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Agricultural Biodiversity in Climate Change Adaptation Planning

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Abstract
Climate change is one of the biggest threats to food production worldwide. Recently, an increasing number of initiatives have embraced the concept of climate smart agriculture to respond to climate change adaptation and mitigation challenges. A central component of this approach is the use of agricultural biodiversity at the genetic, species and ecosystem levels for increasing productivity, adaptability and resilience of agricultural production systems. This paper analyses the extent to which the use of agricultural biodiversity is included in the National Adaptation Programmes of Action (NAPAs) developed by 50 least developed countries to guide their actions in relation to climate adaptation. The results of the analyses indicate that in the majority of the NAPAs, agricultural biodiversity has not been incorporated in a comprehensive manner and that increased efforts can be done at national and international levels for effectively making agricultural biodiversity work for most vulnerable countries' adaptation to climate change.

Key words: agrobiodiversity, NAPAs, smallholder farmers, developing countries, climate change adaptation

1. Introduction

Climate change is one of the biggest threats to food production worldwide. Researchers estimate that it has already reduced the production of globally important crops [1]. Increases in the frequency and intensity of extreme climatic events are expected to amplify agricultural production risks, particularly among smallholder farmers in developing countries [2]. In recent years, the concept of climate smart agriculture has rapidly gained ground among initiatives and organizations dealing with these challenges and has reached a high profile in international discussions around climate change mitigation and adaptation [3, 4, 5]. The climate smart agriculture approach builds on the experience and knowledge of sustainable agricultural development for transforming and reorienting agricultural systems in response to mitigation and adaptation needs [6]. A central element of the sustainable agricultural development concept and the climate smart agriculture approach is the use of agricultural biodiversity at the genetic, species and ecosystem levels for increasing productivity, adaptability and resilience of agricultural production systems. The combination of intra- and inter- specific diversity in farming systems contributes to soil fertility, biological pest control, nutrient cycling, water retention and pollination [7]. By using domesticated and wild biodiversity wisely and by capitalizing on agro-ecological dynamics, farmers can manage risks, reduce their vulnerability and increase the long-term productivity of their agricultural systems [8, 9]. Using agricultural biodiversity as an adaptation strategy may be a particularly promising and viable option for small holder farmers in least developed countries (LDCs), who

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usually do not have the purchasing power necessary to increase their adaptive capacity by using more expensive inputs, like irrigation.

This paper analyses the extent to which the use of agricultural biodiversity is included in the 50 National Adaptation Programmes of Action (NAPAs) developed as of January 2016. NAPAs are the main planning documents development by national governments to define their priority areas in long term climate change adaptation and guide their steps towards the access to the Least Developed Countries Fund created under the United Nations Framework Convention on Climate Change (UNFCCC) [10]. With this analysis, we aim to provide an overall picture of the actual status of biodiversity conservation and use vis-à-vis LDCs' priorities in agricultural development and adaptation to climate change as defined in their NAPAs. Since existing institutional settings and agricultural research and development capacities present in any given country influence the capacity of farmers to capitalize on agricultural biodiversity, this analysis looks beyond the use of diversity in agricultural production systems *per se* and takes also into consideration the extent to which NAPAs include strategies oriented to increase plant and animal research and breeding, and the conservation of agricultural biodiversity from the genetic to the ecosystem levels.

Ultimately, we seek to provide useful insights for the experts involved in the future development of National Adaptation Plans (NAPs) under the Cancun Adaptation Framework adopted in 2010 by the Conference of the Parties to the UNFCCC and to all those aiming at promoting climate smart agriculture approaches.

2. Methods and Findings

Our study focuses on the climate adaptation activities that LDCs have identified as priority ones within their NAPAs and which do, or at least could, involve the introduction, use or conservation of higher levels of biological diversity in: (1) production systems; (2) agriculture research and development; and (3) *ex situ*, *in situ* and *circa situ* conservation efforts. We use the qualifier 'or at least could' because for a number of priority activities the information provided in the NAPAs did not allow us to be sure that increasing biodiversity in the production systems was either the intention or a necessary result of such activities.

An analysis of all the NAPAs allowed us to identify 38 priority activities that fall under the scope of our study. Out of the total 544 proposed priority projects across the 50 NAPAs, 169 (31%) include one or some combination of these 38 agro-biodiversity-related activities. Table 1 shows these 38 activities as well as the number of times that each of them is included within the priority project proposals in the 50 NAPAs (column 2). Column 3 of the table presents the points given to each activity (from 1 to 3) based on a ranking system explained later in this section. The table presents these 38 agro-biodiversity-related activities classified according to the sectors in which they are most relevant (crops/forages, livestock, fisheries, forestry, agroforestry and natural resources).

Table 1. Agrobiodiversity-related activities mentioned in the NAPAs as priority activities which do (or at least could) involve the introduction or use of higher levels of biological diversity in production systems or in agriculture research and development, by sector.

Prioritized adaptation activities identified in the NAPAs	**Frequency across the 50 NAPAs**	**Degree of involvement of agricultural biodiversity (from 1 to 3)**
Crops/Forages		
Promotion/improvement of local, indigenous or traditional crop varieties	3	3
Encouragement of farmers to cultivate several varieties of 1 crop type/association of crops	1	3
Promotion of vegetable/horticulture systems	20	3
Reseeding rangelands with suitable/resistant varieties	3	3
Promotion of soil conservation practices	9	3
Zero and minimum tillage systems	2	3
In-situ conservation practices of plant genetic resources	1	3
Ex-situ conservation practices of plant genetic resources	1	2
Establishment/maintenance of community seed banks	4	2
Development/dissemination of stress-tolerant varieties	24	2
Establishment of nurseries of vegetables and fruit trees	9	2
Introduction of early maturing/short cycle crops/varieties and species more resistant to climate conditions such as cassava, sorghum, millet and sweet potatoes	23	2
Introduction/expanded production of cash crops	12	1
Crop rotation	3	1
Terracing	4	1
Livestock		
Domestication of small animals (rabbits and small ruminants)	2	3
Genetic improvement of animal breeds	2	2
Promotion of livestock species resistant to drought and flood conditions	6	2
Support for the production of short-cycle animals	2	2
Selection and breeding of suitable varieties of indigenous goat and sheep breed types	1	2
Fisheries		
Development of multi-species fish systems that are more resistant to climate change	4	3
Protection of the diversity of the fish population and prevention of over-fishing	4	3
Establishment of fish gene banks to maintain genetic diversity of freshwater fish resources	2	2
Establishment of fish breeding and fish farming sites for restocking	2	2
Promotion of stress-tolerant fish species	1	2
Forestry		
Enhancement of the biodiversity conservation and management of forests	8	3
Regeneration of degraded areas with local/native tree species	5	3
Promotion of the regeneration of indigenous forests	1	3
Establishment of new or upgraded existing community forest nurseries	18	2
Plantation of stress-tolerant, multi-use and fast-growing tree species	9	2
Promotion of community-based forest management	9	1

Agroforestry		
Promotion of agroforestry systems/species	26	3
Introduction of herbaceous (graminaceous) shrubs in hedges	5	3
Improvement of agro-silvo-pastoral production/promotion of the integration between agriculture, livestock and forestry	12	3
Other natural resources		
Mangrove conservation and restoration practices	14	3
Sustainable utilization and management, conservation or rehabilitation of degraded wetlands	7	3
Reconstitution of highly degraded areas with adapted species	4	1
Introduction of anti-erosion (soils) and dunes fixation	5	1

The eight agro-biodiversity-related activities that are most often mentioned in the NAPAs are, in order of appearance: "promotion of agroforestry systems/species" (26 times), "development/dissemination of stress-tolerant varieties" (24 times), "introduction of early maturing/short cycle crops/varieties and species more resistant to climate conditions such as cassava, sorghum, millet and sweet potatoes" (23 times), "promotion of vegetable/horticulture systems" (20 times), "establishment of new or upgraded existing community forest nurseries" (18 times), "mangrove conservation and restoration practices" (14 times), "introduction/expanded production of cash crops" and "improvement of agro-silvo-pastoral production/promotion of the integration between agriculture, livestock and forestry" (12 times in both cases). Considered together, these eight activities account for 149 (more than half) of all of the 268 priority activities mentioned across the 50 NAPAs.

Figure 1 shows the distribution of all the agro-biodiversity-related activities included in the 50 NAPAs across the following sectors: production of crops or forages, forestry, agroforestry, livestock, fisheries and natural resource management. It also shows their distribution across the three widely recognized levels of biodiversity: genetic, species and ecosystems.

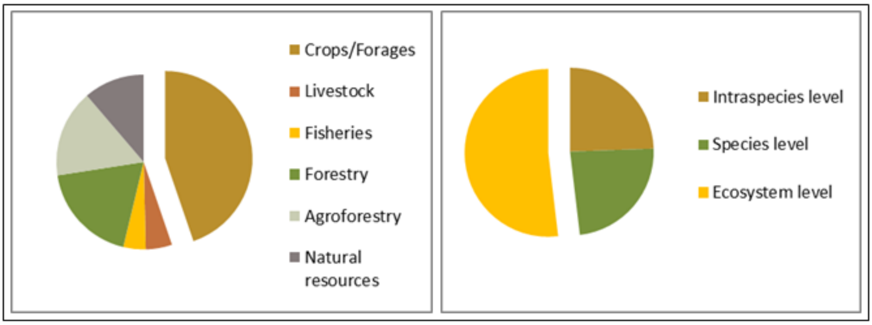

Figure 1. Distribution of the 267 prioritized activities across six sectors involved in agricultural production and the three levels of diversity

Our master 38 activities present a high degree of variation in relation to their potential to effectively capitalize on agricultural biodiversity for climate change adaptation purposes. While some activities are oriented towards both making effective use and increasing levels of agricultural biodiversity in farming systems, other activities rely on agricultural biodiversity only to a limited extent and are not expected to capitalize on intra- and inter-species variation and biodiversity-based dynamics for agriculture adaptation purposes. Taking into consideration this ample degree of variation in our list of master activities, we gave each activity a relative weighting between 1 and 3, with the aim to better compare NAPAs depending on the weight that they actually give to the role of agricultural biodiversity in climate adaptation strategies. For example, we gave "introduction or expanded production of cash crops" a score of 1 because, while it certainly relies on the diversity among crop species, it can eventually limit the potential contribution of agricultural biodiversity to climate change adaptation efforts by replacing the pre-existing crops and decreasing the level of biodiversity overall. A score of 2 was awarded to activities that rely on the use of agricultural biodiversity in upstream activities (for example, conservation, characterization, pre-breeding and breeding) but do not necessarily make use of the complex dynamics between different species to improve agricultural production in the face of climate change. Finally, activities that would involve the use of increased agricultural biodiversity in the production agricultural systems were given a score of 3; for example, "develop multi-species fish systems more resistant to climate changes" and "encourage farmers to cultivate several varieties of one crop type/association of crops". The resulting score for each of the 38 master activities is presented in the third column of table 1. Figure 2 shows the 50 countries that have developed NAPAs. Color codes have been used to represent the degree of integration of agrobiodiversity (high, medium and low) in these countries' NAPAs according to our ranking system.

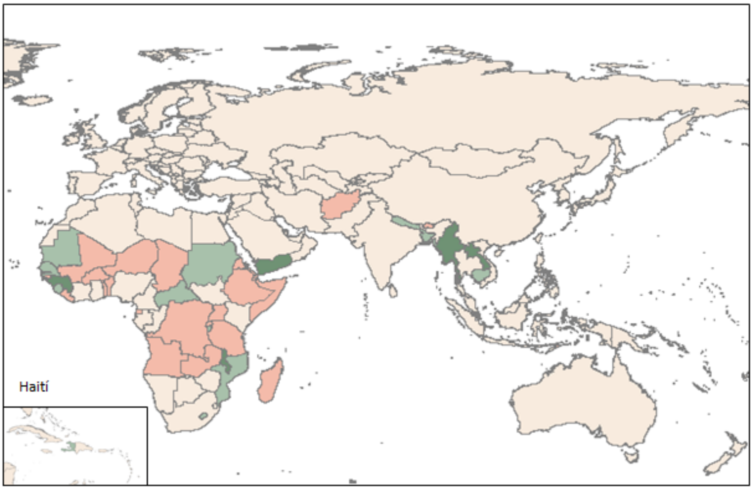

Figure 2. Countries which have approved NAPAs by January 2016, with colour codes showing the degree of integration of agricultural biodiversity in their NAPAs. In dark green, the five countries with NAPAS with the highest degree of integration of agricultural biodiversity in their priority activities: Myanmar, Yemen, Malawi, Laos PDR and Guinea; in light green, the 15 countries with NAPAS with a medium degree of integration of agrobiodiversity: Lesotho, Gambia, Mozambique, Mauritania, Sierra Leone, Cambodia, Haiti, Senegal, the former Sudan, Central African Republic, Solomon Islands, Nepal, Comoros, Burundi and Bangladesh; and in dark pink the 30 countries with the NAPAS with the lowest degree of integration of agrobiodiversity in their priority activities. In addition to Comoros and Solomon Islands, other Small Development Island States which have approved NAPAs and are not clearly visible in the map are Cape Verde, Guinea Bissau, Maldives, Sao Tome and Principe, Samoa, Kiribati, Timor-Leste, Tuvalu and Vanuatu (all of them in dark pink).

As shown in figure 2, the countries that developed these 20 NAPAs are spread across the globe, with no evident positive correlation for geographic or regional location. Nor is there evidence of influence from lead national coordinating agencies or external supporting agencies. As in most countries, the lead agencies for the coordination of most of these countries' NAPAs were the Ministries of the Environment and received support from either the UN Development Programme (UNDP) or the UN Environment Programme (UNEP) during the NAPA preparation process.

These 20 NAPAs account for 165 of the 267 agrobiodiversity-related activities included in the 50 NAPAs. In this subset of NAPAs, the spread of activities across the six sectors and the three levels of diversity was fairly similar to the overall spread for all of the 50 NAPAs reported above, with more activities related to the production of crops and forages and focusing on agricultural diversity at the ecosystem level. Only in a few of these NAPAs the activities were evenly distributed across the intra-species, species and ecosystem levels (Senegal, Malawi and Sudan, Myanmar and Comoros). In many of them, the majority of the activities referred to one or two of the three levels of diversity.

3. Conclusions and Discussion

Even though according to the results of our study one third of all of the priority projects set out in the 50 NAPAs include some combination of agrobiodiversity-related activities, when looking at the numbers in detail, we notice that: (1) just 8 of the agrobiodiversity-related activities, which are most frequently repeated across the NAPAs, account for the majority of activities overall, demonstrating a relatively limited range of actions; (2) the presence of agrobiodiversity-related activities varies considerably across the NAPAs: 20 NAPAs present the highest levels of inclusion of agricultural biodiversity; 11 of them concentrate approximately 39% of the 267 agrobiodiversity-related activities; 10 NAPAs have between zero and two agrobiodiversity-related activities; (3) most activities focus on crops and forages; whereas the livestock and fisheries sectors are, in contrast, comparatively under-represented even though this might reflect the relatively lower importance of these two sectors in some countries; and (4) only a small number of NAPAs pay a balanced attention to the three levels of diversity, which may translate into limitations in countries' efforts to make effective use of agricultural biodiversity in adaptation strategies.

In addition, and despite their widely recognized importance in terms of climate adaptation, and in food and nutrition security [11, 12, 13], the improvement and adoption of local, indigenous or traditional crop varieties and animal breeds appear in just a few NAPAs, whereas the use of underutilized species was not found within any of them.

In terms of location along value chains, it is noteworthy that all of the agrobiodiversity-related activities relate to research, development and production systems, while none of the activities focuses on the marketing and consumption ends of value chains, i.e., there is no activity that aims at creating a demand for the products of agricultural biodiversity or promoting and regulating their commercialization in national and international markets. This concentration of activities at the initial part of the value chain could ultimately contribute to less-than-optimal outcomes. Diversification measures at the research and production stages are less likely to succeed if they are not accompanied by complementary actions taking place at later stages of the value chain.

Interestingly, none of the 50 NAPAs was found to acknowledge the potential growing importance that international agreements for the conservation and exchange of genetic material such as the Convention on Biological Diversity, its Nagoya Protocol on Access and Benefit Sharing and the International Treaty on Plant Genetic Resources for Food and Agriculture might have under the context of climate change. In fact, possible synergies between the UNFCCC and these other conventions and, most importantly, between the national agencies in charge of their implementation, are barely mentioned across the NAPAs.

In conclusion, although the literature and increasingly international dialogues on biodiversity recognize that agricultural biodiversity can play an important role in increasing agriculture's adaptive capacity and resilience to cope with climate change, our analysis indicates that in the majority of the NAPAs, agrobiodiversity has not been incorporated in a comprehensive or systematic manner. A number of factors in combination may have contributed to this outcome. An analysis of them is largely beyond the scope of this paper, however, we note a few issues here for possible future investigation.

The NAPAs are not meant to constitute brand new, stand-alone policy initiatives and national planning documents. Instead, they are meant to build upon, and complement, existing national economic development strategies and priorities, building in short-term adaptive capacity. Very few countries have national economic development plans that promote increased use of agricultural biological diversity agricultural production systems. Indeed, the more familiar approach to national agricultural development strategies is based on streamlined and simplified production systems, oriented to satisfy a reduced number of market chains, and often with aspirations for supplying goods in international commodity markets. The pre-existence of such plans and policy directives may constrain, from the outset, NAPA developers' willingness to consider adaptation strategies involving increased biological complexity.

The limited inclusion of agricultural biodiversity in the NAPAs could be also a result of the usually compartmentalized way in which national governments work. Often, the Ministry of Agriculture and the Ministry of Environment work independently, and the lack of or insufficient dialogue among the two ministries often leaves agricultural biodiversity as an unexplored area, not clearly falling under either Ministry.

Some challenges to the integration of agricultural biodiversity in national adaptation strategies are of very practical nature: In reality, there are few clearly established precedents for scaling up agricultural biological diversification strategies at the national level. Although the literature is rich in successful experiences, how to translate them into short-term national adaptation strategies is not always clear.

A number of international initiatives have developed guiding tools to facilitate the inclusion of agricultural biodiversity use as an adaptation strategy in national adaptation plans. National and international actors behind national planning processes could make a broader use of these tools. One example is the Voluntary Guidelines to Support the Integration of Genetic Diversity into National Climate Change Adaptation Planning developed by the Commission on Genetic Resources for Food and Agriculture of the

Food and Agriculture Organization of the UN. International bodies granting financial and technical support to NAP development processes (such as the UNEP and the UNDP) could consider promoting agricultural biodiversity as a key component of NAPs. This would reflect and safeguard the complementarities among different UN environmental conventions and agencies. Finally, at the time of planning for climate change adaptation, Ministries of Agriculture, Ministries of Environment and other governmental agencies could exploit, instead of avoiding, existing or potential overlaps in the area of biodiversity conservation and use, as an approach for the effective adaptation of agriculture, and possibly other production systems, to climate change.

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