Improving rural livelihoods through the conservation and use of underutilized species: evidence from a community research project in Yemen

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Abstract

The aim of this paper is to analyze the impact of a set of interventions related to conservation and use of neglected and underutilized species (NUS) on people's livelihoods. Specifically a simultaneous three-equation model of households' participation on undertulized crops conservation and income generation activities is applied to evaluate the outcome of a pilot research project implemented by Bioversity International in Yemen between 2002 and 2005. Results generated show a relation between project participation and the perceived yield increase demonstrating the importance for farmers to actively participate in the project's activities and subsequently apply agronomic practices learnt to improve their livelihood. The generated benefits incentivized farmers to continue to apply the interventions beyond the lifetime of the project ensuring thus a sustainable process in which exogenous interventions, once adopted by farmers become integrant part of farmer's agronomic practices.

Key words: agro-biodiversity, on farm conservation, neglected and underutilized species, livelihood, impact assessment

Introduction

The preservation of agricultural biodiversity as a means to empower poor people and improve their well-being has attracted many research and development projects. Agro-biodiversity conservation and its use can be a valuable option for poor people not only in terms of income opportunities, but also for diet diversification, community involvement and health (Bellon, 2004; Bellon *et al*., 2006; Meinzen-Dick *et al*., 2009; Smale *et al*., 2008; Sthapit *et al*., 2008), and for the sustainable management of agricultural systems (Frison *et al*., 2011; Jackson *et al*., 2007; Mijatović *et al*., 2012). Experimental studies have demonstrated that higher diversity ecosystems give greater productivity than lower diversity ones (Vernooy and Song, 2004; Tilman *et al*., 2005) and furthermore that agro-biodiversity helps risk-averse farmers to cope with uncertainty by allocating land to different crop species (Di Falco and Perrings, 2005; Roe *et al*., 2011). Neglected and underutilized species (NUS), key componets of agrobiodiversity, comprise domestic and wild species and varieties that are considered "minor" in terms of poor research and development (R&D) efforts and their socio-economic potential not being fully exploited by policy makers, scientists and development workers, mainly because they fail to compete with major commodity crops (Padulosi *et al*., 2002; Andersen, 2012). However NUS are often far from minor in the lives of the rural poor, particularly the more vulnerable members of society such as women, children and elderly groups. This diversity is a key asset of the rural poor in developing countries who depend on agriculture for their livelihoods and well-being (Lockie and Carpenter, 2010). Moreover, NUS occupy important agro-ecological niches, holding a comparative advantage over commodity crops in terms of adaptation to marginal and fragile ecosystems (such as arid and semi-arid lands, mountains, steppes and tropical forests), to changing environmental conditions, and to low-input agricultural systems (Bala Ravi *et al*., 2010); Mal (2007) and Dansi *et al*., (2012) report that many NUS since are recorded to be adapted to difficult environments unfit for other crops can provide sustainable productions contributing significantly to maintain diversity rich and hence more stable agroecosystems. By contributing to agricultural diversification they also offer indirect benefits, such as increasing the stability of production systems, and supporting self-reliance in countries that aim to reduce the import of agricultural products (Padulosi *et al*., 2002). Finally, many such species have high cultural significance and are therefore ideal instruments for promoting the maintenance of the traditional knowledge, identity and self-esteem of local communities.

The international community has made clear calls for greater conservation and development of NUS in agriculture. This is an agreed priority of the Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture, and its importance has been recognized by Agenda 21 and the Global Forum for Agricultural Research (GFAR), which has been instrumental in the establishment of a German-supported Facilitation Unit for Underutilized Species in 2002 (Frison *et al*., 2000). The IFAD-supported Consultative Workshop on Enlarging the Basis of Food Security (Chennai, India, 1999) reaffirmed the importance of NUS, but also recognized that R&D activities on NUS have been sporadic and lacking in a coherent framework and strategy. In 2010, the 10th meeting of the Conference of the Parties to the Convention on Biological Diversity (COP 10), confirmed the role of NUS "*to address the impacts of climate change and other pressures as well as to contribute to food security*"(Decision X/34).

To exploit the full potential of NUS, Bioversity International, in early 2000 implemented a global programme of work to support their conservation and use so as to enhance NUS contribution to rural livelihoods. A conservation strategy for NUS was thus developed to prevent them from falling into disuse. The strategy developed, based on "conservation through use" concept, enhanced the use of NUS in order to create more demand for them and thus triggering more production of the resource. This would in turn lead to the conservation of more diversity within the genepool required to improve the productivity and use of the resource.

Participation in project activities, sharing information and adopting new agronomic practices are essential steps for achieving a tangible strategy's impact: well informed and trained farmers can improve their income and livelihood opportunities while contributing to the conservation and improvement of the resources to which they have access (Nabahungu and Visser, 2011).

However, despite results to crop diversity being well-documented, there is a lack of structured and systematic impact evaluation of the success of these projects in terms of livelihood benefits to farmers (Lutz and Munasingheb, 1994). Moreover there is also an intresting international open debate on the role played by NUS in preserving agrobiodiversity and improving farmers wellbeing (Padulosi and Hoeschle-Zeledon, 2004; Johns and Sthapit 2004; Andersen, 2012). The scope of this study is to enter in this debate analysing and evaluating the impact of a set of interventions related to conservation and use of neglected and underutilized crops on people's livelihoods, specifically based on the outcome of a pilot research project implemented by Bioversity in Yemen.

The project background

From 2001 to 2010, an international effort was made through the implementation of two global projects aimed at enhancing the sustainable conservation and use of NUS. These projects represented the first UN-supported endeavors on NUS and tested out a novel collaborative framework involving all actors along the value chain of certain representative target species. Stakeholders involved in the implementation of these projects ranged from scientists engaged in surveying, collecting, conserving and studying the genetic diversity of target species to farmers contributing to their maintenance *in situ*/on farm, from breeders and experts working to develop better varieties and value addition technologies to user groups, including women's associations. The project being analyzed was conducted from 2002 to 2005 within the framework of a multi-country research programme financially supported by the International Fund for Agricultural Development (IFAD) entitled 'Enhancing the contribution of neglected and underutilized species to food security and to incomes of the rural poor' (hereafter IFAD-NUS). The goal of the programme was to contribute to strengthening food security and raising the income of small-scale farmers and rural communities around the world through securing and exploiting the full potential of the genetic diversity contained in NUS through pilot activities in strategic areas of the World (West and South Asia, North Africa, and Latin America).

Project activities in Yemen were carried out by Bioversity and national partners such as the Agricultural Research and Extension Authority (AREA) and the Ministry of Agriculture. Yemen is one of the poorest countries in the world with 45% of the population living with less than US$2 per day and 80% of the poor located in rural zones (UNDP, 2007). The harsh conditions of the poor are worsened by scarce and diminishing water resources, and by an oil-led growth of the economy which mainly benefits the urban population. The use of Medicinal and Aromatic plant (MAPs) species in Yemen goes back thousands of years and forms an important part of the Yemeni culture. Although many species have fallen into disuse, some still play an important role especially in the health and body care system. In Yemen there are about 273 endemic plant species most of which are of medicinal, cosmetic and aromatic use (Al-Nassiri, 2005).

The project target species identified were henna (*Lawsonia inermis*), nigella (*Nigella Sativa*), coriander (*Coriandrum sativum*), and cumin (*Cuminum cyminum*). These were mainly used for food flavoring or as a health or beauty remedies and provided no visible contribution to increasing farmers' income due to poor marketing strategies. They were selected on the basis of their potential for increased use, level of exposure to genetic erosion and local or regional importance for potential income generation and cultural significance. The project aimed at improving their conservation, characterization and market oriented production in order to help diversify income sources and support more sustainable rural production.

Several constraints for the conservation and use of MAPs were identified and a set of activities was thus tailored to the Yemeni context and implemented in 13 communities among three different ecological zones: the Highlands, divided into Northern, Central and Southern area; the Coastal zone, divided in eastern, western and southern areas; and the Eastern Plateau, a semi-desert area. Specifically interventions in order to offset the lack or loss of germplasm and traditional knowledge of target species were implemented identifying constraints and opportunities for their better use. Through the introduction of *ex situ* and on-farm conservation agronomic practices the project aimed at creating and securing the conservation of selected species as well as promoting their use. A Seed Supply System was established and seeds were purified and conserved in genebanks and then planted out for multiplication and distribution to farmers and the private sector. Pilot farmers produced certified seeds that were cleaned, sorted and distributed to a larger number of farmers to establish a seed bank and to sell seeds through cooperatives. Fertilization trials were carried out under farmers' management in Central Highlands by using organic matter (manure) and chemical fertilizers (NPK) and the result was an increase in the yield of target crops by almost double (table1).

Table 1 | **Fertilizer trial in Maber, Central Highlands**

Crop	**Treatment**	**Yield (kg/ha)**
Nigella	Manure+ 50kg/ha NPK	2200
	Manure	1300
Coriander	Manure+ 50kg/ha NPK	2300
	Manure	1350
Cumin	Manure+ 50kg/ha NPK	1400
	Manure	800

Moreover studies on innovative, more effective or cheaper post harvest and processing methods for the target crops were carried out. Traditional knowledge on cultivation, processing and utilization was collected and documented and research was conducted on growing, irrigation, cultivation and fertilizer application methods, in order to provide tailored trainings to farmers. Extension staff, both female and male, was selected in various sites to provide assistance in the initial implementation of the project and to facilitate the exchange of indigenous knowledge and experience among local communities. Community-based participatory courses were undertaken to improve farmers' and herbalists' knowledge on selected crops and accustom them to enhanced agronomic practices.

Table 2 shows the impact pathway of the project under assessment, its major goal, outcome achieved and outputs produced.

Table 2 | **Impact Pathway**

Areas of intervention	Tangible outputs	Outcome	Impact
- Availability of genetic material of the target species; - Conservation of germplasm and associated traditional knowledge; - Documentation of knowledge on uses, constraints and opportunities; - Income generation; - Market, commercialization and demand limitations; - National capacities for research and development-oriented activities; - Effective links between conservation and crop "filières"; - Adequate policy and legal frameworks and public awareness.	- Seed supply communities established; - Improved planting material produced and distributed to farmers; - *Ex situ* accessions collected, evaluated and multiplied; - Field genebanks established; - New varieties introduced in the Central highlands, Southern uplands and Southern coasts; - Publication in reports of indigenous knowledge of production, utilization, constraints and opportunities; - Agronomic techniques improved; - Botanical and agronomic characterization of target species.	- Improved availability of seeds and planting material (quantity and quality); - Enhanced information on use, constraints and opportunities; - Adoption of cost-effective production practices; - Increased availability of low-cost post-harvest technologies; - Added value through innovative marketing strategies.	Raising income through securing and exploiting the full potential of the genetic diversity contained in NUS.

Assessing the impact of the project

The impact assessment of a reseach or development project attempts to determine the extent to which the project has achieved the intended changes in the short- or medium-term, attributing these changes to an intervention. A major consideration for impact evaluations is the counterfactual, which is the change that would have occurred without the intervention. Thus, the approach attempts to measure the outcome of a programme in isolation of other possible interventions and effects not caused by the programme (Rossi and Freeman, 1993; Backer, 2000). Other confounding factors may have contributed to the magnitude and distribution of the outcomes, and is thus necessary to establish the causal relationships between the intervention and the outcome.

There are mainly three broad methods of evaluating impact of research and development programmes. These are distinguished as quantitative, qualitative and participatory methods. These methods have different data requirements, data collection and analysis, and each have inherent strengths and weaknesses. Social outcomes of development projects are usually difficult to measure using quantitative approaches, while qualitative approaches are much better in this respect as they are able to give a broader picture, expose causal links between events, processes and outcomes, and allow for more indirect impacts of development programmes to be revealed (Wright, 2003). Though participatory methods tend to be more qualitative, not all qualitative methods are participatory e.g. the use of semi-structured interviews, yet, on the other hand, it is possible for some participatory methods to yield quantitative data. Participatory evaluation usually emphasizes the inclusion of a broad range of stakeholders including the beneficiaries (or target groups) in the evaluation design, data generation, analysis and interpretation (Mulwa and Nguluu, 2003). In cases where qualitative techniques are used in carrying out impact evaluation one relies on the respondents' knowledge on the conditions surrounding the programme being evaluated or carries out a participatory evaluation in which all or almost all stakeholders are involved. In this way the data is easily corroborated. The qualitative evaluation enables the evaluator to assess perceptions, conditions and to describe the processes by which programme outputs and activities influence outcomes and eventual social impacts that are not easy to assess with quantitative evaluations. However, the main drawback is usually the small size of the sample that always makes it difficult to have a statistically robust analysis (Baker, 2000). Determining the counterfactual and causality is usually a challenge with qualitative impact analysis. Using quantitative's techniques, Caliendo and Hujer (2006) indicate that impacts of programme participation have to be evaluated following a three steps process. Firstly impacts at micro level have to be considered, observing the participation effect on the individuals; secondly, social impacts at a broader level have to be measured. Lastly, a cost-benefit analysis should assess the economic efficacy of the programme, calculating and comparing benefits and costs of the implemented project. The economic surplus approach (which measures returns on investment by calculating the change in consumer and producer surpluses that result from technological change, and the net present value or internal rate of return) is in fact the most popular methodology used to assess the impact of agricultural research. In this study however methodological difficulties do not allow the application of this framework (Maredia *et al*., 2000) thus alternative quantitative methods of analysis are applied focusing specifically on the first step indicated by Caliendo and Hujer (2006).

Data and methods of analysis

This study employs a quasi-experimental design, where a control group is sought from a larger survey and matched with the treatment group. Randomly placing individuals within the treatment and control groups ensures that on average any differences can be attributed to the project. Contamination of the control group however does occur from people's interaction and movement in and out of the control area in the case of interventions which take place over a long period of time. Our analysis is based upon 148 randomly selected households, of which 61 represent project participants (treatment group that voluntarily expressed their willingness to participate) and 87 the non-participants (control group). The questionnaires were submitted in the three different ecological zones covered by the project as shown in Table 3 and Figure 1.

Table 3 | **Distribution of questionnaires in different designated project areas**

Region	**Project Sites**	**No. of observations**			**Activities Undertaken**	**Percentage of observations**
		Treat.	**Contr.**	**Tot**		
Highlands		**40**	**57**	**97**		**65.5%**
Northern	Jedder	8	8	16	-Setup of local germplasm supply system -Collection & documentation of indigenous knowledge on use of NUS -Seed production -Traaning on marketing opportunities	
	Shebam	0	4	4		
Central	Assm	5	8	13	-Establishing farmers Genbank -Establishing farmer school for NUS(use ,constraints and opportunity) -studing agricultural practices for targeted NUS (nigella, cumin and coriander) -Training farmers on marketing opportunities and some practices on value chain -Formulation farmers groups for production and marketing NUS	
	Maaber	7	8	15		
	Rusabah	6	9	15		
	Anis	4	1	5		
Southern	Kitab	6	11	17	- Testing new varieties of coriander and nigella . - Collection and documentation of Indigenous knowledge on traditional medicinal use.	
	AlSaddah	4	8	12		
Coastal		**19**	**27**	**46**		**31.1%**
Southern	Lahj	11	5	16	- On farm conservation of henna - Testing new Henna varieties - Studying Agriculture practices on henna cultivation - Post harvest technology of henna	
	Abian	1	4	5		

					- Marketing opportunities	
Eastern	Kail Bawazeir	6	14	20	- On farm conservation of henna - Testing new henna varieties - Studying Agriculture practices on henna cultivation - Post harvest technology of henna - Marketing opportunities of henna. - organizing Farmer groups for production and marketing henna	
	Al-Mukalla	1	4	5		
Plateau		**2**	**3**	**5**	-	**3.4%**
	Seiyun	2	3	5	- Germoplasm collection - Establishment seed supply system - Testing new varieties of nigella and henna - Commercialization and marketing henna - Post harvest technologies	
Total		**61**	**87**	**148**		

The different distribution of observations per project site is given by the degree of project intervention in each area. The majority of activities in fact were implemented in the Highlands because of geographical, social and political reasons, while there were fewer activities in Costal and Plateau areas due to difficult access, lack of infrastructure and security concerns.

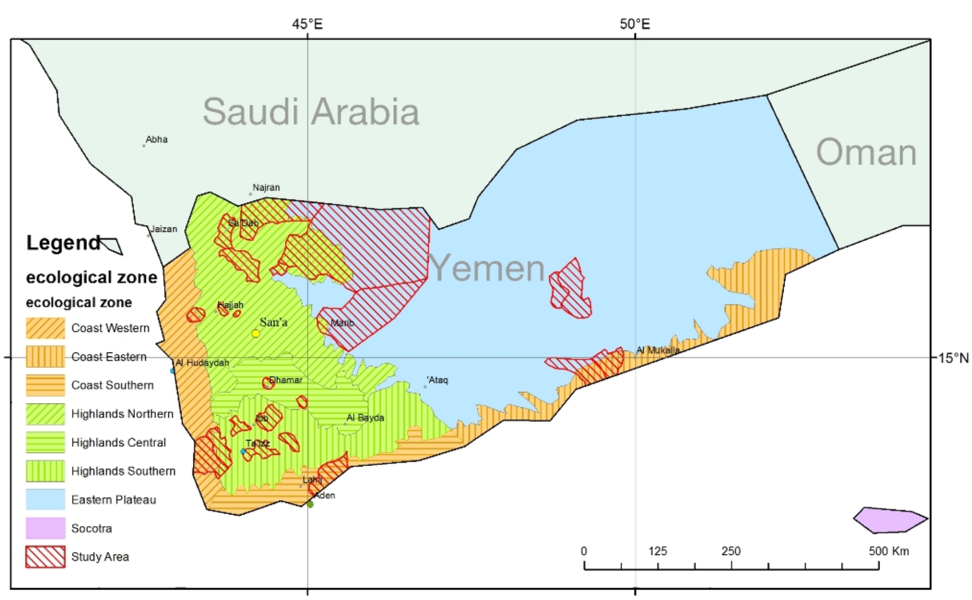

Figure 1: Project sites distribution

The questionnaire submitted to farmers was divided in five sections: the first investigated socio-demographic matters on household size and composition; the second part was drawn up to establish household wealth in terms of assets and services to which they have access; the next two sections concerned agronomic matters, while the last investigated gender issues and household decision making, and collected information about the participation of the household in local organizations. One limitation of this study was the unavailability of baseline data. In the absence of the 2002 dataset, the study design was modified to generate pre-treatment data by use of recall. This proved to be a difficult task for some households. The enumerators aided the recall process by use of important events that occurred in Yemen or in the communities in 2002 identified during pre-interview focus group discussions.

The data analyzed in this case present a number of important problems common to many impact evaluations which affect our ability to correctly determine the causal impact of the programme within the households, i.e. the potential presence of correlation between the participation and the unobserved components that may influence the participation. The correlation can stem from various reasons, including omitted variables, sample selection and simultaneous causality. Therefore in order to assess the impact of project participation on cultivation of MAPs and ultimately on rural livelihoods, a simultaneous multivariate probit framework is developed. The statistical model adopted in this work is based on the hypothesis that the probability of observing an increase of agricultural perceived yields depends on the households' voluntary participation to the program. The empirical approach follows a three-equation form where the household participation to the program is a dummy endogenous regressor and outcomes are the observed agricultural yields improvements reported by farmers. In order to avoid biased results in our estimation, endogeneity of the project participation is taken into account. Programme participation in fact is included in the system equations both as dependent variable (in the first equation) and as explanatory variable (in the second and third equation). Angrist (2001) presents the estimating issue of modeling binary endogenous regressors with binary and nonnegative outcome.

The first equation estimates the probability of the household's participation in the program:

Participation = f(livestock assets; age; education; region; farm land size; tractor owner; producers of MAPs; producers of other crops; availability of irrigation; agricultural capital assets).

The second and the third equations estimate respectively the probability of observing an increase of yields and profits from growing MAPs (henna, curmin, nigella and coriander) and other crops (wheat, khat, fruits, onion, garlic, legumes and others).

Yields increase MAPs/ other crops = f(participation; age; education; region; producers of MAPs; producers of other crops; availability of irrigation; farm land size; tractor owner; agricultural capital assets).

$$y_1^*=(\mathbf{X'\beta} + \varepsilon_1),\ y_2^*=(y_1\delta_2 + \mathbf{Z'\gamma} + \varepsilon_2),\ y_3^*=(y_1\delta_3 + \mathbf{W'\chi} + \varepsilon_3) \quad (1)$$

Additional model details are provided in Annex 1. The presence of 'livestock asset' has been chosen as instrument variable; the rationale behind this choice is that this variable is correlated with the endogenous regressor (household participation) but it should not be directly correlated with the perceived yields increase of MAPs and other crops.

Following Arendt and Holm (2006), the proposed empirical model project participation (y_1) could be linked to the observed increase in productivity (y_2 and y_3) because of three basic hypotheses:

1. There is a direct causal relation between the project participation (y_1) and the increase of yields in growing MAPs (y_2) and other crops (y_3) through the estimation of parameter δ_2 and δ_3 (the scalar parameters).
2. There is a correlation due to the independent variables (**Z**, **X** and **W**, specifying households' socio-demographic characteristics) that influence both the project participation and the increase of yields.
3. There is a correlation due to the unobserved characteristics of the household (ε_1, ε_2, ε_3).

Results and discussion

As shown in Table 4, the average household size is 8 members, but noteworthy differences are found in the Northern Highlands, with an average of 13 members per household, and the Eastern Coast and Southern Highlands where average household size is the lowest. This is reflected in the household dependency ratio which is low on the Eastern Coast and high in Central Highlands[1].

Table 4 | **Averages of Selected Socio-Economic Indicators of the Survey Households**

Variable	**Northern Highlands**	**Central Highlands**	**Southern Highlands**	**Eastern Coast**	**Southern Coast**
	Means (StDev)	Means (StDev)	Means (StDev)	Means (StDev)	Means (StDev)
Number of Household Members	13.3 (4.7)	8.12 (3.3)	5.62 (2.04)	5.3 (1.6)	8.72 (3.99)
Dependency Ratio	.35 (.15)	.47 (.17)	.35 (.26)	.13 (.21)	.36 (.20)
Age of household head in years*	52 (15.3)	50.3 (14.7)	49.7 (13.7)	54.3 (12.3)	54.5 (11.9)
Average education level of adults in years	3.53 (0.93)	2.77 (0.8)	3.13 (1.08)	3.85 (1.13)	3.07 (0.67)

Land owned in hectares	2.96	3.82	3.46	3.68	1.39
Land under cultivation (ha)	2.74	3.32	3.3	2.69	0.94

Household decision making with regard to financial matters and expenditures is mainly a male prerogative (Table 5), as the husbands are the main cash earners. However, the farmers who answered the gender section of the survey (66%) stated that women have a predominant role in the production of MAPs. Women are highly involved in MAP weeding, harvesting and cleaning, in different food preparations and in selling fresh products in local markets, especially for coriander. Women's condition in Yemen is among the worst in the world: the legal framework itself accentuates gender inequalities restraining women from access to resources and entrepreneurship, leaving them to the only alternative of unpaid labor in agriculture (World Economic Forum, 2008). Therefore this priority role and the fact that women participate in group decision making concerning MAPs, deciding upon strategies towards farm improvements, is relevant for conservation strategies and gender empowerment warranting further research. Authors such as Nussbaum (2000) and Dreze and Murthi (2001) sustain that households where women take cash spending decisions perform better in terms of nutrition, health, education and overall well-being of the family.

Table 5 | **Gender Roles in Household Decision Making**

Gender Role	**HH Member Making Decisions**				
	Wife	Husband	Together	Other	Total (N=98)
Production of MAP	10%	87%	3%	0%	100%
Member receiving cash	8%	90%	2%	0%	100%
Cash spending decisions	7%	84%	8%	0%	100%
Leadership role in the production of MAP	66%	33%	0%	0%	100%
Participation in group decision making	81%	18%	0%	0%	100%
Strategies towards farm improvement	78%	19%	0%	0%	100%

Positive changes in women’s roles in handling minor crops were also reported by many authors in Benin, Ethiopia, Kenya and Nigeria (Rahman and Ibrahi 2007; Ogato *et al*. 2009; Gotor and Irungu 2010; Ogunniyi and Ajao, 2010; Umar *et al*. 2010; Ayoola *et al*. 2011; Dansi *et al*. 2012) therefore further research should be conducted in order to promote a sustainable production of MAPs and upscale women’s roles in handling cash generated .

Land use varies across the regions based on the agroclimatic conditions (90% in the Highlands and 70% in the Coastal regions). Table 6 reports the percentage of farm area under different cultivation in 2002 and 2007, and farmers’ perceived yields.

Table 6 | **Percentage of farm area and reported yield under different cultivations**

Cultivations	**% of farm area 2002**	**2002 yield (ton/ha)**	**% of farm area 2007**	**2007 yield (ton/ha)**
Fruit Trees	19	180	25	155
Onion	15	243	19	264
Khat (*Catha edulis F)*	17	21	23	28
Legumes	12	25	11	41
Wheat	24	102	24	125
Nigella	6	19	11	27
Henna	13	374	19	516
Cumin	5	2	11	7
Coriander	8	40	12	63
Other Crops	25	339	25	339

Overall percentage of cultivated land and related yield increased over the years (except for legumes and wheat). It is interesting to note that, although MAPs are minor crops covering less than 20% of the cultivated area, their production in terms of percentage of farm area cultivated doubled or increased significantly between 2002 and 2007 (+83% for nigella, + 46% for henna, +120% for cumin, and + 43% for coriander). The increased production in terms of percentage of farms cultivated under MAPs is also reflected in a significant increase in yields generated between 2002 and 2007.

The increase in production reported between 2002 and 2007 (shown in Table 6) was accompanied by an increase in MAPs use both for self consumption and marketing. Table 7 shows trends of MAPs use for self consumption and marketing in 2002 and 2007. Compared to 2002, the number of farmers growing henna (produced only in the Eastern Coast), nigella and cumin (produced in the Northern Highlands) for self consumption almost doubled. Also the number of farmers marketing MAPs followed a similar trend. Moreover, the number of farmers growing MAPs for marketing purposes is almost double compared to the those growing MAPs for self consumption.

Table 7| **Percentage of farmers who grew MAPs for self consumption and for marketing and the generated income in 2002 and 2007**

	Self Consumption		**Marketing**		**Income (YER)***		**% Change**
	2002	2007	2002	2007	2002	2007	
Henna	12%	19%	24%	35%	13.365	11.648	-13%
Nigella	9%	13%	14%	20%	6.021	9.271	54%
Cumin	6%	9%	6%	7%	5.284	9.492	80%
Coriander	15%	17%	17%	24%	7.236	10.153	40%

**1,000 YER = 4.5 $US*

Table 7 shows that income gained from marketing MAPs also increased consistently (nigella +54%, coriander +40% and cumin +80%). However, data for henna show a decrease in income (-13%) despite the number of farmers marketing it and the significant increase in average yields of henna cultivation (see Table 5 for yield). It should be noted that the 13% drop is related to the income generated by the marketing of henna dry leaves, while the income derived from fresh leaves increased. Dry leaves are in fact mainly used for export and their processing implies high costs sustained by only 20% of the farmers interviewed, while the others tend to sell henna in the form of fresh leaves in local markets. This result shows the need to focus on marketing as well as post harvest handling in order to improve product competitiveness. Further research should focus on the analysis and development of value -addition chains in order to increase income-generating potential from MAPs for the export market.

The above explorative analysis provides some preliminary understanding of the impact of project participation on household livelihoods highlighting changes occurring over a period of time (2002-2007). Therefore we believe that these preliminary findings require an analytical approach described in the previous section in order to formally analyze these results and assess whether or not these changes occured as a result of the project interventions.

Table 8 reports on the variables used for the model (see Annex 1 for model specification), their mean and standard deviation.

Table 8 | **Descriptive statistics of the variables used in the model – (n = 148)**

Variable	**Variable label**	**Average**	**Std. Dev**
Participation	*Whether households participated in the program*	.426	.496
Livestock Assets	*Whether households have livestock*	.860	.350
Yield Incl. MAPs	*Whether households have had an increase of MAPs yields*	.392	.491
Yield Incl. Other	*Whether households have had an increase of other crop yields*	.426	.496
Farm size	*Number of Ha*	3.40	4.49
Irrigation	*Whether households have irrigation system*	.322	.469
Location	*Project site*	6.55	3.58
Age	*Age of the head of the household*	49.55	14.63
Education	*Number of years in school*	5.02	6.01
Agr.assets	*Number of agricultural capital assets of the household*	19.03	7.94
Tractor	*Whether households have a tractor*	.135	.343
Other Producer 02	*Household producer of Other Crop in 2002*	.579	.495
MAPs Producer 02	*Household producer of MAPS in 2002*	.344	.476

The system estimation results are listed in Table 9. Overall, the model shows a good explanatory capacity. Indeed, prediction indexes, which measure the relation between Y values correctly determined and total Y values observed are 68.2, 76.3 and 72.3 respectively for equation 1, equation 2 and equation 3 of the system[2]. The first equation of the model with response variable 'whether household is from treatment group or not' shows that participation in the project does not depend on the household socio-economic characteristics or on the farm size. However the project has attracted mainly households with past experience in growing MAPs and other crops.

Table 9 | **Regression results from the multivariate probit**

	Participation		Increased MAPs yields		Increased Yields Other Crops	
Equation	Coeff.	Robust Std. Error	Coeff.	Robust Std. Error	Coeff.	Robust Std. Error
HH Participation			1.210 ***	0.241	1.149 ***	0.455
Livestock Assets	0.773 ***	0.348				
Age	-0.002	0.011	-0.013	0.011	-0.020 **	0.011
Education	0.008	0.025	-0.009	0.025	-0.035	0.025
Location	-0.017	0.038	0.083 ***	0.039	0.063 **	0.038
Other producer 02	0.641 ***	0.305	-0.201	0.332	0.648 **	0.336
MAPs producer 02	0.610 ***	0.300	1.007 ***	0.346	0.458	0.323
Farm size	0.026	0.021	-0.008	0.032	-0.020 **	0.029
Tractor	-0.286	0.373	-0.646 *	0.449	-0.064	0.356

Observation	*148*	*ρ(Part./ Y. Other)*	*-0.668****	*Prob>χ2*	*0.000*
LogLikelihood	*-239.13*	*ρ(Y.MAPs./ Y. Other)*	*-0.005*	*L.R χ2 (d.f)*	*7.20(3)*
ρ(Part./ Y. MAPs)	*-0.473***	*Wald χ2 (d.f)*	*178.3(30)*	*Prob>χ2*	*0.065*

Notes: *significant at the 15% level; **significant at the 10% level; ***significant at the 5% level

The above results are also confirmed by the computed marginal effects reported in Table 10, which demonstrate and quantify the role of participating in project activities in the three equations of analysis.

Table 10 | **Average marginal effects of selected variables on probability of project participation and yield increase (%)**

Variables	**Program Participation**	**Increase Yields MAPs**	**Increase Yields Other Crops**
Other Producer 02	+21.4		+19.1
MAPs Producer 02	+20.6	+28.6	
HH Participation		+36.0	+35.7
Irrigation	+17.5	+27.1	
Agr Assets	-1.34		+1.07

Table 10 shows the effect of our covariates reported in rows on our three dependent variables reported in columns. As reported in Table 9, in our first equation the fact that households were producing both MAPs and other crops is significant as a determinant of project participation at 5% level. This means that

MAPs producers have a higher propensity (+20.6%) to participate in the project's activities than those who do not produce MAPs.

Table 9 also shows that in our second and third equation, project participations (used as a covariate) is significant as a determinant for MAPs or other crops yield increase at 5% level. Therefore, a household participating in project activities has a propensity of almost 36% to increase its MAPs' yield and of 35.7% to increase the yield of other crops compared to those that do not participate. It is interesting to note that having an irrigation system increases the probability of growing MAPs by 27.1%, while it does not appear to be significant for other crops. On the contrary, owning agricultural assets increases the propensity of incrementing other crops' yield by 1% but does not seems to be significant for MAPs yields. The presence of agricultural assets and farm size coefficients has been deemed not significant in in increased MAPs yields. This result is attributed to poorer households owning or cultivating less land than richer ones, but owning a smaller or less capital-intensive farm does not significantly differ from zero.

Lastly the correlation coefficients between the error terms among the equations ($\rho_{1/2}$ and $\rho_{1/3}$) are negative and significantly different from zero. This result confirms the empirical efficacy in simultaneously modeling the equation system; it improves the estimation efficiency, including in the analysis the impact of valuable non-observable information, identifying and correcting the participation endogeneity bias.

Conclusion

In this paper we have analyzed the impact at the outcome level of a research project, lead by Bioversity and its partners in Yemen, aimed at increasing NUS conservation and use to improve people's livelihoods. The project has attracted small- scale farmers mainly with past experience in growing MAPs and other crops. Participants were trained in various activities including introduction of new varieties, plant protection, fertilizer application, irrigation and better post harvest practices. Access to material conserved in the newly established genebank in Sana'a increased significantly as awareness on MAPs and the introduced Seed Supply System grew. Meetings, informative fairs and national workshops further developed stakeholders' awareness of the opportunities connected with MAPs. In order to assess the impact of project participation on the cultivation of MAPs and ultimately on rural livelihoods, we developed a simultaneous multivariate probit framework. Results show that project participation positively impacts the probability of observing an increase in yields both of MAPs and other crops. The increase in perceived yield is likely to have an impact in terms of income generation and in improving people's wellbeing thanks to the increased self consumption and marketing opportunities generated as a result of project participation. This direct causal relation between project participation and increased yields shows that the project was successful in transferring knowledge and providing information on better agronomic practices and opportunities related to growing MAPs. These results also support findings from Anderson and Hazell 1989, Ceccarelli *et al*. 1992, Cleveland 1993, Cooper *et al*. 1992, Pimentel *et al*. 1992, which recognize the contribution of agrodiversity to yield stability in agricultural systems. The generated benefits incentivized farmers to continue to apply the interventions beyond the lifetime of the project ensuring thus a sustainable process in which exogenous interventions, once adopted by farmers become integrant part of farmer's agronomic practices.

Subsistence farmers are sometimes disincentivized from conserving agricultural diversity because of the lack of economic returns in the market (Pascual and Perrings, 2007). Given that the main constraints to profitable MAPs production are on the market side, we argue that the application of a participatory approach focused on reviving and improving traditional agronomic knowledge, marketing strategies and income generation, such as the one applied by Bioversity's research projects, has great potential in improving rural livelihoods while conserving crop diversity, but should be implemented consistently over time.

These findings should stimulate further research on tailoring knowledge transfer and encourage the development of projects aimed at improving rural livelihoods through greater knowledge transfer and use of local agrobiodiversity, while supporting the conservation of important genetic resources. If sustainable agriculture is defined as optimizing long-term diversity and stability (Cleveland *et al*., 1994) and long term stability is achieved by locally diverse and specific management strategies (Cleveland 1991, Ghersa *et al*. 1994, Richards 1986) that take into consideration indigenous knowledge (NRC 1992, Thurston 1992) and the rights of small-scale farmers to control their crop and farm resources (Cooper *et al*. 1992, Soleri *et al*. 1994) we can ultimately appreciate the important role played by NUS for the achievement of sustainable agriculture.

Notes

1. The dependency ratio is the ratio of dependents - people younger than 15 or older than 64 - to the working-age population–those aged 15-64 (Kleiman, 1967).
2. An observation is classified as positive (negative) if the value of the corresponding cumulative distribution function is $\geq$ (<) 0.5.

Acknowledgment

The authors wish to thank staff from the Agricultural Research and Extension Authority (AREA) for facilitating the field work. The contribution of research assistants from El Mukalla, Lahj and Sana'a is highly appreciated. The authors are very grateful for careful and thoughtful comments received from

Stefano Padulosi, Mauricio Bellon and number of anonimous reviewers. This paper was edited by Olga Spellman (Bioversity International).

Annex 1: Model Specification

In empirical terms, if we consider three binary variables, y_1, y_2 and y_3, the structural trivariate probit model supposes that:

$$y_1^*=(\mathbf{X'\beta} + \varepsilon_1),\ y_2^*=(y_1\delta_2 + \mathbf{Z'\gamma} + \varepsilon_2),\ y_3^*=(y_1\delta_3 + \mathbf{W'\chi} + \varepsilon_3) \qquad (2)$$

with

$$y_1 = \begin{cases} 1 & if \quad y_1^* > 0 \\ 0 & if \quad y_1^* \le 0 \end{cases}$$

$$y_2 = \begin{cases} 1 & if \quad y_2^* > 0 \\ 0 & if \quad y_2^* \le 0 \end{cases} \qquad (3)$$

$$y_3 = \begin{cases} 1 & if \quad y_3^* > 0 \\ 0 & if \quad y_3^* \le 0 \end{cases}$$

and **X**, **Z**, **W** are matrixes of exogenous variables, relative to the household's socio- demographic characteristics, such as education level, age, type of house and its agricultural assets; $\boldsymbol{\beta}$, $\boldsymbol{\gamma}$ and $\boldsymbol{\chi}$ are parameter vectors and δ_2 and δ_3 are scalar parameters.

The error terms are assumed to be independently and identically distributed as trivariate normal:

$$\begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{pmatrix} \sim N(0,\Sigma) \qquad \Sigma \equiv \begin{bmatrix} 1 & \rho_{12} & \rho_{13} \\ \rho_{12} & 1 & \rho_{23} \\ \rho_{13} & \rho_{23} & 1 \end{bmatrix} \qquad (4)$$

In this context the $\Pr[y_1 = 0, y_2 = 0, y_3 = 0]$ is equal to:

$$\int_{-\infty}^{-\mathbf{X}'\boldsymbol{\beta}} \int_{-\infty}^{-(\mathbf{Z}'\boldsymbol{\gamma}+y_1\delta_2)} \int_{-\infty}^{-(\mathbf{W}'\boldsymbol{\chi}+y_1\delta_3)} \phi_3 \ (\varepsilon_1, \varepsilon_2, \varepsilon_3, \rho_{12}\rho_{13}\rho_{23}) \mathrm{d}\varepsilon_3 \mathrm{d}\varepsilon_2 \mathrm{d}\varepsilon_1 \quad (5)$$

Where $\phi_3(\cdot)$ is the trivariate standard normal distribution and the ρ_{ij} is the correlation coefficient between the error terms of the equation *i* and *j*. In estimation, if the null hypothesis that coefficient of $\rho_{ij} = 0$ cannot be rejected, this implies that the equations do not need to be estimated as a system and can be estimated separately. The condition $\rho_{ij} = 0$ can be tested using a LR test. In order to approximate the trivariate normal CDF, we use the GHK (Geweke-Hajivassiliou-Keane) smooth recursive simulator (Mariano *et al.,* 2000).

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