,000	2,021,100	2,119,905	2,223,650	2,332,582	12,461,619
Indirect Cost	1,057,293	1,109,814	1,164,960	1,222,864	1,283,663	1,347,502	7,186,098
	8,134,715	8,538,856	8,963,204	9,408,770	9,876,615	10,367,851	55,290,011

Total Flagship budget by participating partners (signed PPAs) (USD)

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Total
ILRI	6,979,412	7,328,382	7,694,801	8,079,541	8,483,519	8,907,694	47,473,352
CIAT	189,599	199,079	209,033	219,484	230,459	241,982	1,289,637
ICARDA	965,704	1,011,395	1,059,371	1,109,745	1,162,639	1,218,176	6,527,033
	8,134,715	8,538,856	8,963,205	9,408,770	9,876,616	10,367,852	55,290,014

The 6 year total budget is 55,290,000, with W1/W2 funds representing 28%, and secured W3 and bilateral funds representing 72% in 2017.

The most significant cost driver is Personnel costs at 36% of the total budget. To realize its 7 outcomes, a total of 311 FTEs are required over the 6 year life of the program or an average of 34 FTE per year. These include research support staff (research technicians, analysts and field research support staff); administrative support staff (program management officers, communications support, accountants, and administrative assistants) and research scientists (flagship and cluster leaders, principle investigators, and other scientists) with 69% being international staff and the balance national staff in 6-8 locations. This number also includes at least 6 new hires to build needed capacity in the areas of human nutrition, policy, gender and research support. New hires will however increase as additional bilateral/W3 projects are added to the program.

In general terms and in descending order of budget proportion, approximately equal proportions of the budget are mapped to Outcome 1 'increased livelihood opportunities' (26%) and Outcome 2 on 'reduced market barriers' (24%) . Outcome 7 on 'conducive agricultural policy environment' will be targeted using 18% of the overall budget while almost 10% of the budget is mapped to each of Outcome 6 on 'Increased household capacity to cope with shocks' and Outcome 5 on 'increased access to nutrient rich foods' while about 7% is mapped to the both Outcomes 3 and 4 on gender-equitable control of productive assets and resources' and 'improved capacity of women and youth to participate in decision-making' respectively.

Across the 7 outcomes, almost 30% of the FTE (66 IRS FTE and 25 NRS FTE) will contribute to Outcome 1 'increased livelihood opportunities' while 20% (32 IRS FTE and 29 NRS FTE) will be directly working on Outcome 2 'reduced market barriers'. Approximately the same number of FTEs will contribute to the other sub IDOs: 14% combined for Outcome 3 'gender-equitable control of productive assets and resources' and 'improved capacity of women and youth to participate in decision-making' (Outcome 4); 10% for 'increased access to nutrient rich foods' (Outcome 5) and 15% each for 'Increased household capacity to cope with shocks' and 'Conducive agricultural policy environment' (Outcomes 6 and 7 respectively). In terms of FTE, these figures demonstrate a strong focus on livelihoods (Outcome 1), with the other components being relatively well balanced.

The second most important cost driver relates to non-CGIAR collaborators which represent 23% of the total budget with 88% of this funding from bilateral projects. As described in the narrative, a diverse range of strong partners will be needed to deliver the desired outputs and outcomes. The flagship will further develop many of the partnerships already established; it will initiative new ones ranging from research organizations to development agencies and actors in the targeted livestock value chains and systems and it will involve specific strategic partners to harness scientific comparative advantage at the regional and global levels. An essential element of the Theory of Change are the partners for effective innovation systems in program sites. These partners are especially important for adaptive research, fieldwork and national scaling. Partners in this category include NGOs, Producers' Organizations, local and national governments agencies. At a global level, the Flagship will work with partners for effective scaling as part of regional and global innovation systems and multi-stakeholder platforms, to ensure that the flagship research and its results are integrated into broader initiatives and influencing global policy.

The third most important cost driver is other supplies and services which represents 22% of the 6 year total budget and includes costs associated with fieldwork, the use of consultants and employment-related charges. Seventy percent of the supplies and services budget is supported by W1/W2 funding. The fourth most important cost driver is overheads at 13% with travel costs contributing only 6% of the total budget.

Management of the Flagship is budgeted at 20% of the Flagship Leader's time and smaller amounts are provided for other management staff such as a Program Management Officer, Program Accountant and Administrative support staff. Also included here are the costs of an annual Flagship planning meeting and Theory of Change reflection workshop at \$50,000 annually. The management costs are pro-rated across the outcomes.

2.5.2.3 Additional explanations for certain accounting

For the CGIAR partners, personnel costs are defined as the total remuneration costs of an individual: base salary, fringe benefits and other employment costs. Actual computations on average for fringe benefits and employment costs in relation to base salary would translate to an average multiplier of 97% and 68% for international and national staff respectively. The reason for the high multiplier for international staff is because of the housing allowance, security and education allowance that are not provided to nationally recruited staff. Fringe benefits include: pension, housing allowances, education allowance, security, health insurance, other insurances, catastrophe fund, annual leave and severance pay. Other employment related costs include staff training and development; transportation, recruitment, appointment and repatriation allowances and payroll administration fees.

The cost structure of research undertaken during the first phase CRPs has been applied to estimate average research costs for collaborators, consumables, other supplies and services, and travel. The actual cost structure for secured W3 and bilateral projects is first applied, and the average research cost factors are then applied to the remaining portions of the budget that are yet to be secured.

2.5.2.4 Other Sources of Funding for this Project

The program is funded by a mix of W1/2 and W3/bilateral funding. Funding from other sources and significant in-kind contributions from program partners or other collaborators are not anticipated. The action research and development-oriented nature of the outputs of this flagship, however, mean that W3/bilateral sources of funding will be significant due to demonstrated demand from investors for this type of work. Funding from W3 and bilateral sources is fully secured for Year 1 under the Base Budget scenario.

Recognizing the high degree of uncertainty with W1/2 funding, both in terms of whether the indicative allocation assigned to the CRP in the CRP2 guidance document will be maintained once the CRP portfolio has been approved, and in terms of whether the projected budget assigned to the CRP in the System Financial Plan each year is actually achieved through donor W1/2 commitments, the program will be prepared to reduce the scope of its activities and outcomes to reflect any W1/2 funding shortfalls. Within this flagship, the W1/2 funded activity specifically on cross-site strategic synthesis analysis related to the work on 'optimizing livestock systems for productivity and resilience', as well as on 'enabling policy, markets and institutions' will be reduced or postponed if there is a shortfall, with the work continuing using W3 and bilateral projects, focusing on achieving specific development outcomes in certain locations, in accordance with donors priorities. Research on gender-

transformative approaches and on livestock-mediated improved nutrition, will be protected to the extent possible given the importance of these areas of research for the CRP as a whole.

The program is giving high priority to mobilizing bilateral funding to improve its ability to implement the full program and achieve the outcomes. This is required to:

- Generate replacement funding for current bilateral funded projects as they end and follow-up or initiate new research activities in later years; and
- Offset the uncertainty associated with W1/2 funding
- Contribute to a possible Uplift scenario if and when investor conditions improve

In the event of a potential increase in the resources available either through W1/2 or W3/bilateral funding, this is the planned Uplift scenario:

- Expansion of target countries to include India, Burkina Faso and to provide greater scope and effort of research in Vietnam.

The areas of research in which effort would be increased would be:

Systems analysis and policy: A new strategic initiative on analyzing and highlighting the role of livestock in rural livelihoods and well being across Asia and Sub-Saharan Africa. This would include modeling projections under alternative investment and growth scenarios, and identifying changes in multiple well being metrics. This would be accompanied by high level partnership development for advocacy to facilitate multi-country decision-maker awareness and action.

Gender and youth: Expansion of action research in gender-transformative approaches to a larger number of comparative sites, working closely with the technology flagships to more strategically understand technology-gender interactions. Avenues for using social media towards behavioral change to support GTAs will be explored. Research on opportunities for youth in livestock value chain enterprises will be increased, particularly in rapidly growing markets such as in Vietnam.

Improved nutrition: New initiatives will include examining alternative animal-source food product technology interventions that could aid in increased consumption among target populations, and also specifically addressing policy options that could contribute to the same outcome. Avenues for using social media towards behavioral change will be explored. Additional livestock systems and value chains that would be added would include small ruminants and poultry. New modeling approaches will also be developed that are better able to evaluate nutritional outcomes from livestock interventions.

Clusters 4 and 5: Large scale research for development projects in this clusters would be expanded and accelerated, building on existing planned methods and approaches, to reach wider outcomes and impacts.

Livestock CRP: Full Proposal 2017-2022

Project focus	Total amount (\$)	Start Year
Links between milk production and child nutrition in Kenya and Tanzania (cluster 2)	250,000	2017
Leveraging indigenous pig production systems for improved rural livelihoods, genetic conservation, and improved nutrition in Vietnam and Philippines (cluster 4)	3 M	2018
Improved livelihoods through sustainable intensification and diversification of market oriented crop-livestock systems in southern Malawi	800,000	2017
Climate-smart smallholder pig value chains in Uganda - Integrated mitigation and adaptation strategies for improved livelihoods, food security and environmental sustainability	6,7 M	2017
Improving the livelihoods of agro-pastoral communities under threat of climate change in the Near East & North Africa Region (Algeria, Morocco, Sudan and Tunisia)	3,5 M	2017
Tapping camel genetic resources to build resilience and improve livelihoods of pastoralists in the Horn of Africa and North Africa regions	1,5 M	2017
India small ruminants value chain development	1 M	2018
Vietnam pig value chain	1 M	2018
Burkina small ruminants value chain development	1 M	2018
TOTAL FUNDING GAP	18,75 M	

2.5.2.5 Budgeted Costs for certain Key Activities

	Estimate annual average cost (USD)	Please describe main key activities for the applicable categories below, as described in the guidance for full proposal
Gender	680,290	Integration of gender concerns into the work of the Livestock Livelihoods flagship is achieved by having gender scientists working both on strategic and integrated gender research, as explained in the narrative and the gender annex. The objective is to have a gender scientist and/or research staff in all the 6 priority countries; in addition, about half of the non-gender research staff will also produce gender outputs, by designing and implementing research tools that are sex-disaggregated and conducting analysis on the same. In some cases, the research will be collected for both women and men, therefore increasing data reliability and its relevance to gender research. In particular, gender will be integrated in the work on human nutrition; indeed, the nutrition cluster recognizes women's key roles in household food and nutrition security and explores the nexus women's empowerment - nutritional status of household members vis-à-vis livestock development. Gender analysis is also strong in the work on policy, markets and institutions, drawing from a growing literature and evidence on gender and value chain development and focusing on creating policy frameworks that enhance an equitable participation in the value chain. Gender is a key topic on LLAFS since this flagship systematizes, guides and informs the gender-integrated research undertaken across the CRP Livestock as well as sets the agenda for strategic gender research related to livestock.
Youth (only for those who have relevant set of activities in this area)	150,000	Pending decisions regarding the direction of work related to youth, a budget of approximately \$150,000 will be set aside annually. The budget is used largely to finance the staff time of researchers working at the intersection between gender and age, as well as new initiatives aiming at supporting the inclusion of youths in livestock value chains and systems through the identification, testing and evaluation of specific interventions, as described in the narrative. Working with the other flagship and possibly using resources from the CRP's Strategic Investment Fund, the first step is to design and disseminate a Youth strategy, thereafter providing the Flagship with sufficient evidence to raise additional resources funds for this important cross cutting theme. Indeed, the livestock sector could potentially provide important employment opportunities to the youth, not only at production level but also at other points along the value chain. This Flagship will coordinate research on inclusion of youth in institutional arrangements for the delivery of packages of interventions as well as post-harvest interventions.
Capacity development	687,119	The budget comprises capacity development specialists staff time as well as staff time funds allocated to non-capacity development researchers who design and implement capacity development activities as part of the work, including on capacity needs assessment and intervention strategy in order to identify the gap between existing and required competencies of both research and development partners, in particular in relation to institutional innovations. This flagship has relatively large bilateral projects with a strong development orientation, including the capacity strengthening of livestock keepers and other value chain actors.

	Estimate annual average cost (USD)	Please describe main key activities for the applicable categories below, as described in the guidance for full proposal
Impact assessment	0	Funds for Impact Assessment are held in the CRP's Strategic Investment Fund . This flagship had dedicated approximately 1 FTE/ year (funded by W1/W2), to be able to plan, design, manage and report CRP-wide impact assessment studies, with the other costs (e.g. field costs) being covered either by bilateral or by the Strategic Investment Fund.
Intellectual asset management	2,721	A small budget has been set aside for ad hoc IP advice and support for contract development. This will be supported by in-kind investments of the partners and support from management level.
Open access and data management	84,344	The budget is allocated to covering costs of open access. Since some journal articles are limited access and the flagship will reserve funds each year to supplement bilateral projects to pay article open access fees. The flagship has allocated funds on an annual basis to ensure proper curation and publishing, including inputs to research quality and design. Bilateral projects in this flagship are expected to budget for these activities. To ensure flagship research information and data is globally accessible and taken up, this flagship will invest from its annually from its W1/W2 budgets to these activities.
Communication	27,208	The budget covers staff time as well as as direct costs to ensure effective communication of its results. Bilateral projects in this flagship are expected to budget for these activities.

2.5.2.6 Other

not applicable

2.5.3 Flagship Uplift Budget

2022 additional outcome description	Amount needed (\$)	W1 + W2 (%)	W3 (%)	Bilateral (%)	Other (%)
Gender equity relative to their level of effort (i.e. labour) at household level in the use of, and control of income generated by, livestock related productive assets and resources, impacting 800,000 women across 6 countries.	5,132,400	0	0	100	0
Improved capacity of 2.4 million women and young people to participate in livestock related decision-making in 6 countries.	5,132,400	0	0	100	0
8 million poor people (men and women), in 6 countries, with increase in access to more affordable, safe and nutrient rich animal-source foods.	8,798,400	0	0	100	0
Innovative institutional options that improve resilience tested and adopted by national and international research & development partners, increasing the resilience of 1 million rural livestock-keeping households (5 million individuals) in 5 countries.	5,132,400	0	0	100	0
15% Increase, on average in total household income from livestock-related activities, including 25% increase, on average, in proportion controlled by women, for 1.2 million households (& 6 million individuals) in 9 countries.	4,765,800	0	0	100	0
1.1 million livestock keeping households (representing 5.5 million individuals, including women) increase their supply of livestock to the market by 15%, on average, in 7 countries.	4,032,600	0	0	100	0
Laws, rules and regulations within and across 6 countries at local, country and regional level explicitly include pro-poor livestock mediated development, reaching 6million livestock keepers & other value-chain actors.	3,666,000	0	0	100	0