Methodology mapping for resilient production systems: approaches and results from surveys in Bolivia, India, and Nepal

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Abstract

Traditional and novel management strategies for agricultural biodiversity will be central in the adaptation of smallholder farmer systems to climate change. As many neglected and underutilized species (NUS) of crops and trees are tolerant of harsh conditions linked to climate change, these species could be integral in strengthening resilience of farming systems. Relative to their importance, very little is known about how farmers are using agricultural biodiversity and NUS in climate change adaptation. We thus investigated this topic in a survey of 2118 smallholder farmers in Bolivia, Nepal, and India. Many farmers in all locations perceived increasing temperatures and shifts in precipitation, leading to lower yields and food insecurity. Planting new crops or varieties was a common coping strategy in all three locations. In Bolivia, farmers faced with intensified crop pests and disease, planted disease-resistant varieties, such as blight-resistant potato *doble H*. Quinoa, and native *luki* potatoes were also recognized for their hardiness in Bolivia. In India and Nepal, farmers faced with increased drought planted early-maturing varieties, such as spring rice 1442. Many also identified minor millets, which are tolerant of marginal and dry soils, as resistant to climate change. Planting trees was another common coping strategy in all three countries. Trees can shelter crops from heat and desiccation, as well as diversify production to protect against crop failure. Given the importance of agricultural biodiversity in farmer adaptation strategies, actions to halt the erosion of agricultural biodiversity and to effectively deploy this resource will be important in strengthening food security under climate change. Stress-tolerant NUS (e.g. millets, quinoa) deserve more attention in climate change adaptation strategies.

Key Words: Climate change, adaptation, NUS, agricultural biodiversity, farmer perceptions

Introduction

Strengthening food security for a growing population in conditions of climate change is a pressing global issue (Wheeler and von Braun, 2013). Rising temperatures and shifts in precipitation could mean crops growing locally become maladapted, while greater incidence and severity of extreme events such as drought and flooding will seriously challenge crop production (Easterling et al., 2007; Lane and Jarvis, 2007). Shifts in pest and pollinator interactions, soil fertility, and other ecosystem functions will further impact crop performance (Jarvis et al., 2010). Substantial declines in crop yields and stability are projected to result from these impacts in many parts of the world, but especially in developing countries, where existing hunger could be strongly exacerbated (Wheeler and von Braun, 2013).

In areas expected to be most affected by climate change, much of the population is reliant on the production of smallholder farms (Nwanze, 2011). Climate change is expected to compound the existing vulnerability of these producers, who are strongly reliant on their farm production, have few available resources and face numerous other pressures, including poor market integration, population growth, insecure land tenure, and erosion of traditional knowledge (Morton, 2007; Mijatovic et al., 2012). The resilience and adaptability of these farming systems depend on farmers' assets, knowledge, social networks, the political environment, and perceptions of risk (Nyanga et al., 2011).

Smallholder farmers typically manage diverse production systems that involve intercropping several different crops and varieties, collecting wild resources, and raising livestock (Morton, 2007). Agricultural biodiversity and associated traditional practices will play a vital role in climate change adaptation (Mijatovik et al., 2012). The practice of crop diversification mitigates risk by leveraging the insurance effect of diversity (Di Falco and Perrings, 2003). Meanwhile, smallholder farmers' traditional use and development of locally adapted crops and varieties through dynamic seed selection and exchange practices facilitates adaptation to shifts in the abiotic and ecological community context (Wood and Lenne, 1997).

While traditional practice holds promise for adaptation, the speed and magnitude of the shift in conditions could require drastic adjustments in cropping systems, planting schedules, locations, and soil and water management practices. Farmers may need to increase production or introduce crops that are better suited to prevailing conditions (Kurukulasuriya and Mendelsohn, 2008). The cultivation of more stress-tolerant crops and varieties is expected to be crucial in sustaining production as the weather becomes harsher under climate change (Mijatovik et al., 2012). In this sense, the neglected and underutilized species (NUS), which include a vast diversity of crops and trees cultivated in traditional production systems that are not well exploited in global markets, could play a strong role (Padulosi and Hoeschle-Zeledon, 2004). Many of these crops are tolerant of marginal conditions and produce nutritious food products, and so could be integral in diversification strategies for climate change adaptation (Nangula et al., 2010; Bala Ravi et al., 2010).

Considering its importance, the role of agricultural biodiversity in the resilience and adaptation of smallholder farming systems to climate change has not been adequately recognized. A recent review brought together examples highlighting the role of agricultural biodiversity in climate change resilience at crop/variety, farm, and landscape levels (Mijatovik et al., 2012). Still, very little is known about how farmers are making use of agricultural biodiversity and specifically, NUS crops and trees to cope and adapt to climate change. This study by Bioversity International in partnership with the Foundation for the Promotion and Research of Andean Products (PROINPA), Local Initiatives for Bioverdiversity Research and Development (LI-BIRD), the M.S. Swaminathan Research Foundation (MSSRF), and the Platform for Agrobiodiversity Research (PAR) addressed these issues through a survey of smallholder farmers in Bolivia, Nepal, and India.

Materials and Methods

The survey was carried out in late 2012 and early 2013. Farmers were interviewed in two departments in Bolivia (Cochabamba and La Paz), two districts in India (Namakkal and

Nainital), and four districts in Nepal (Bara, Dolakha, Kaski, and Jumla). The survey questions used for the study have been published previously (see Padulosi et al., 2012; pp.188-197). Some survey questions were modified or the sequence in which they were asked was shifted in the different locations to suit the local language and context.

In total, 2118 farmers were interviewed. We sought to include a strong representation of women in the sample so the sex-ratio of respondents was effectively 50-50 in all countries (Table 1). The farmers interviewed were younger in India compared to Nepal and Bolivia, with more under 40 years of age and fewer over 60. In Nepal and India, it was most common for farmers to have no formal education, whereas in Bolivia, farmers were most-commonly educated to primary level.

Numerous farms were larger than 10 ha in Bolivia whereas, essentially no farm in Nepal or India was so large (Table 1). These larger farms were included in this preliminary analysis, as they could be considered smallholders under definitions that emphasize reliance on farm production (Berdegué and Fuentealba, 2011).

Table 1. Survey participants and their farm profiles.

	Bolivia (% of N=234)	**Nepal** (% of N=1171)	**India** (% of N=713)
Women	52	47	50
Age			
Under 40	22	39	48
40 to 59	43	40	40
Over 60	35	22	12
Education			
None	12	52	42
Primary	60	16	25
Secondary	24	25	20
Intermediate	1	5	11
University	0	3	1
Other	3	0	0.1
Farm size			
< 1 ha	17	76	81
1 to 10 ha	44	24	19
> 10 ha	36	0.2	0
Livestock	94	90	85
Irrigation system	23	74	49
Tractor	0.4	11	24
Vehicle	11	0	19
Hire farm labour	29	52	39

Results

The grand majority (88%) of farmers interviewed had noted a change in the weather in the last 20 years (Figure 1). In India especially, effectively all farmers interviewed had noted changes in the weather. Higher temperatures and shifts in the timing of precipitation were observed by the majority of farmers across all three sites, with late rains commonly noted in Bolivia and India. In the south Asian sites, many farmers noted a reduced amount of rainfall, leading to drought or lower water availability (i.e. springs drying up, lower water levels). In

Bolivia, heightened pest and disease pressure was a highly noted impact. As a result of these changes, many farmers in Bolivia and India reported yield declines and in Nepal many suffered food insecurity.

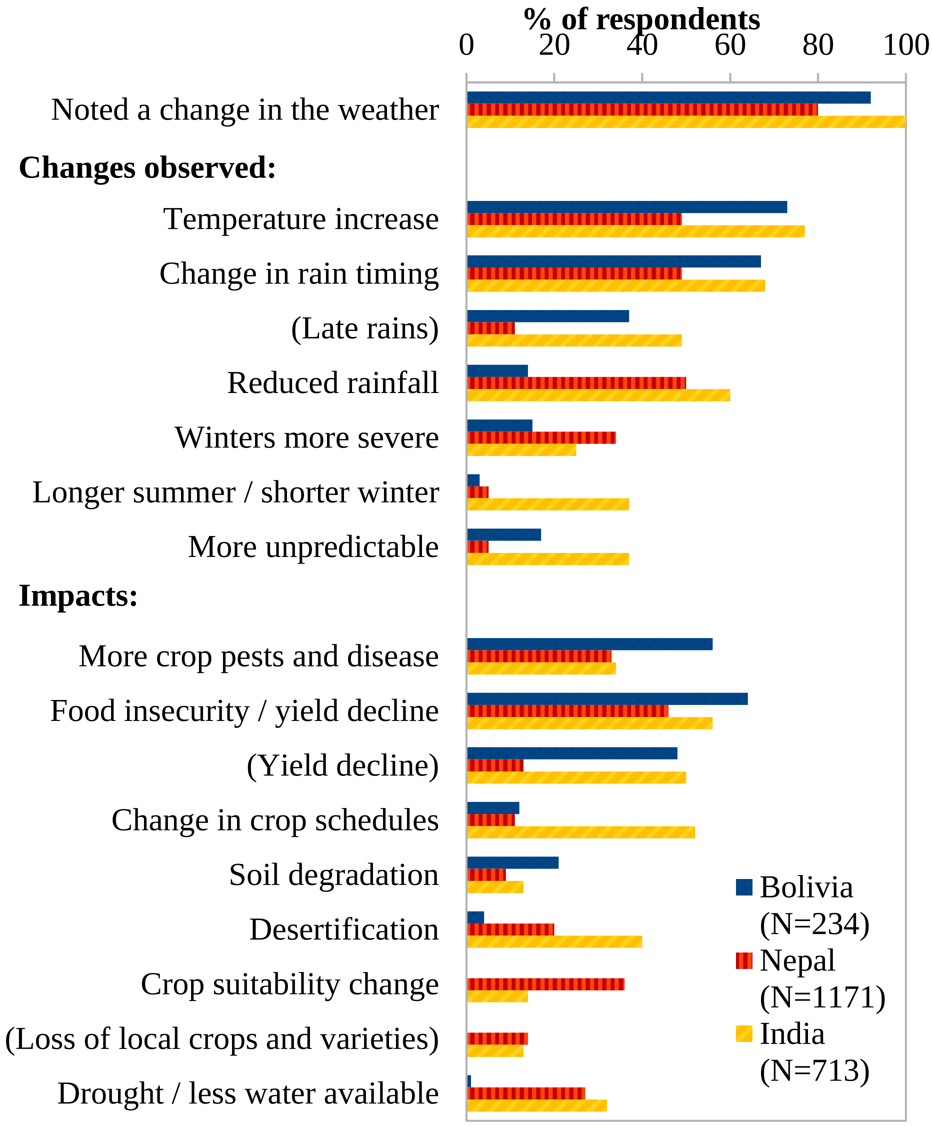

Figure 1. Perceptions of climate change and its impacts by smallholder farmers in Bolivia, Nepal, and India.

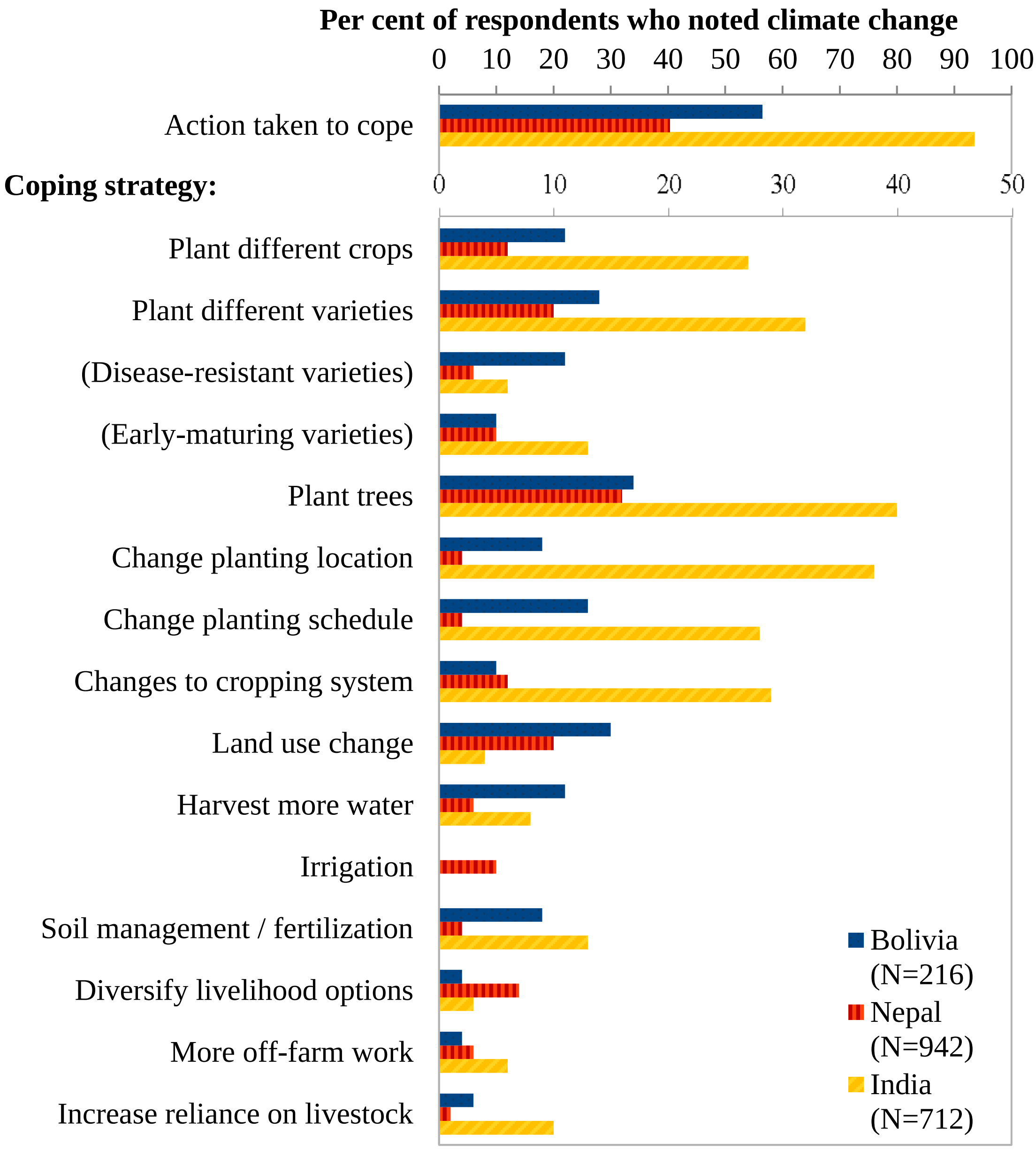

Figure 2. Farmers taking action to cope with perceived climate change and their most common coping strategies. Note the scale change for the coping strategies.

In India, over 90% of farmers who noted a change in the weather reported taking action to cope with the impacts (Figure 2). Fewer farmers in Bolivia and Nepal took action to cope. Farmers reported taking a broad range of coping actions. Planting different crops species or varieties was common across all sites. In Bolivia, many farmers planted disease-resistant varieties and in India, early-maturing varieties. Planting trees and changing land use or cropping systems were other common coping actions taken in all three countries. In Bolivia and India, many farmers modified cropping locations and schedules.

Farmers considered several NUS crops to be resistant to the challenges they faced with climate change (Table 5). Quinoa was considered resistant by over a quarter of farmers who noted climate change in Bolivia. In India and Nepal, minor millets including finger millet, Italian foxtail millet, and barnyard millet were popularly considered resistant, with finger millet the top-listed resistant crop in the Indian sites. In Namakkal, however, many farmers considered millets to be susceptible to climate change (data not shown).

Traditional and modern varieties of dominant crops such as potato, wheat, rice and maize were also considered by many farmers to be resistant to the challenges faced with climate change. In Bolivia, about three quarters of farmers who noted climate change considered potato to be resistant but unfortunately, very few farmers indicated specific varieties. Where varieties were noted, the most commonly mentioned were native *luki* potatoes and introduced variety *doble H* (also known as *runa toralapa*; Uzeda, 2005). The resistant varieties of rice and wheat noted in Nepal were both modern bred and were only listed by farmers in the Terai (Joshi et al., 2012; Ghimire et al., 2012).

Table 2. Most common crops farmers listed as resistant to climate change.

	Bolivia (% of N=216)	**Nepal** (% of N=942)	**India** (% of N=712)
Potato	76	3	1
Variety *luki*	13		
Variety *doble H*	8		
Wheat		21	8
Variety *NL297*		12	
Rice		20	6
Variety *1442*		5	
Maize		8	36
Barley	11	8	0
Quinoa	28		
Minor Millets			
Finger Millet		8	45
Italian Foxtail Millet			8
Barnyard Millet			6
Kodo Millet			4
Red gram (pigeon pea)		1	8
Peas		6	0.4
Taro		5	3

Table 3. The percent of farmers who took action to cope with perceived changes in the weather depending on whether they were informed about climate change or not.

	Bolivia	**Nepal**	**India**
Informed: Took action	72%	45%	90%
Not informed: Took action	48%	36%	89%

A good proportion of farmers in Bolivia and Nepal (34% in both sites) had been provided information on climate change but it was still a minority. Only 12% of farmers in India had been informed. Farmers had various sources of information, including the radio and NGOs. In Bolivia and Nepal, farmers who were informed about climate change were more likely to take action to cope with perceived impacts (Table 3).

Discussion

Farmers in all three countries noted increasing temperatures and shifts in precipitation over the last two decades that have lead to lower yields and food insecurity, among other impacts. These results are consistent with data that demonstrate rising global temperatures, shifts in precipitation patterns, and their projected impacts for food security (Wheeler and von Braun, 2013). Strong perception of climate change by farmers has also been documented in a similar survey by Oxfam Novib et al. (2013) in Peru, Vietnam and Zimbabwe.

Results presented here reflect the most common observations. There was strong agreement among farmers about some of the effects of climate change but their observations conflicted in other cases. Divergence could result from different microclimates within the landscape or farmers' different sensitivities. A finer geographic-scale analysis of climate change effects will be developed, which may resolve some of these conflicts. In any case, the focus of this study was not to judge the merit of farmer observations, rather to understand how their perceptions and responses would relate to their adaptive capacity and resilience.

Many farmers reported taking action to cope with the problems they encountered with climate change. It is unclear from the survey whether these actions were made proactively in anticipation of greater change to come. Rather, it is more likely these actions were reactive adjustments of practice to deal with circumstances that hindered production. Here, the distinction between strategies for "coping" and "adapting" is not emphasized because coping strategies can become means of adaptation (Morton, 2007).

The spatial and temporal deployment of agricultural biodiversity was central in farmer adaptation strategies. In this sense, a notable coping action in all three locations was planting new crops or varieties. The specific crops and varieties farmers planted are not conclusively known from the survey, but those recognized as resistant to climate change were likely among the seeds introduced. For instance, spring rice variety 1442 that was recognized as resistant to climate change in Bara, Nepal may have been among the fast-maturing varieties farmers planted to cope with drought (Kafle et al., 2012). Minor millet species that were considered resistant to climate change in India and Nepal may also have been planted to cope with drought, as they are tolerant of arid soils (Padulosi et al., 2009). In Bolivia, modern blight-resistant potato variety *doble H* was likely one of the disease-resistant varieties farmers introduced to deal with heightened pest and disease pressure. Farmers in Bolivia also recognized several crops as resistant that are more generally appreciated for their hardiness, including frost-resistant *luki* potatoes and quinoa, which is tolerant of dry and low-input conditions (Galewey, 2003; Giuliani, 2013). Stress-tolerant crops and varieties such as these are expected to be crucial in climate change adaptation, as extreme conditions occur more frequently (Mitajovik et al., 2013).

The crops considered to be resistant to climate change included both NUS and major crop species. Development and use of climate-hardy varieties of major staple crops will play an essential role in adapting food production to global climate change. However, we note that these crops are already gaining strong attention in research and development efforts, unlike the NUS crops that farmers also recognize to be resistant to climate change. NUS crops are also typically accessible to poor farmers and embedded in local cultural traditions, and this gives them greater potential to enhance socio-ecological resilience as compared to introduced or modern crops and varieties. We thus argue that more attention should be paid to hardy NUS crops in climate change adaptation strategies. Quinoa and minor millets, for instance, could be highly strategic in strengthening food security under climate change, as they are both resistant to harsh environmental conditions and provide highly nutritious grains (Saleh et al., 2013; Padulosi et al., 2009).

Planting trees was another common coping strategy across all three sites. This action has several effects that can alleviate the impact of climate change on farm production. Trees shelter crops from heat and desiccation by providing shade, protect the soil from wind erosion, and can diversify farm production to protect against crop failure (Rao et al., 2007). In Bolivia, planting trees is a strategy recommended by NGOs (e.g. CARE − Cooperative for Assistance and Relief Everywhere) working in the region to mitigate soil erosion and climate change impacts. In the Kolli Hills (in Namakkal), tribal farm families are engaged in a project to establish integrated *Wadi Farms* that consist of food and cash crops, fruit and timber trees, and fodder grasses. Such diversification strengthens the capacities of farm families to meet the challenges of vagaries of the weather. While the identity of the trees the farmers planted is not known definitively from the survey, this strategy could include NUS. In one of the sites we surveyed in Nepal (Jumla), farmers have been supported by LI-BIRD and The Development Fund of Norway in planting the dhatelo tree (*Princepia utilis*) on barren slopes. The farmers appreciate this species for its fruit, oil and evergreen quality but it has been in decline in the area. The restoration of the dhatelo population would recover the benefits of the tree for local community use and also the option to gain income through sale of the oil in high value international markets. Similar benefits from planting trees have been promoted in Africa through conversion to agroforestry with the multi-purpose and nutritious moringa tree that is gaining attention as a global superfood (Amaglo, 2013).

Diversification by planting trees fits with tradition in these systems of maintaining high diversity for risk mitigation. Maintaining a broad portfolio of crops was surprisingly not mentioned by farmers as a strategy to cope with climate change. However, as diversification is standard practice in these production systems, it may be that the farmers did not consider this a specific "coping strategy". In Nepal, farmers interviewed planted on average three cereals, three legumes, nine vegetables, four spices, 3-4 fruit species and typically more than one variety within each crop. In Bolivia, the farmers maintained an average of seven varieties of potato and a few other crops, including native tubers (isaño, oca, and papalisa) and andean grains (quinoa and cañihua). In India, the farmers practised mixed cropping, relay cropping and crop rotation of small millets and pulses. This diversity provides alternative sources of food or income, strengthening resilience to climatic stress.

While many farmers took action to cope with climate change, many others who observed changes in the climate did not report taking specific action to cope. Information had a positive effect on farmers' likelihood of taking action in Nepal and Bolivia. In India, the fact that very few farmers were informed about climate change may underlie the absence of this effect. Our results corroborate research that identifies access to information as a major barrier to climate change adaptation (Deressa et al., 2008). However, the nature and quality of information is critical. Further study should investigate the availability of information concerning the role of traditional crops in climate change adaptation, which may be weakly available. An interesting observation is that farmers reported taking a wide range of coping strategies that were often not being practised by their neighbours. Improving information access and sharing within and between communities regarding climate change coping options could improve adaptive capacity in these locations. We also note that access to information often differs between gender and social groups. Further analysis will be performed to see if divergence between gender exists in these sites that may lead to different vulnerabilities, coping strategies, and support required.

Conclusions

This study revealed that smallholder farmers in Bolivia, Nepal and India strongly perceive climate change and that the management of agricultural biodiversity to be central in their adaptation strategies. The strong recognition of NUS crops as resistant to climate change conditions points to their potential role in adaptation. The resistant crops (both NUS and dominant) recognized by the farmers could be leveraged to strengthen resilience through diversification of production systems or replacement of crops that no longer perform well via (re-)introduction or increasing the area allocated to their production.

Adding to the challenge of adapting to climate change is that agricultural biodiversity fundamental to climate change adaptation is increasingly being lost due to a suite of interacting pressures, including development of global markets, agricultural technology, and shifts in cultural norms (Padulosi et al., 2012). In order to secure food security for humankind today and the future, we must promote the conservation of agricultural biodiversity and its effective deployment to cope with climate change.

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