Diversification for Climate Change Resilience

Participatory assessment of opportunities for diversifying agroecosystems

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Foreword

Climate change is dramatically disrupting agricultural production. Extreme temperatures, recurrent drought, and violent storms are causing major crop losses; incidence of weeds, pests, and fungi attacks are worsening; and pollinators and soil biota that support food production are being negatively affected. In such a bleak scenario, agrobiodiversity stands out as one of the most strategic allies in fighting climate change and is a central element in climate-smart agricultural practices, now widely promoted.

Early maturing crops help farmers to adapt to changes and cope with drought, while the use of intra- and inter-specific diversity in intercropping and crop rotations helps reduce pest and disease incidence, improve soil structure, fertility, and pollination processes. Trees and cover crops help improve soil moisture and increase survival of seedlings in areas suffering temporary drought. Bringing landraces and neglected and underutilized species (like fonio, millets, or Bambara groundnut) back to cultivation is helping farmers manage hotter and drier seasons and secure harvests vital for feeding their families, while broadening their income options.

Supporting farmers in developing crop diversification strategies has long been a central preoccupation in Bioversity International's mission. Owing to the upsurge of climate change impacts in people's lives, attention for approaches, methods, and tools to help communities has never been greater. This publication was developed to support identification of ways to enhance agrobiodiversity for greater resilience, through a participatory approach. It provides examples as emerged through a number of case studies around the world.

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About this guidebook

This guidebook presents an assessment method to identify opportunities for diversifying agroecosystems to strengthen climate change resilience. The assessment draws on participatory research approaches to describe local agrobiodiversity and support its conservation and revival. The assessment can be conducted with large or small groups of farmers to understand the effects of climate change, assess local diversity and management practices, and explore diversification options. Opportunities for diversification are identified based on an analysis of gaps in the farm portfolio and recognition of species, varieties, breeds, landscape features, and management practices that support resilience. The assessment is simple by design to be accessible to farmers and "non-experts", who can adapt and apply the method independently or with supporting NGOs, extension agents, or development actors.

In this guidebook, the diversification assessment method is presented along with results and reflections from the pilot sites. The assessment was piloted in 2017 with communities in Guatemala, India, and Mali. Examples from the pilot sites presented throughout the guidebook illustrate how each step is conducted in practice and the type of information and conclusions that can be drawn from the results. We hope that this guidebook will support community efforts to diversify their fields, farms, and landscapes for improved resilience.

The guidebook opens with an introduction that presents the concept of diversification, the overall framework for the assessment, and information about the pilot sites. The subsequent four sections are dedicated to the four steps of the diversification assessment. Each step is described and supported by a review of relevant literature and examples from the pilot sites. The final section presents concluding remarks and recommendations for actions to support diversification based on results from the pilot sites. A facilitator's guide for conducting the assessment in a community workshop is provided in the Annex. The facilitator's guide summarizes the different steps and provides practical tips for organizing and implementing the workshop.

Introduction

Diversification for climate change resilience

A resilient agroecosystem should be able to survive, recover from, and even thrive in the face of climate stresses.[1] Cultivation of multiple crop varieties and species, and mixed crop–animal production, have long been strategies used by farmers to increase productivity and reduce risk from biotic and abiotic stresses (e.g. pest and diseases, drought).[2-4] With accelerating climate change and ecosystem degradation, there is a growing need to encourage and facilitate diversification through agroecological methods that build on local experiences and knowledge.[3,5]

Diversification of agroecosystems is recognized as a key strategy to strengthen resilience and adapt to climate change and variability.[6-8] Agroecosystems are more resilient when they have high genetic diversity in different types of cropping or crop-animal systems that are embedded in a landscape mosaic.[3,9–11] Diversification offers opportunities to optimize yields and ecosystem services[12] and can provide greater income, food, and nutrition security in the face of climate change.[13–19] A number of recent studies have described the importance of diversity in production systems for yield stability, livelihoods, and nutrition.[16,17,20–24]

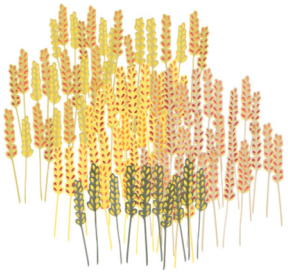
There is no universal solution for diversification to support climate change resilience. Diversification strategies depend on the local environment, agrobiodiversity, social and economic factors, and the specific needs and priorities of communities.[25-28] Despite calls to diversify agroecosystems,[6-8] more support and guidance are needed to develop targeted, locally-specific solutions. Research and development initiatives that aim to support climate change adaptation often focus on one species or one trait, such as early-maturing varieties or drought tolerance. The method presented in this guidebook takes a more holistic approach to understand opportunities for diversification at different levels of the agroecosystem. The aim is to increase complementarity of traits in crop and livestock portfolios, encourage integrated practices, and promote ecosystem protection and restoration.

Women harvesting little millet in Mandla, India
Credit: E.D.I.O. King / M.S. Swaminathan Research Foundation

A participatory approach to assess diversification options

Participatory research approaches create a collaborative space for communities to discuss and identify locally-tailored action plans. Drawing from existing participatory methodologies and a wide range of experiences with community-based agrobiodiversity research[29], this assessment engages local actors to explore opportunities to enhance the contribution of agrobiodiversity to climate resilience. The assessment involves four steps. The first step focuses on understanding local experiences with climate change and variability and the next three steps involve evaluations and discussions to recognize opportunities for diversification to strengthen resilience to these challenges at different levels of the agroecosystem. The steps are briefly explained below and described in detail in the following sections of this guidebook.

Step 1: Understanding local experiences of climate change and variability. To ensure the assessment closely considers the local situation and needs, in the first step, the main climate-related challenges are identified, as well as adaptation strategies already being applied in the community.



Step 2: Diversification of species, varieties, and breeds. In the second step, the characteristics of species, varieties, and breeds are evaluated to identify opportunities to increase the diversity of traits (e.g. early maturing, drought tolerance, pest tolerance, and diseases resistance) to spread risk of harvest loss and support adaptation.

Step 3: Diversification of fields and farms. In the third step, cropping practices and mixed species systems are evaluated to identify diversity-rich practices that can improve soil conditions, reduce pest and disease pressure, and moderate field-level climate conditions.

Step 4: Diversification of the landscape. In the fourth step, the role of different land uses is evaluated to identify areas that can be protected and restored to buffer climate extremes, support regeneration of natural resources, and provide alternative food, medicine, and income sources.

Piloting the method

The diversification assessment was piloted in communities with distinct agroecosystems in Guatemala, India, and Mali (Figure 1). The pilot workshops took place between May and August 2017 with mixed groups of 16–35 participants (38%–71% women). The results of these sessions are shared throughout this guidebook to illustrate the method in both execution and analysis. Details on the participating communities are described below:

Guatemala: A workshop was held with participants from four villages in the municipalities of Camotán and Jocotán in the Department of Chiquimula. The participating Maya Ch'orti' communities grow maize and beans in the *milpa* (see page 20), complemented by production of livestock (primarily poultry) and a diversity of fruit and vegetable species in homegardens and communally managed forests.

Mali: Workshops were held with the community of Bolimasso in Ségou Region and the community of N'Gountjina in Sikasso Region. Staple crops in these sites include sorghum, pearl millet, rice, and maize, which are grown alongside peanut, cowpea, livestock, and minor crops like fonio, Bambara groundnut, and vegetables. N'Gountjina is situated in the south of Mali where cotton as a major cash crop has displaced many food crops.

India: In eastern Madhya Pradesh, two workshops were held with the community of Dungariya in Mandla District and the community of Magar Tagar in Dindori District. Gond farmers in this region produce rice, kodo millet, and little millet as major staples, as well a diversity of pulses and vegetables.

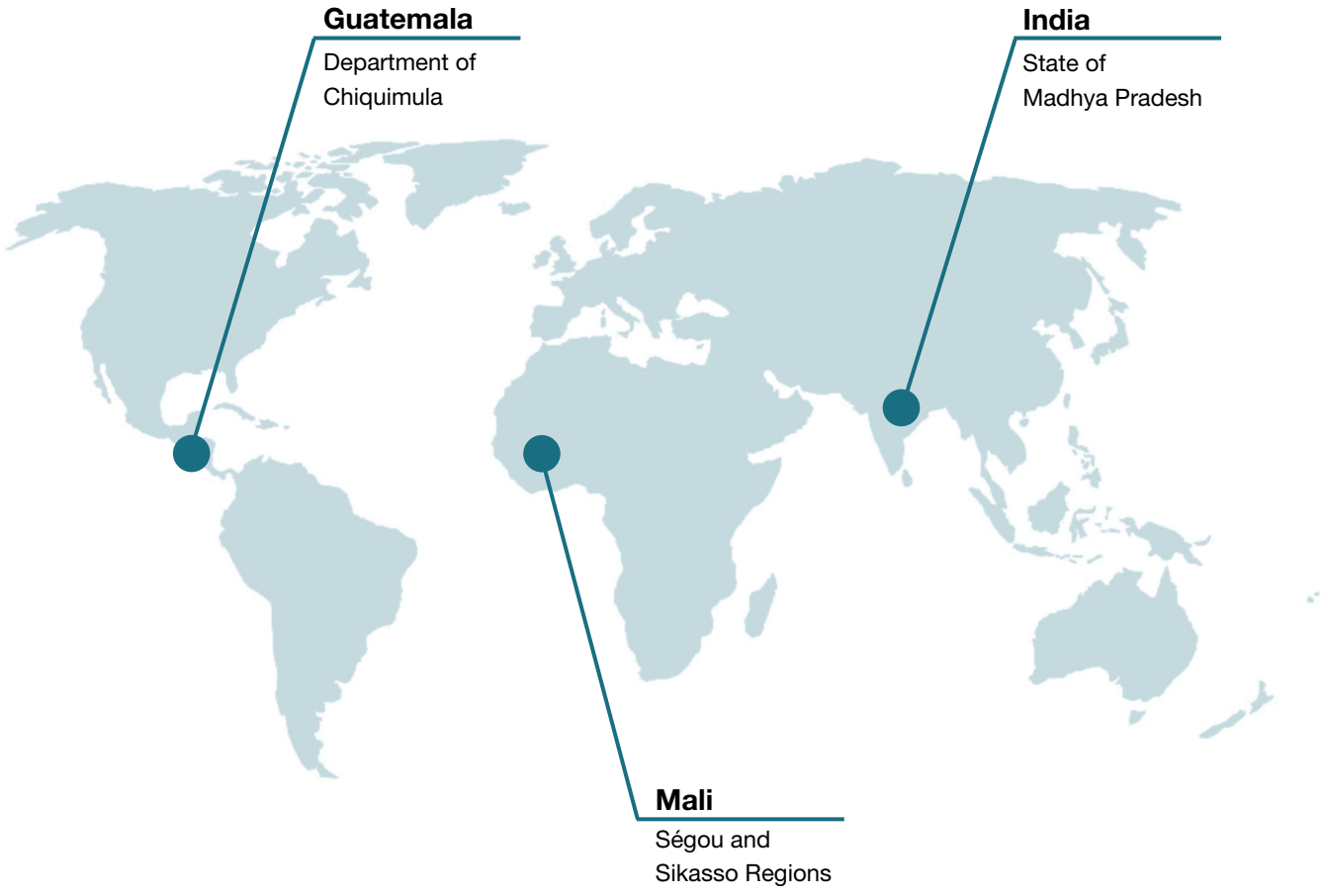


Figure 1 – Sites where the diversification assessment method was piloted

STEP 1: Understanding local experiences of climate change

Designing diversification strategies for resilience requires a good understanding of the impact of climate change and weather variability at the local level. The effects of climate change vary from place to place, and interact with other processes affecting local livelihoods such as deforestation, loss of local varieties, and weak social capital. Adaptation practices must accordingly be targeted to address local needs while considering the specific climate and agrobiodiversity.

Step 1 of the diversification assessment explores the local effect of climate change using a climate change timeline (**Step 1.1**) and seasonal calendar (**Step 1.2**). These exercises provide information about climate change and variability over the years and across seasons, and enable identification of the main hazards faced with climate change. These exercises also provide an opportunity to discuss adaptation strategies applied by farmers individually and as a community through collective action.

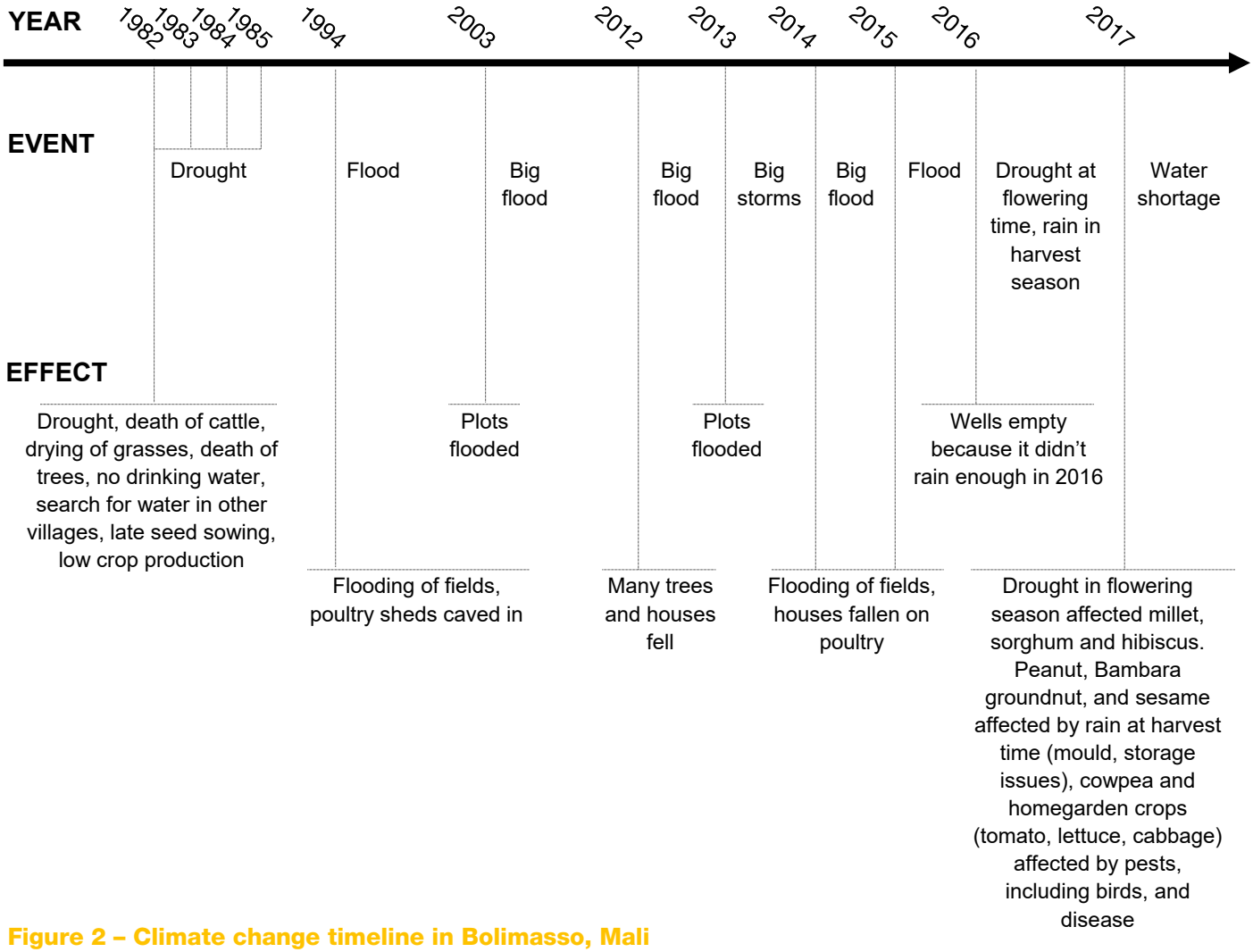


Figure 2 – Climate change timeline in Bolimasso, Mali

1.1 Climate change timeline

The aim of the climate change timeline exercise is to identify the major climate stresses (e.g. cyclones, severe droughts or floods) faced by the community and to recognize possible changes in the frequency or severity of extreme events.

The climate change timeline is created on a large sheet of paper by recording the climate events and changes along a line for the last 30–50 years. More detail can be added for the most recent 10 years. Example climate change timelines from Bolimasso, Mali, and Magar Tagar, India are shown in Figures 2 and 3.

The climate change timeline is created by asking the following questions:

- What extreme weather events occurred in the last 30 years?
- What were the impacts of these events (e.g. harvest loss)?
- Have temperatures, rainfall, or seasonal patterns changed? When?
- Have these changes affected agricultural activities (e.g. planting and harvesting time, livestock migration)?

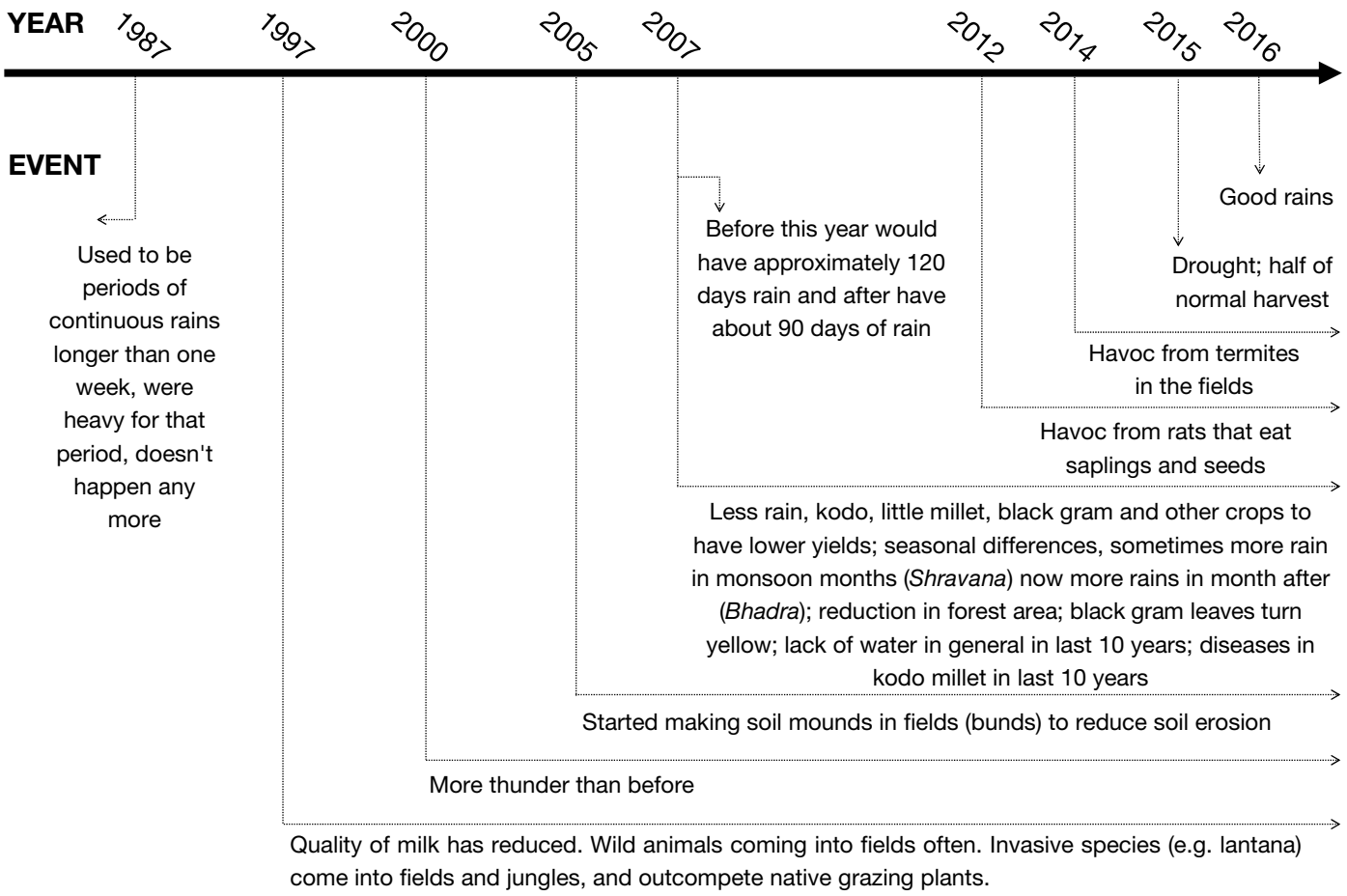


Figure 3 – Climate change timeline in Magar Tagar, India

1.2 Seasonal calendar

The aim of the seasonal calendar exercise is to recognize the effects of climate change on seasonal patterns and associated agricultural activities.

Example seasonal calendars from Dungariya, India and Jocotán and Camotán, Guatemala are shown in Figures 4 and 5.

The seasonal calendar is developed with reference to the local calendar by asking the following questions:

- What are the main seasons (rainy, dry, etc.)?
- What activities are carried out in each month (e.g. harvesting specific crops, gathering wild plants, etc.)?
- Has the timing of the seasons, weather events or activities changed (e.g. in January it used to rain but it does not rain any more)?
- How are local farmers adapting to climate changes?

Figure 4 – Seasonal calendar in Dungariya, India

1.3 Discussion of climate change and adaptation practices

The climate change timeline (Step 1.1) and the seasonal calendar (Step 1.2) reveal the major climate stresses and changes that are occurring. Farmers are often already taking action to cope and adapt. Identification of the major hazards faced with climate change and recognition of adaptation actions supports a deeper understanding of the challenges and potential for diversification to support climate resilience.

Reflecting on the climate change timeline and seasonal calendar, participants discuss the major challenges and adaptation practices by asking the following questions:

- What are the main challenges the community faces with climate change?
- What are the main climate hazards for agricultural production?
- What actions are taken to cope and adapt to climate challenges?

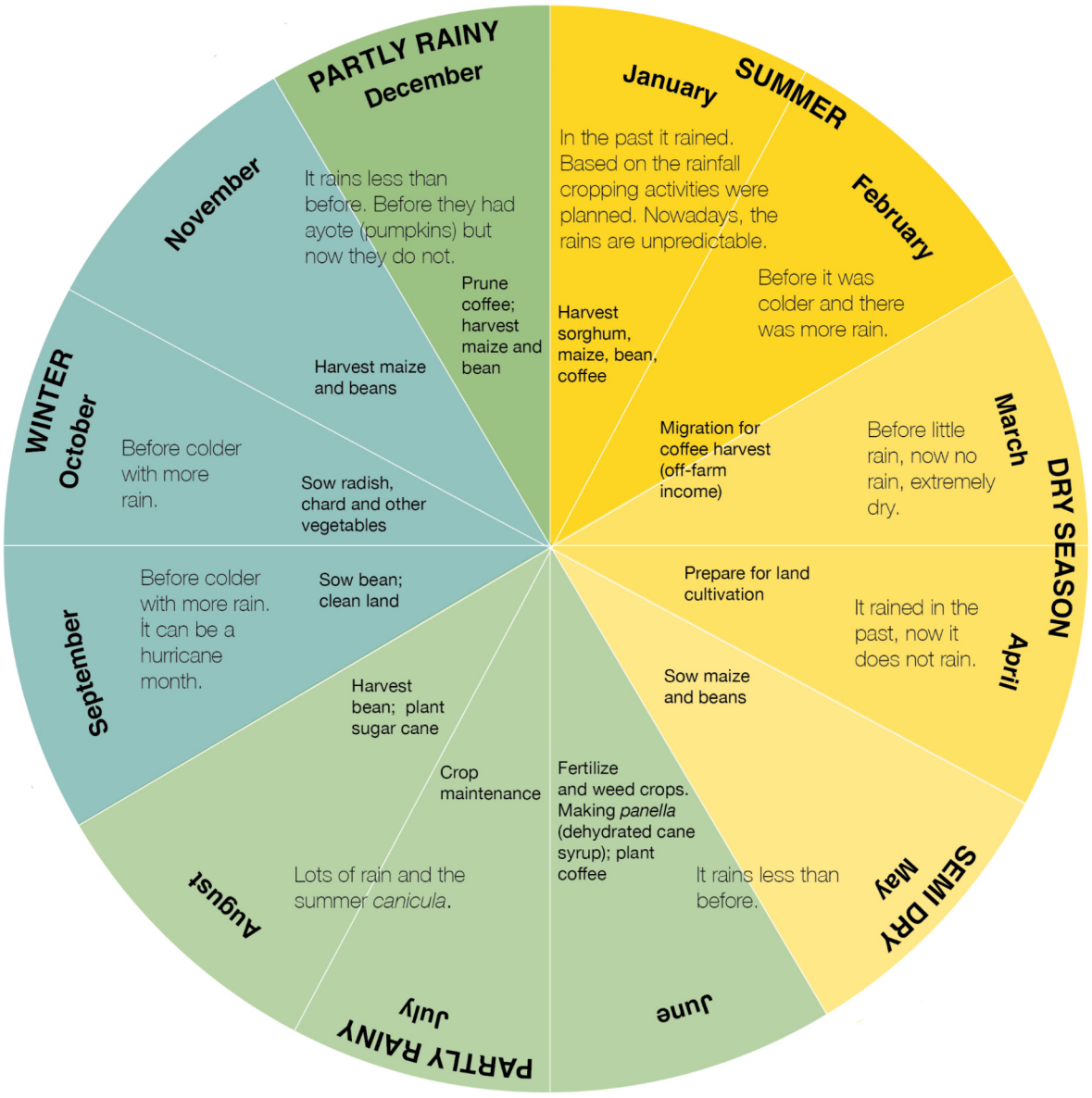


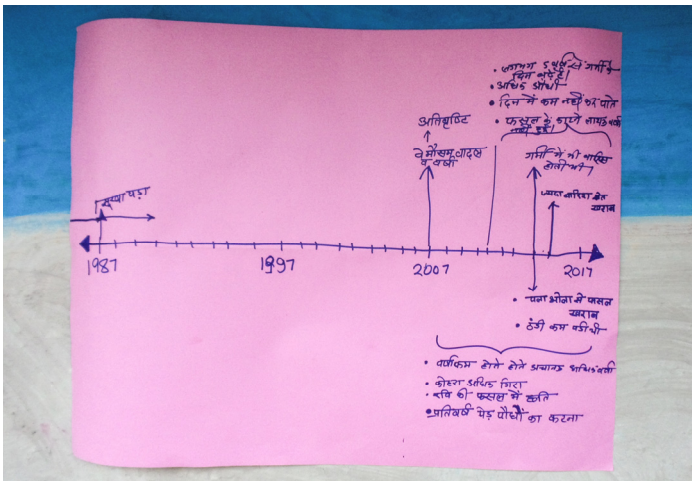
Figure 5 – Seasonal calendar in Camotán and Jocotán, Guatemala

Results from the pilot sites

The communities in Guatemala, Mali, and India have all experienced increasingly erratic and decreasing rainfall and unpredictable seasonal fluctuations. Rains come at the wrong time, which affects planting schedules and crop yields. For example, in Jocotán and Camotán, Guatemala, until 20 years ago, the communities planted maize in May based on the Mayan calendar but now because of shifts in rainfall, they can no longer follow the traditional calendar. In all the sites, water sources are increasingly scarce, with streams and wells running dry. The changes in weather are contributing to soil degradation and increasing problems with pests and diseases. In addition to these common observations, some climate changes are more site specific. The focal communities in India are facing problems with frost affecting their winter crops, while in Mali, flooding has been increasingly frequent. The changes in climate are negatively affecting farm production and livelihoods in all the communities.

Diversification practices are helping farmers to cope with weather unpredictability and adapt to climate changes. Drought-tolerant crops, and early- and fast-maturing crop varieties are cultivated. More stress-tolerant breeds of animals such as drought-tolerant chickens and local disease-resistant ducks adapted to harsh conditions are becoming more widely used in the communities in Guatemala. Cereal–legume rotation, polyculture, tree planting, and reforestation have been adopted across the sites as adaptation strategies. Planting hedges and grass strips are additional strategies taken by the communities in Mali to moderate extreme climate conditions.

Diversification strategies are combined with other techniques for soil and water management, such as use of crop residue for mulching, composting, building small walls around fields, irrigation, contour planting (planting perpendicular to the slope to control water run off and soil erosion), and using the traditional Zaï practice of planting in pits in Mali. Adjustments in planting times (e.g. early planting of cereal crops) and good crop management and care (e.g. soaking seeds) are other practices used to improve yields under the challenging climate conditions.



Development of a climate change timeline in Madhya Pradesh, India
Credit: G. Meldrum / Bioversity International

STEP 2: Diversification of species, varieties, and breeds

Maintaining a diverse portfolio of crops and livestock with tolerance and resistance to a range of stresses contributes to long-term resilience.[30,31] Genetic diversity in crops has been observed to stabilize production under adverse environmental conditions and weather variability, and to enable crop adaptation to climate change.[31–35] Crop diversification through the cultivation of multiple species contributes to resilience by buffering crop production from climate variability, drought, and extreme events.[2] Diversification of livestock portfolios with more stress-tolerant species and breeds is similarly an important adaptation strategy.[36] Local crops and animals often have important traits such as early maturation, drought tolerance, and pest and disease resistance. Diversification of farms with such, often neglected and underutilized species, varieties, and breeds can improve resilience as well as other production objectives.[37–39] For example, the use of local breeds adapted to stress-prone environments is a production strategy in challenging environments and for pastoral communities with limited access to resources.[7]

Step 2 of the assessment is designed to identify options for diversification of crop and livestock portfolios to increase the diversity of traits (e.g. early maturing, drought tolerance, pest tolerance, and disease resistance) to spread risks of harvest loss and support adaptation. The assessment involves 1) evaluating diversity and characteristics of species, varieties, and breeds and their contribution to resilience (**Step 2.1**), and 2) discussing diversification options for crops and livestock based on the results (**Step 2.2**).

Practices for diversification of species, varieties, and breeds and their contribution to resilience

- Planting multiple varieties
- Maintaining different livestock types
- Use of species, varieties, and breeds with traits such as early maturation, drought tolerance, heat tolerance, pest tolerance, and disease resistance
- Exchanging seeds and breeds within and between communities

- Moderating the impacts of extreme weather events and irregular rainfall patterns
- Long-term adaptation to climate-change related stresses

2.1 Evaluation of species, varieties, and breeds and their contribution to resilience

Evaluating the diversity and characteristics of crops and livestock reveals gaps in important traits and enables recognition of species, varieties, and breeds that can strengthen resilience.

To support the development of diversification strategies for more complete nutrition, the evaluation is conducted with the focus on different food groups that provide distinct nutrients (e.g. cereals and other starchy staples, pulses, fruits, vegetables, meat, milk products, eggs). Consuming a diet with multiple food groups is recommended for good health and can be supported by more diverse farm production.

The evaluation begins by listing all the species and varieties or breeds that exist in the community by food group. For example for the cereals, a list of species and varieties is developed by asking the following questions:

- What are the names of all the cereal species and their varieties grown in the community?
- Are there wild cereals collected by community members?
- Once the list is complete, participants are asked to score each species and variety for traits that are important for resilience:
  - earliness or fast maturation
  - drought tolerance
  - tolerance to intense rainfall events and storms
  - resistance to pests
  - resistance to diseases
  - tolerance to poor soil quality
  - any other trait identified as important (e.g. frost tolerance, salt tolerance, heat tolerance).

The results are recorded in a table with check marks that show the scores for resistance and tolerance to climate stresses. An example is given in Table 1 showing an evaluation of traits of cereals in Dungariya, India.

Diversity of cereals and pulses in Northeast India
Credit: D. Mijatović / Platform for Agrobiodiversity Research

Table 1 – Contribution of species and varietal diversity to resilience of cereal production in Dungariya, India. The traits assessed were identified by the workshop participants as important for climate change resilience.

Crop	Variety	Heat tolerance	Tolerance to unseasonal rains	Pest resistance	Resistance to high wind speed	Frost escape*
Kodo millet	Bade (big)			✓✓		✓
	Chote (small)		✓✓	✓✓	✓✓	✓
	Rakhi	✓✓	✓✓	✓✓	✓✓	✓
	Unnat		✓	✓✓	✓✓	✓
Little millet	Bhadeli		✓✓			✓
	Kali (black)		✓✓		✓✓	✓
	Safed (white)		✓✓		✓✓	✓
Barnyard millet	Mudhiya	✓✓	✓✓	✓✓		✓
	Chota (small)	✓✓	✓✓	✓✓		✓
Foxtail millet	Safed (white)	✓✓	✓✓	✓✓	✓✓	✓
	Kali (black)	✓✓	✓✓	✓✓		✓
	Lal (red)	✓✓	✓✓	✓✓		✓
Maize	Safed (white)			✓✓		✓
	Peela (yellow)	✓✓	✓✓	✓✓	✓✓	✓
	Lal (red)			✓✓		✓
Rice	Kranti				✓	✓
	Lochi				✓	✓
	Kardhan (black)	✓✓	✓✓	✓✓		✓
	1010	✓✓	✓✓	✓	✓✓	✓
	Orai bhoota			✓		✓
	Badi nunagi (big)		✓✓	✓✓	✓✓	✓
	Chhoti nunagi (small)	✓✓	✓✓	✓✓	✓✓	✓
	Jholaar	✓✓	✓✓	✓✓	✓✓	✓
	Batari dhan	✓✓	✓✓	✓✓		✓
	Cheendi Kapoor			✓✓		✓
Wheat	WH		✓✓	✓✓		
	Sujaata			✓✓		
	Narmaachaar			✓✓		
	Mangala			✓✓	✓✓	
Pearl millet			✓✓	✓✓	✓✓	✓
Sorghum		✓✓	✓✓	✓✓	✓✓	✓

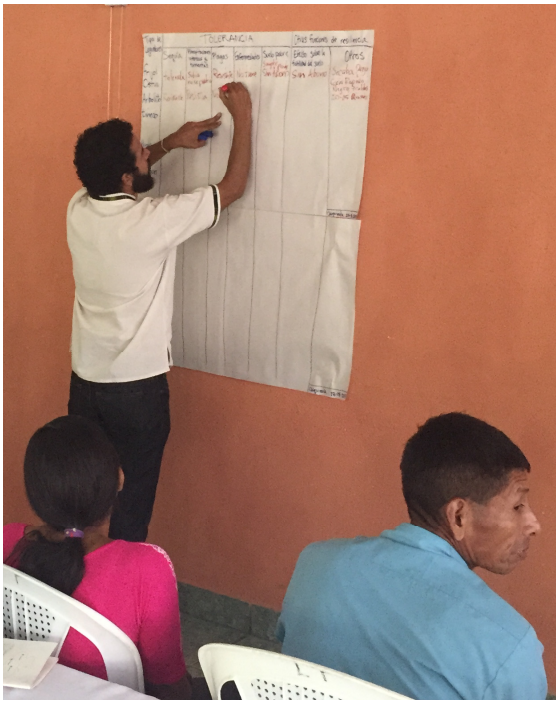
*Species with check marks are planted in the summer and are therefore not affected by frost

2.2 Discussion of diversification options for crops and livestock

The evaluation of species, varieties, and breeds (**Step 2.1**) highlights crops and livestock of importance for resilience (e.g. drought-tolerant varieties) and reveals gaps in diversity portfolios at the farm or community level for facing biotic and abiotic stresses. The results of the evaluations for different food groups can be summarized as in Table 2 as an overview.

Options for diversification are explored by reflecting on the results of the evaluation and discussing the following questions:

- Which traits are the most important for resilience and climate change adaptation?
- What stress-tolerant species, varieties and breeds can be revived or introduced? Are they still available in the community or in neighbouring communities?
- How can the use of stress-tolerant species, varieties, and breeds be supported?
- Are there some food groups (e.g. pulses, fruits) that are particularly vulnerable or tolerant to climate change stresses?



Evaluation of bean characteristics in Chiquimula, Guatemala
Credit: R. Robitaille / Bioversity International

Table 2 – Stress tolerance portfolio of cereals, pulses, vegetables, and fruits cultivated in N'Gountjina, Mali. The species (and number of varieties) with specific stress tolerances are listed.

Type	Drought tolerance	Tolerance to intense rainfall events and storms	Pest resistance	Disease resistance	Adaptability to poor soil
Cereals	Maize (4) Sorghum (6) Fonio (3) Pearl millet (1) Fonio (3)	Maize (4) Sorghum (2) Rice (2) Fonio (3)	Maize (3) Sorghum (2) Rice (3) Fonio (3)	Maize (5) Sorghum (6) Rice (3) Fonio (3)	Maize (1) Fonio (3)
Pulses	Bambara groundnut (1) Cowpea (2)	Bambara groundnut (1) Cowpea (2)	Bambara groundnut (1)	Bambara groundnut (1)	Bambara groundnut (1)
Vegetables	Aubergine Chili African eggplant Okra	Okra African eggplant		Aubergine Chili	Aubergine Chili
Fruits	Local Mango Lemon	Local Mango Lemon	Local Mango Lemon	Local Mango Lemon	

Results from the pilot sites

In Dungariya, India, nine species and 31 varieties of cereal are cultivated (Table 1). The portfolio of cereals shows a range of tolerance and resistance. Wheat is the only cereal grown in the winter (*rabi*) and is susceptible to frost. It is also the most vulnerable crop to unseasonal rains. The millets (six species) are generally more tolerant to the unseasonal rains that communities have been experiencing compared to rice, wheat, and maize. However, while the farmers recognize their stress tolerance, they are hesitant to increase millet cultivation because of lower market potential.

In Jocotán and Camotán, Guatemala, maize is the primary cereal. Five varieties of maize were characterized and all were susceptible to pests, disease, and drought. Sorghum was noted to have better pest and disease resistance and drought tolerance and could be promoted to support more reliable cereal harvests. In addition to the cereals, many varieties and several species of beans are cultivated that show different levels of tolerance and resistance to climate stresses, pests, and diseases. The assessment made more farmers aware of bean varieties that have greater tolerance and plans were made to exchange seeds of these varieties between villages.

In N'Gountjina, Mali, several species of cereals are cultivated that show good tolerance to climate stresses. Fast maturing varieties can escape drought but they tend to have lower yields. Local farmers generally plant both fast maturing and higher yielding varieties. When rains are late, they plant fast maturing varieties. Fonio and Bambara groundnut stood out for their contribution to resilience, especially for their adaptation to poor soil, pest tolerance, and disease resistance. These traditional crops have largely been replaced by maize and cotton but their revival could be strategic for climate change adaptation. There is a gap in availability of pest-tolerant vegetables and fruits adapted to poor soils (Table 2). A wide diversity of wild fruits and vegetables could be better explored and leveraged to secure harvests of these important food groups.

Pearl millet variety preferred by women in Bolimasso community in Ségou Region of Mali
Credit: D. Mijatović / Platform for Agrobiodiversity Research

STEP 3: Diversification of fields and farms

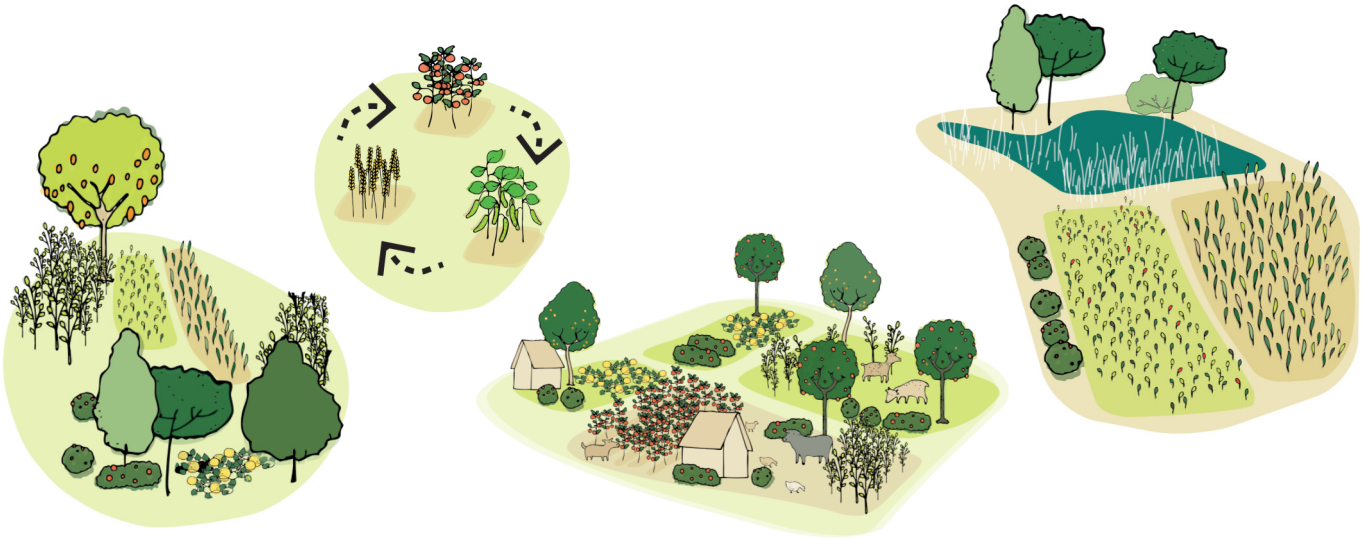
Diversity in fields and on farms encourages positive agroecological interactions that help to mitigate the impact of climate stresses. Practices of polyculture, crop rotation, cover crops, agroforestry, and integrated crop-livestock production maintain agrobiodiversity and support climate resilience as described in the following paragraphs.

Polyculture is the cultivation of two or more crops together. It can take many forms, including mixed cropping (more than one crop planted in the same plot), relay cropping (a second crop is planted into a more mature crop before harvest), and strip cropping (different crops planted in alternate rows). Crop rotation consists of alternating crops by season and over different years. Cover crops are grown to improve soil fertility, suppress weeds, reduce soil erosion, and control pests and diseases. Polyculture, crop rotation, and cover crops help reduce risks associated with fluctuations in climatic and market conditions.[20,21,40,41] Polyculture can be an important pest control strategy as some species host natural enemies of pests or repel pests.[42,43] Planting mixtures of crop varieties has also shown benefits for pest and disease control.[35,44] Mixed cropping with annual and perennial leguminous species can improve yield stability, minimize the need for synthetic inputs, and replenish degraded soils due to the positive effect of legumes on soil fertility.[45,46] Polyculture is more beneficial in less fertile fields and in more marginal environments, where smallholder farmers often practice cereal–legume mixed cropping to mitigate risks of crop failure .[47,48]

Field and farm diversification practices and their contributions to resilience

- Polyculture, crop rotation, and cover crops
- Planting varietal mixtures
- Agroforestry
- Integrated crop–animal production

- Moderation of the effects of extreme weather events and irregular rainfall patterns
- Pest and disease control
- Soil erosion control
- Improved soil productivity
- Shade for animals



Agroforestry is an integrated system that combines trees with agricultural crops and livestock. It is widely recognized as a practice to strengthen resilience in both dry and humid environments.[49,50] There are many types of agroforestry ranging from alley cropping (planting crops among tree rows), crop–tree–livestock systems, and tree-based aquaculture, to complex multi-strata agroforestry that mimics natural forest ecosystems. Tree cover helps control soil erosion, regulates microclimatic conditions, provides windbreaks and shade for animals, and can improve growing conditions for crops under irregular and variable temperatures and rainfall.[2,49,51] A number of case studies have shown that agroforestry systems recover faster from extreme weather events in comparison to systems without trees.[52,53] Agroforestry confers livelihood resilience to floods and drought.[54] Planting nitrogen-fixing tree species can improve soil fertility and help to stabilize crop production during drought and extreme weather events.[49,55]

Integrated crop–livestock agricultural systems reduce risk of damage from unfavourable weather and irregular rainfall.[56] Integration of livestock with cropping activities improves resilience at the field and farm scale, often by ameliorating soil fertility.[56,57] The presence of animals serves as a form of insurance against shock-related losses. Integration of crops, livestock, trees, and fish on farms can result in highly productive and complementary systems that are resilient to shocks such as drought and flooding, and have benefits to food security, nutrition, and sustainable rural livelihoods.[58–60] Similarly, diversification of pastoral systems through the introduction of trees, fodder, or cereal crops can increase resilience to drought.[61]

Step 3 of the assessment is designed to identify options for diversification of fields and farms by promoting polyculture, agroforestry, and crop-livestock integration to improve soil conditions, reduce pest and disease pressure, and moderate field-level climate conditions. The assessment involves 1) evaluating the diversity of cropping and mixed systems and their contribution to resilience (**Step 3.1**), and 2) discussing diversification options for fields and farms based on the results (**Step 3.2**).

A *milpa* field in Guatemala, a local production system involving intercropping of maize with beans, squash, and a diversity of other edible plants
Credit: R. Robitaille / Bioversity International

3.1 Evaluation of cropping and mixed systems and their contribution to resilience

Evaluating the crop, tree, and animal combinations used on farm—both in the past and present—and their benefits can help identify diversity-rich practices that support resilience.

The evaluation begins by listing all cropping practices and mixed systems used currently and traditionally. The list is developed by asking the following questions:

- Which crops and varieties are planted together?
- What crop rotations are followed over the seasons and over several years? What sequence of crops and fallow periods is used? How long is the fallow period?
- What are local agroforestry practices? Where are trees planted on farm? Which crops and animals are associated with trees?
- How are livestock and aquaculture integrated on farm? Are there links between animal and crop production?
- After the different practices are listed, participants are asked to score each for its contribution to:
  - drought mitigation
  - moderation of intense rainfall events and flooding
  - pest and disease control
  - soil fertility enhancement
  - any other role of importance for resilience (e.g. wind protection, shade provision).

The results are recorded in a table with check marks that show the level of the contribution of cropping and mixed systems to mitigating climate stresses. An example evaluation from Dungariya, India is shown in Table 3.

Table 3 – Contribution of diversity-rich cropping and mixed systems to resilience in Dungariya, India

Diversity-rich cropping and mixed systems	Drought mitigation	Mitigation of intense rainfall events and flooding	Pest and disease control	Soil fertility enhancement
Seasonal crop rotation on yellow soils: Rice or millets in monsoon season; lentils and peas in winter season				✓✓
Intercropping on red soils in monsoon season: kodo millet, little millet, pigeon pea, niger seed, black gram				✓✓
Planting trees on field bunds for black soils	✓✓	✓✓	✓	
Integrated crop–livestock production				✓✓

3.2 Discussion of diversification options for fields and farms

The evaluation of cropping and mixed systems (**Step 3.1**) reveals farming practices that can mitigate the effects of climate hazards. These practices can be better supported and new practices can also be explored.

Options for diversification are explored by reflecting on the results of the evaluation and discussing the following questions:

- How can positive interactions between different crops, animals, and trees be encouraged to mitigate climate change related stresses?
- How can diversity-rich cropping and mixed systems be encouraged?
- What are the barriers for diversity-rich cropping and mixed systems? How can they be overcome?

Results from the pilot sites

Across the sites, the role of intercropping and rotating crops with legumes was acknowledged for supporting soil fertility. In Guatemala, black beans were noted to have an important role in maintaining soil fertility in crop rotations with maize. In India, legumes are intercropped and included in crop rotations to contribute to soil fertility and also to provide protein-rich pulses. The communities recognized that if they do not follow their crop rotation sequences their yields start to decline. The role of animals in providing manure for soil fertility enhancement was also highlighted across the sites. In Guatemala, manure from chickens and pigs maintained in the homestead is a critical fertilizer for the crops.

Local cattle breeds in an agroforestry system in Mali
Credit: D. Mijatović / Platform for Agrobiodiversity Research

STEP 4: Diversification of the landscape

At the landscape scale, managing a diversity of land uses and ecosystems is a traditional way of obtaining a range of benefits from heterogeneous environments.[62,63] Diversification of cropping systems in the landscape can increase resilience to erratic weather and market conditions by providing alternative sources of food and income.[64,65] The presence of healthy ecosystems in agricultural landscape mosaics moderates the effects of extreme weather events (e.g. hurricanes, drought, floods) on cropping systems.[50,66,67] These natural areas also provide alternative sources of food, medicine, and other resources of importance for surviving periods of crop harvest losses. For these reasons, community-based protection and restoration of forest patches, mangroves, rangelands, woodlands, and riparian corridors can enhance the capacity of production systems to absorb and recover from climate change related disturbance.[50,67] Landscape heterogeneity moreover plays an important role in the maintenance of diverse pollinator communities, and supports the resilience of pollinator populations to climate change.[68]

Step 4 of the assessment is designed to identify options to maintain different land uses and encourage protection and restoration of natural areas to buffer climate extremes, support regeneration of natural resources, and provide food, medicine, and income sources. The assessment involves 1) evaluating the contribution of different land uses to resilience (**Step 4.1**) and 2) discussing diversification options at the landscape level based on the results (**Step 4.2**).

Landscape diversification practices, and their contributions to resilience

- Land-use mosaic
- Increasing land-use diversity
- Ecosystem protection and restoration

- Drought moderation
- Flood regulation
- Windbreaks
- Soil erosion control

- Recovery after extreme events
- Pollination
- Pest and disease control

4.1 Evaluation of the contribution of different land uses to resilience

Evaluating the role of different land uses and land covers (e.g. forests, wetlands) for providing resources (e.g. water, food), moderating extreme weather events, and controlling pests and diseases helps to recognize areas that should be protected and restored to strengthen climate resilience.

The evaluation starts by listing all the different land uses, land covers, and land (or soil) types. The identification of land uses can be supported with participatory landscape mapping, which involves drawing a map that shows the distribution and location of land uses, crops, and important natural resources.

The list of land uses is developed by asking the following question:

- What land uses and land types are present in the landscape?

- After the land uses are listed, participants are asked to score each for its contribution to:
  - water sources
  - food, fodder, and medicine
  - drought mitigation
  - flood regulation
  - soil erosion control
  - pest and disease control
  - any other role of importance for resilience (e.g. habitat for pollinators).

The results are recorded in a table with check marks showing scores for the level of their contribution to mitigating different climate stresses. Examples from evaluations in N'Gountjina, Mali and Dungariya, India are given in Tables 4 and 5.

Table 4 – Contribution of land uses and land types to resilience in N'Gountjina, Mali

Land uses and types	Water sources	Wild foods, fodder, medicine	Drought mitigation	Flood regulation	Soil erosion control	Pest and disease control	Other
Forest	✓	✓✓✓	✓	✓	✓	✓	✓ food for wild animals
Pasture		✓					✓ food for wild animals
Rivers	✓	✓	✓	✓	✓		
Crop fields		✓✓✓			✓	✓	

Table 5 – Contribution of land uses and land types to resilience in Dungariya, India

Land uses and types	Mitigation of unseasonal rains	Mitigation of summer heat	Mitigation of high speed wind	Pest control	Frost mitigation
Red soil (*barra*)				✓	
Yellow soil					
Black soil	✓	✓			
Forest	✓✓	✓✓	✓✓		
Creek					✓✓

4.2 Discussion of diversification options at the landscape scale

The results of the evaluation (**Step 4.1**) reveal land uses that are important for mitigating extreme weather events and proving a range of benefits. These areas could be protected or restored to support resilience.

Options for diversification at the landscape scale are explored by reflecting on the results of the evaluation and discussing the following questions:

- Which land uses and land types are the most important for resilience?
- How can the contribution of land-use diversity to resilience be increased?
- Are some climate change stresses not mitigated by current land uses? What type of land uses could help to mitigate these stresses?
- What are opportunities and barriers to promote land-use diversity, and protect and restore ecosystems?

Results from the pilot sites

In all communities where the pilot assessments were conducted, trees and forests were identified as playing an important role in mitigating climate stresses linked to climate change. In Jocotán and Camotán, Guatemala planting trees is a strategy to control soil erosion, pests, and diseases. Not cutting native trees in areas with compacted soil is important for drought mitigation. Soft and sandy soils were observed to be suitable areas for reforestation. In India, forest areas were perceived to bring more rainfall, mitigate heat, and provide a wind barrier. The trees have been cut and as a result, now it is hotter. Deforestation has also contributed to rising issues with pests and wild animals coming into the fields. In Mali, reforestation, and planting hedges and grass strips were recognized as important adaptation actions at the landscape level.

In the sites in India, the distribution of crops and cropping systems in the landscape is influenced by soil types and elevation. Higher quality yellow and black soils are dedicated to rice and other crops that require deeper and richer soils. On poor quality red soils, the crops grown—especially kodo millet and little millet—are more drought tolerant and resistant to pests and diseases and provide an important role for harvest security.

A Ch'orti' woman harvesting wild taro in Chiquimula, Guatemala
Credit: C. Lira / Renacer Tres Veces

Concluding remarks from the pilot sites

The diversification assessments in Mali, Guatemala, and India revealed local perceptions of climate change, adaptation practices, diversification opportunities, and the ways in which diversification can be supported. The results showed that farmers cultivate species and varieties adapted to harsh and variable climatic conditions with important resilience traits such as early maturation, drought tolerance, and pest and disease resistance. The production of these species and varieties can be further encouraged and better supported.

The assessments also showed that there are gaps in crop and livestock portfolios with respect to resistance and tolerance traits, which makes food production vulnerable to the effects of climate change. For example, in the workshop in Guatemala, the five maize varieties characterized were all susceptible to pests, diseases, and drought. Sorghum is more resistant but is currently grown on a small scale. It could be one promising crop to promote through diversification. In Mali, while a gap in availability of pest tolerant cultivated vegetables was found, many wild-harvested vegetable species used by the community could potentially fill this gap.

Intercropping, crop rotation, agroforestry and integrated crop-livestock production were identified as important practices that improve soil conditions, reduce pest and disease pressure, and moderate field-level climate conditions. In particular, the use of legumes in intercropping and rotation was acknowledged for supporting soil fertility. Animals, from chicken to cattle, were

Wild fruits in Northeast India
Credit: D. Mijatović / Platform for Agrobiodiversity Research

highlighted as critical sources of manure that enable crop production on increasingly degraded soils. The role of natural areas and different land uses in providing food, medicine, and income sources under climate stress was also highlighted. Forests and trees were observed to moderate the impact of climate extremes such as drought and flooding. Planting trees was recognized in all the sites as an important strategy to control soil erosion. Priority areas for reforestation and ecosystem protection were identified in the discussions for strengthening resilience.

Supporting diversification

The assessments revealed some limitations and barriers for diversification, including degraded and poor soils, increasing pressure on wild areas, and lack of a market or other incentives for using stress-tolerant crops and diversity-rich practices. A need for better access to crop species and varieties—especially those that are drought tolerant, and pest and disease resistant—was expressed in all communities.

Diversification can be supported by a number of actions, including:

- Promoting seed exchange within and between communities to increase access to material needed to diversify crop traits and farm portfolios by organizing seed fairs and establishing community seed banks[69]
- Monitoring diversity, for example, by creating and regularly updating community biodiversity registers to track the performance of crops and animals under weather conditions year to year
- Adopting agroecological practices that integrate biodiversity, soil, and water management for better productivity and more efficient use of resources
- Establishing and strengthening community-based protection, rules, and plans for grazing, forest management, water use, and harvesting in natural areas.

A farmer and her granary in Bolimasso community, Mali
Credit: D. Mijatović / Platform for Agrobiodiversity Research

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Annex: Facilitator's guide

This Annex provides a facilitator's guide for conducting the diversification assessment in a community workshop. The assessment can be carried out with large or small groups of farmers to identify opportunities for diversification of varieties, breeds, species, fields, farms, and landscapes. Farmers may apply the method independently or with supporting NGOs, researchers, extension agents, or development actors. The assessment can be carried out with participants from one or more communities within a common landscape. The participants in the assessment should be of mixed age and gender to capture a range of experiences and ideas from men and women, youth, and elders. In cases where women and men may not speak freely in mixed groups, gender-specific workshops are recommended.

The instructions in this Annex are directed to the facilitator, who is the person responsible for leading the assessment with the participants and who may also have a role in inviting the participants and organizing the logistics of the workshop.

Facilitator roles

During the assessment, the facilitator is responsible for communicating the purpose of the assessment and making sure all steps are taken in the right order. In order to guide the workshop in a way that each person can participate, the facilitator needs to show respect for participants' knowledge, experiences, opinions, perceptions, and customs. Qualities of a good facilitator include being a good speaker and listener, knowledgeable on the topic, and having a sense of humour to keep the discussion relaxed and interesting.

Notetaker responsibilities

In addition to the facilitator, it is recommended to have a notetaker in the workshop responsible for documenting the results of the discussion, time management (Table A1), and ensuring that all questions are covered.

Workshop materials

All information collected during the workshop (**Steps 1-4**) should be written on large sheets of paper or otherwise made visible to all participants. Basic materials required are large sheets of paper, markers, tape (or other means of displaying the information), the facilitation script, and supporting material for illustrating diversification and its benefits. Prior to the workshop, this facilitator's guide should be reviewed, translated, and further developed as necessary to convey the concepts and to run the workshop in a way that is understandable for the participants. After the workshop, all collected information should be shared and given back to the community.

Table A1 – Overview and approximate timing of the workshop

Step	Topic	Estimated time
Introduction	Diversification for climate change resilience	30 minutes
1	Understanding local experiences of climate change and variability	1 hour
2	Diversification of species, varieties, and breeds	1 hour
3	Diversification of fields and farms	1 hour
4	Diversification of the landscape	1 hour
Closing discussion	Summary of the assessment results and diversification strategies	1 hour
	Total	5 hours 30 minutes

Introduction

Aim: Welcome the participants, establish an open atmosphere for discussion, and present the main concepts for the workshop

- Welcome the participants and open the discussion with an icebreaker (a song, story, or short game) and a round of introductions.
- Present the purpose of the assessment. For example: "*The purpose of this workshop is to explore diversification opportunities for increasing climate change resilience".*
- Present the outline and timeline of the discussion (Table A1).
- Explain the meaning of resilience in the local context and ask for local examples. For example: *"Resilience refers to the ways in which fields, farms, and ecosystems recover after stresses such as drought, floods, and hurricanes; resilience is also about the ways in which farmers are adapting to changes. A resilient agroecosystem should be capable to survive, recover from, and even thrive in the face of climate stresses".*
- Explain diversification. For example: *"Diversification is about increasing diversity: increasing the number of species, varieties, and breeds in fields and on farms, and the number of cropping systems and land uses in the landscape. Diversification is a key strategy for enhancing climate change resilience."*
- Explain the benefits of diversification and find and discuss local examples for how diversity contributes to the following:
  - Increasing harvest security in the face of multiple stresses
  - Fostering positive interactions between different plants or between plants and animals that mitigate climate stresses
  - Moderating or reducing the effects of extreme events like droughts and floods
  - Controlling soil erosion
  - Improving regeneration of fields, pastures, and other areas
  - Supporting crop and animal adaptation to changing conditions.

Step 1: Understanding local experiences of climate change

1.1 Climate change timeline

Aim: Identify the major climate stresses faced by the community and changes in the occurrence or severity of extreme events

Draw a line on a large sheet of paper. Ask the following questions and record the answers along the line:

- **What extreme weather events occurred in the last 30 years (e.g. cyclones, severe droughts or floods)?**
- **What were the impacts of these events (e.g. harvest loss)?**
- **Have temperatures, rainfall, or seasonal patterns changed? When?**
- **Have these changes affected agricultural activities (e.g. planting and harvesting time, livestock migration)?**

For the most recent 10 years, increase the level of detail, e.g. late onset of rains, increased occurrence of dry spells within rainy seasons.

1.2 Seasonal calendar

Aim: Identify the effects of climate change on seasonal patterns and agricultural activities

Ask the following questions with reference to the local calendar months and record the answers in a table (Table A2) on a large sheet of paper:

- **What are the main seasons (rainy, dry, etc.)?**
- **What activities are carried out in each month (e.g. harvesting specific crops, gathering wild plants, etc.)?**
- **Has the timing of the seasons, weather events or activities changed (e.g. in January it used to rain but it does not rain any more)?**
- **How are local farmers adapting to climate changes?**

Table A2 – Seasonal calendar

Months	Seasons	Activities/crops	Changes in weather and climate	Adaptation practices

1.3 Discussion of climate change and adaptation practices

Aim: Discuss the major challenges faced with climate change and adaptation practices taken by farmers and their communities

Review the climate change timeline (**Step 2.1**) and seasonal calendar (**Step 2.2**), and discuss:

- **What are the main challenges the community faces with climate change?**
- **What are the main climate hazards for agricultural production? Do they include:**
  - **drought**
  - **intense rainfall events and floods**
  - **pests**
  - **diseases**
  - **soil degradation**
  - **other**
- **What actions are taken to cope with and adapt to climate challenges?**

Notes

Step 2: Diversification of species, varieties, and breeds

2.1 Evaluation of species, varieties, and breeds and their contribution to resilience

Aim: Evaluate the characteristics of species, varieties, and breeds to identify crops and livestock with important traits and gaps in the trait portfolio

The following exercise will be conducted by food group:

- Cereals
- Roots and tubers
- Pulses
- Nuts and seeds
- Vegetables
- Fruits
- Livestock, optionally by product (egg, milk, meat)

For example, for the **cereals**, draw a table similar to Table A3 on a large sheet of paper and list all species and varieties, both cultivated and wild, by asking the following questions:

? **What are the names of all the cereal species and their varieties grown in the community?**

? **Are there wild cereals collected by community members?**

After listing all the species and varieties, ask the participants to give a score to each for traits that contribute to climate resilience. Ask the following questions to fill in the table:

? **How would you score each species or variety for tolerance or resistance to the following stresses:**

- **drought**
- **intense rainfall events and storms**
- **pests**
- **diseases**
- **poor soil**

High	✓✓✓
Medium	✓✓
Low	✓
None	

? **How would you score each species or variety for other important traits for resilience?**

- **early or fast maturation**
- **any other trait identified as important (e.g. frost tolerance, salt tolerance, heat tolerance)**

Repeat all steps for each food group. For livestock, focus on breeds/types rather than varieties.

Table A3 – Example table evaluating the contribution of species and varieties/breeds to resilience

Species	Variety/ breed	Tolerance to drought	Tolerance to intense rains and storms	Pest tolerance	Disease resistance	Adaptation to poor soil	Early or fast maturation	Other

2.2 Discussion of diversification options for crops and livestock

Aim: Discuss options for diversification of crop and livestock portfolios and identify species, varieties, and breeds that can be promoted to strengthen resilience

Considering the results of the evaluation (**Step 2.1**), discuss diversification options by asking the following questions:

- **Which traits are the most important for resilience and climate change adaptation?**
- **What stress-tolerant species, varieties, and breeds can be revived or introduced to increase resilience? Are they still available in the community or in neighboring communities?**
- **How can the use of stress-tolerant species, varieties, and breeds be supported?**
- **Are there some food groups (e.g. pulses, fruits) that are particularly vulnerable or tolerant to climate change stresses?**

Notes

Step 3: Diversification of fields and farms

3.1 Evaluation of cropping and mixed systems and their contribution to resilience

Aim: Evaluate the cropping practices and mixed species systems used both in the past and present for their contribution to resilience

The evaluation starts by listing all the different cropping and mixed species systems used in the community currently and traditionally. Draw a table (Table A4) on a large sheet of paper. Ask the following questions and record the answers in the table:

- **Which crops and varieties are planted together?**
- **What crop rotations are followed over the seasons and over several years? What sequence of crops and fallow periods is used? How long is the fallow period?**
- **What are local agroforestry practices? Where are trees planted on farm? Which crops and animals are associated with trees?**
- **How are livestock or aquaculture integrated in the farm? Are there links between animal and crop production?**

After all practices are listed, ask the participants to give a score for the contribution of each practice to resilience.

- **How does each practice contribute to:**
  - **drought mitigation**
  - **moderation of intense rainfall events and flooding**
  - **pest and disease control**
  - **soil fertility enhancement**
  - **any other role of importance for resilience (e.g. wind protection, shade provision)**

High	✓✓✓
Medium	✓✓
Low	✓
None	

Table A4 – Example table for the evaluation of cropping and mixed systems to resilience

Cropping and mixed-species systems	Drought mitigation	Moderation of intense rainfall events and flooding	Pest and disease control	Soil fertility enhancement	Other

3.2 Discussion of diversification options for fields and farms

Aim: Discuss options for diversification of fields and farms and identify diversity-rich practices that can increase resilience

Reviewing the results of the evaluation (**Step 3.1**), discuss options for diversification of fields and farms with the following questions:

- **How can positive interactions between different crops, animals, and trees be encouraged to mitigate climate change related stresses?**
- **How can diversity-rich cropping and mixed systems be encouraged?**
- **What are the barriers for diversity-rich cropping and mixed systems? How can they be overcome?**

Notes

Step 4: Diversification of the landscape

4.1 Evaluation of the contribution of different land uses to resilience

Aim: Evaluate the role of different land uses for providing resources, moderating extreme weather events, and controlling pests and diseases

The evaluation starts by identifying all the different land uses in the landscape. The identification of land uses can be supported by participatory landscape mapping, drawing a map of local land uses, land tenure systems, and the spatial distribution of crops and natural resources. Draw a table similar to Table A5 and ask the participants to list all land uses:

What are all the land uses and land types in the landscape?

Then, for each land use ask the participants to give a score for its contribution to resilience.

How would you score the contribution of each land use and land type to:

- **food, fodder, medicine**
- **water sources (drinking water, water for animals, and irrigation)**
- **drought moderation**
- **flood regulation**
- **soil erosion control**
- **pest and disease control**
- **any other role of importance for resilience (e.g. habitat for pollinators)**

High	✓✓✓
Medium	✓✓
Low	✓
None	

Table A5 – Table for assessing the contribution land use diversity to resilience

Land uses and types	Water sources	Food, fodder, medicine	Drought moderation	Flood regulation	Soil erosion control	Pest and disease control	Other

4.2 Discussion of diversification options at the landscape scale

Aim: Discuss options for diversification of the landscape and identify land uses or areas that can be better protected or restored to increase resilience

Explore options for diversification of the landscape by reflecting on the results of the evaluation (**Step 4.1**) and discussing the following questions:

- **Which land uses and land types are the most important for resilience?**
- **How can the contribution of land-use diversity to resilience be increased?**
- **Are some climate change stresses not mitigated by current land uses? What type of land uses could help to mitigate these stresses?**
- **What are opportunities and barriers to promote land-use diversity, and protect and restore ecosystems?**

Notes

Closing discussion

Aim: Review the results of the assessment and define diversification strategies and supportive actions

Review the results of **Steps 1–4** and summarize the diversification options at different levels. Questions to guide the discussion:

- **Which crops and varieties, and animal species and breeds, could be promoted, revived, or introduced, and how?**
- **Which intercropping practices and crop rotations can enhance soil quality, pest and disease control, moisture retention, and climate moderation?**
- **How to support integrated crop-animal production?**
- **How to promote tree planting, ecosystem restoration, and protection of forest areas?**
- **What support is needed within the community and outside the community to encourage these diversification strategies?**

Notes