Recipes for Change validation report: Rwandan bananas with beans and split green peas

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Summary statement for selected ingredient beans

The main climate risks to beans cultivation in Rwanda are: (i) extreme precipitation levels, primarily in the northern and western regions (Ruhengeri, Gisenyi, Gikongoro and Byumba) where abundant rainfall can cause erosion, flooding and landslides, (ii) Biotic stresses, primarily plant diseases and pests and (iii) post-harvest losses resulting from increasingly favourable environments for damaging micro-organisms and insects.

The main adaptation measures for managing the expected impacts of climate change on bean cultivation include: (i) continued development and adoption of both climate resilient and higher-nutrition bean varieties, (ii) integration of flood and land management practices at the catchment and farm-scale and (iii) improved provision of drying, threshing and storage facilities.

CCAFS validates the climate threats and solutions highlighted in the IFAD statements below (which refer to maize as well as beans). CCAFS also identifies drought stress as a possible climatic hazard to bean cultivation.

One caveat is that CCAFS research, using modelling approaches shown in Figure 2, indicates that average growing conditions, including average precipitation levels, are conducive to the continued and, in some areas, improved viability of bean cultivation.

This does not preclude, however, the possibility of continued or increased variability in precipitation and elevated evapotranspiration combining to enhance the prevalence or severity of droughts during some seasons in future years. But it remains unclear if such an effect would prevail in the situation of generally increasing annual average levels of rainfall. Comparably, if the impact of temperature extremes remains moderate and the risks of biotic stresses can be mitigated, the analysis from climatic niche modeling suggests the continued viability of bean growth in a changing climate.

Less can be said from the scientific point of view about post-harvest risks and solutions in the harvesting, storage and transport of beans, since little research has been done on these issues. However, any reductions of post-harvest losses will have both adaptation and mitigation benefits.

IFAD-identified climate threats to maize and beans:

- In Sub-Saharan Africa maize is predominantly grown in smallholder farming systems under rainfed conditions with limited inputs. Low yields in this region are largely associated with drought stress, low soil fertility, weeds, pests, diseases, low input availability, low input use and inappropriate seeds. Reliance on rainfall increases the vulnerability of growing beans and other staples to climate variability and change. While farmers have a long record of adapting to the impacts of climate variability, current and future climate change represents a greater challenge because the probable impacts are out of the range of farmers’ previous experiences. Climate change will therefore severely test farmers’ resourcefulness and adaptation capacity.

- Precipitation projections in the eastern region suggest changes in rainfall patterns could cause disruptions to the two cropping seasons which characterize Rwanda’s rainfed system.

- In the eastern region, the decline and uneven distribution of rains in September negatively impacted on the germination stage of crops which led to a re-planting of those crops in some areas, mostly in the southeastern region (Bugesera and Kayonza districts). Climate model scenarios suggest that the eastern region will experience greater risk of drought stress in the future.

ASAP solutions:

- Promote crop varieties with crop maturities periods better suited to the changing growing season lengths.
• Facilitate greater collaboration between MINAGRI and National Meteorological Services to support the development of climate information services that provide relevant and timely information to project beneficiaries to mitigate the impacts of climate variability on planting, harvesting and drying.

• Support a detailed survey of existing post-harvest storage structures and MCCs to develop appropriate guidance/building codes that will ensure that current and future infrastructure investments are climate-smart and include appropriate measures to manage excess rainwater.

• HUB business investments in improved climate resilient and low carbon post-harvesting procedures, drying, processing and value addition, storage, logistics and distribution to achieve reductions in product losses and increase smallholder and rural labourer incomes.

• Invest in small scale shelling, threshing, drying, etc. of maize to improve efficiency and value added industries.

Climate risks and responses to bean production in Rwanda

It has been estimated that the common bean (Phaseolus vulgaris) forms part of the diet of over 100 million people in rural and poor urban communities across the African continent (ISAR, 2011). Annual per capita bean consumption in East Africa is the highest in the world (50-60 kg), and is cultivated almost ubiquitously by small holders in Rwanda (Asare-Marfo et al., 2011). Several aspects of bean cultivation contribute to the food security of smallholder farmers in Rwanda. First, beans are rich in protein. They far outweigh meat as a primary protein source in a typical Rwandese diet and are also a source of micronutrients such as iron, vitamins A and B complex and zinc. These are all important supplements considering the deficiencies characteristic of the starch-based diets of the poor (Larochelle & Alwang, 2014). Secondly, bean cultivation is flexible and relatively straightforward. Beans can easily be intercropped, mature quickly in either of two annual growing seasons and can be consumed at various stages of plant development, as leaves, green pods, fresh grain, as well as dry grains. Furthermore, selling surpluses can provide a steady source of income, the value of which can be enhanced further by sorting and grading produce.

In Rwanda, surpluses are now becoming more common largely due to the increased use of climbing varieties. These varieties have seen average yields increase by 40 percent over the last decade with minimal expansion of cultivated land. This has aided a transition in Rwanda from net importer, to self-sufficiency, and now exporter (USAID, 2013). Improved climbing bean varieties were first introduced in Rwanda in the mid-1980s and adoption among farmers reached around 50% just ten years later (Musoni et al., 2001). However, a damaging outbreak of root disease destroyed most of the crop by the late 1990, resulting in many farmers abandoning climbing varieties (Asare-Marfo et al., 2011). Subsequent regional breeding programmes sought to develop disease-resistant varieties. Successful collaboration between the government funded research program at Rwanda Agriculture Bureau (RAB), formally Institut des Sciences Agronomiques du Rwanda (ISAR), international partners such as International Center for Tropical Agriculture (CIAT) and HarvestPlus, has resulted in the release of nearly 100 bean varieties over the last four decades (Larochelle & Alwang, 2014). Adoption is currently highest in the northern and western regions where climbing varieties account for over 80% of production (USAID, 2013). Adoption is lower in southern and eastern regions and production volumes derived from these varieties are 50 and 10 percent, respectively (ibid.). An added benefit of these climbing varieties is their high biomass content and nitrogen fixing properties, both of which can enhance soil fertility. Overall, the virtues of this versatile crop, in terms of food security, diet, and environmental sustainability are manifest.

Agriculture makes up over a third of GDP in Rwanda and the vast majority of the population is engaged with agricultural production. To see a continuation of the trend in per capita income levels, which have roughly doubled in the past decade, targeted development of this sector will be necessary. This has been highlighted by the Government of Rwanda in its key poverty reduction objectives (REMA, 2009). Growing domestic consumption and export opportunities with neighbouring countries have been identified as key avenues for growth and underscore the importance of continued intensification of bean production (USAID, 2013). Achieving this growth would require the
development of efficient trading networks that minimize the transaction costs between producers and consumers, which in turn stimulate the regular production of larger marketable volumes of beans of a consistent quality. This outcome is dependent on infrastructural, institutional and informational improvement. However, in addition to these components of agricultural development, increased production is also contingent of the successful navigation of risks posed by climatic hazards. The negative impacts of these hazards can be both acute and chronic, and some may pose an increasing threat under ongoing climate change. This short report shall inspect each of the major climate hazards before concluding with options for the management of risks and adaptation to expected impacts.

**Climate risks to beans**

Despite being situated in a tropical zone, Rwanda’s high elevation results in generally temperate climatic conditions. Temperatures average 20°C but vary according to topography. Rainfall is concentrated within two main seasons and is driven primarily by the migration of the Inter Tropical Convergence Zone (ITCZ), a belt of low pressure and rainfall which straddles the equator. Along with the ITCZ, several additional synoptic systems determine the sources of moisture in the country. The interaction of these systems results in considerable variability, and constitutes the main source of climatic hazards within the country. Historically, these have impacted significantly upon livelihoods and agricultural production. The eastern, southern and central lowlands have experienced frequent droughts, while the wet western and northwestern highlands have been stressed by landslides, landslips and floods. Both trends have resulted in failure and destruction of crops and infrastructure (Bart, 1993; MINITERE, 2006; MINERENA, 2010 and David et al., 2011).

Historic records of precipitation in eastern Africa show a high degree of temporal and spatial variability, but the prominent trend is one of moderate decline in annual averages (Funk et al., 2008; Williams and Funk, 2011). However, projected changes in precipitation under climate change are likely increases in mean annual precipitation over areas of central and eastern Africa beginning in the mid-21st century for strong warming scenarios (Niang et al., 2013). Regional scale atmospheric processes and local effects complicate the simulation of rainfall on smaller scales. However, downscaled analyses relevant to the national and sub-national scale indicate a pattern for Rwanda that is similar to wider trends. These trends are shown in the bottom panel of Figure 1 below. Extreme precipitation events over eastern Africa such as droughts and heavy rainfall have become more frequent during the last 30 to 60 years, but it remains unclear whether these changes are due to anthropogenic influences or multi-decadal natural variability (Niang et al., 2013). Continued or increased variability in precipitation coupled with elevated evapotranspiration may enhance the prevalence or severity of droughts during some seasons in future years. It also remains unclear if such an effect would prevail under generally increasing annual average levels of rainfall (Seneviratne et al., 2012). On the other end of extremes, the number of heavy precipitation events has increased in frequency since mid-century. There is high confidence in the literature that this trend will to continue in future years (Seneviratne et al., 2012; Vizy and Cook, 2012).
Variability in rainfall, along with extremes, can have adverse environmental impacts on agricultural productivity. Growing seasons are particularly sensitive to water input. A shortening of seasonal rains reduces crop productivity, particularly if water is lacking towards the end of a growth-cycle when water demand is higher (Thornton et al., 2011). Increased rainfall variability also reduces farmers’ capacity for forward-planning, especially in the absence of early rains which often provide traditional indicators for planting. This was the case during the 2008A and 2008B harvests, where droughts destroyed newly-planted seeds and in some instances delayed planting so that crops became vulnerable to dry spells late in the season in ways which affected overall productivity (MINAGRI, 2009). Too much rainfall in too short a period can be equally damaging to agricultural production and, moreover, to livelihoods in general. Heavy rainstorms and flash floods are more prevalent in the west of the country, where the steep relief of the land can result in extensive crop damage and high levels of soil erosion (REMA, 2009).

However, despite the inherent vulnerabilities of rainfed crop production, exposure to high intra- and inter-seasonal climate variability, extreme events and the low adaptive capacity among smallholders in the region, climate change impacts on agriculture may not be exclusively negative for Rwanda itself. Average levels of rainfall, mean monthly temperatures and the onset of the growing season are all expected to change in a manner conducive to bean growth. The spatial pattern of such a change is signified by the difference between figures 2 and 3 below. The area suitable for bean growth is expected to expand slightly under a medium to high warming scenario (RCP 6.0). Areas in the west, corresponding to the high elevation of the Albertine Rift Mountains, show the majority of the increase, a consequence likely due to the steep temperature gradient in these high elevations (Thornton et al., 2009). This analysis indicates that should other climatic hazards be effectively mitigated, continued production of beans is viable under climate change.
Figure 2: Current climatic suitability of bean production in Rwanda

Figure 3: Future climatic suitability of bean production in Rwanda by the 2050s (RCP 6.0 GCM ensemble)
Observations of average temperatures within the region have shown a considerable rise in recent decades (Anyah and Qiu, 2012). Warming projections under medium scenarios indicate that increases in eastern Africa, much like the majority of the rest of the continent, will exceed 2°C by the last two decades of this century relative to present average values (ibid). The spatial pattern of expected temperature change is shown in the first panel of Figure 1 above. Primary and secondary impacts upon agriculture can be expected from such warming. Beans are generally sensitive to high temperatures (Porch & Jahn, 2001). Temperatures in excess of 20°C during the night can reduce pollen fertility and pollination and elevated day temperatures can inhibit growth (Yadav et al., 2011). Regions where beans are currently grown at the margins of their optimum temperature could suffer under higher temperatures. The influence of higher temperatures on plant chemistry is known to reduce the nitrogen fixing capabilities of bean crops. However, few such regions exist in Rwanda.

The most considerable temperature-dependent stress is biotic, i.e. fungal, bacterial, and viral diseases, as well as insect pests. High temperatures may promote plant pest and disease multiplication as well as increased transmission of human diseases, particularly malaria in East African highland regions. Additionally, warming can lead to range expansion of crop pests, again of particular concern to cold-limited areas such as the highland regions of eastern Africa. Most damaging would be temperature increases paired with greater levels of rainfall and moisture availability. Problems with fungal and foliar pathogens, such as angular leaf spot, blight and anthracnose will be intensified under such conditions (Beebe et al., 2011).

Adaptation to climate risks

Several options show promise for managing the main impacts of climate change to bean cultivation across Rwanda. Primarily these include the development and use of more resilient cultivars, improved cropping practices and integration of water resource management.

Improved varieties, achieved through either plant breeding techniques or genetic modification, can improve plant tolerance under environmental stressors. Work on the development of disease resistant bean varieties is well advanced, however, further breeding for resistance to soil-borne pathogens is required (Beebe et al., 2012). Breeding programmes can also address fertilizer use efficiency. Increases in either nutrient acquisition efficiency or nutrient use efficiency can both contribute to increased yields. Furthermore, the potential for a multiplier effect when these varieties are used in combination with added fertilizer inputs could substantially increase yield. Cultivar development should also factor in the potential for improving nutritional outcomes. Biofortification, whereby a micronutrient-rich trait is combined with high-yielding, resistant varieties, has already proven successful in Rwanda. At the end of 2013, a total of 714,000 farm households in Rwanda had been reached with iron-fortified bean seeds. The CIAT-led programme, HarvestPlus, plans to expand this to virtually all bean-growing farm households by 2016 (some 1.2 million households) and achieve a market share of above 50 percent by 2018, thus enabling accessible to non-producing households in urban and rural areas (IFPRI, 2014). Collaboration between national and international research institutes has resulted in the release of 46 improved bean varieties between 1998 and 2010. However, little is known about adoption rates and welfare impacts of these new varieties. Future research efforts could help establish if and where accelerated adoption is required (Larochelle & Alwang, 2014).

Management of risks posed by the hydrological cycle must primarily be addressed at the catchment level. An integrated approach to watershed management can reduce risks from flash floods and soil erosion using a range of measures including cross-sector issues such as forest management in the upper watershed. Coupled with sustainable land management practices, rainfall infiltration can be maximized and surface run-off minimized to reduce erosion and flooding risks (Bradford & Hogarth, 2011). At the farm scale, improved soil management, such as reducing tillage and increasing organic and inorganic fertilizers, will be key. As beans struggle in heavy or compacted soil, these practices can help maintain and improve soil structure, thus offering dual benefits of increased water retention capacity and improved soil fertility.

Progressing up the value chain, interventions are required both to facilitate the regular production and delivery of larger marketable volumes of beans of a consistent quality, and to manage the climate risks in post-production processes. Post-harvest losses are already a problem in the agricultural sector. Specific to post-harvest bean losses in
Rwanda, current on-farm storage losses are estimated at 2.9 percent, yet with improved facilities (ventilation, dry, fumigation, etc.) and handling techniques, it may be possible to reduce this figure to 1 percent (IFAD, 2013). Estimates of full value chain losses are not found within the literature, but the World Bank has estimated averages losses for crops between 10 and 20 percent across Sub-Saharan Africa (World Bank, 2011). Storage is the key stage at which climate related impacts are most relevant. Quantitative losses are caused mainly by weevil and other insect infestations. Qualitative losses, whereby beans become too hard to consume, result from poor humidity and temperature control in storage. Higher humidity conditions at the time of harvest are favorable for development of micro-organisms (particularly molds) and insects (particularly bruchid beetles). Improved provision of drying, threshing and storage facilities is therefore vital for limiting the negative effects of this issue both at present and increasingly in the future.

**GHG emissions and mitigation**

The agriculture sector contributes 40% of Rwanda’s total GHG emissions. Figure 4 below displays the various sources of these emissions. The ambition to raise bean production could increase GHG emissions through more intensive practices, primarily through greater use of nitrogen-based fertilizers, which are GHG-intensive to produce. Disruption of established soils is likely to be limited as beans are already so widely cultivated and further expansion onto new lands is unlikely. However, improving carbon storage in already cultivated soils could be achieved through nutrient management (primarily focused on the timing of fertilizer application, to improve nitrogen use efficiency) and low impact farming measures (reduced tillage) (REMA, 2009). The demand side is also worth considering with regard to mitigation, as the most energy demanding process in the whole market chain is probably cooking itself. Varieties with shorter cooking times could be beneficial in terms of lower energy and greater convenience for the consumer (Beebe et al., 2012).

**Figure 4:** Sources of GHG emission in Rwandan agricultural sector (Byamukama et al., 2011)
References


