

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

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9 **Abstract**

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

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

22
23 **Introduction**

24 The preservation of agricultural biodiversity as a means to empower poor people and improve their well-
25 being has attracted many research and development projects. Agro-biodiversity conservation and its use
26 can be a valuable option for poor people not only in terms of income opportunities, but also for diet
27 diversification, community involvement and health (Bellon, 2004; Bellon *et al.*, 2006; Meinzen-Dick *et*
28 *al.*, 2009; Smale *et al.*, 2008; Sthapit *et al.*, 2008), and for the sustainable management of agricultural
29 systems (Frison *et al.*, 2011; Jackson *et al.*, 2007; Mijatović *et al.*, 2012). Experimental studies have
30 demonstrated that higher diversity ecosystems give greater productivity than lower diversity ones
31 (Vernooy and Song, 2004; Tilman *et al.*, 2005) and furthermore that agro-biodiversity helps risk-averse
32 farmers to cope with uncertainty by allocating land to different crop species (Di Falco and Perrings, 2005;
33 Roe *et al.*, 2011). Neglected and underutilized species (NUS), key componets of agrobiodiversity,
34 comprise domestic and wild species and varieties that are considered "minor" in terms of poor research
35 and development (R&D) efforts and their socio-economic potential not being fully exploited by policy

1 makers, scientists and development workers, mainly because they fail to compete with major commodity
2 crops (Padulosi *et al.*, 2002; Andersen, 2012). However NUS are often far from minor in the lives of the
3 rural poor, particularly the more vulnerable members of society such as women, children and elderly
4 groups. This diversity is a key asset of the rural poor in developing countries who depend on agriculture
5 for their livelihoods and well-being (Lockie and Carpenter, 2010). Moreover, NUS occupy important
6 agro-ecological niches, holding a comparative advantage over commodity crops in terms of adaptation to
7 marginal and fragile ecosystems (such as arid and semi-arid lands, mountains, steppes and tropical
8 forests), to changing environmental conditions, and to low-input agricultural systems (Bala Ravi *et al.*,
9 2010); Mal (2007) and Dansi *et al.*, (2012) report that many NUS since are recorded to be adapted to
10 difficult environments unfit for other crops can provide sustainable productions contributing significantly
11 to maintain diversity rich and hence more stable agroecosystems. By contributing to agricultural
12 diversification they also offer indirect benefits, such as increasing the stability of production systems, and
13 supporting self-reliance in countries that aim to reduce the import of agricultural products (Padulosi *et al.*,
14 2002). Finally, many such species have high cultural significance and are therefore ideal instruments for
15 promoting the maintenance of the traditional knowledge, identity and self-esteem of local communities.

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

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

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

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

14 **The project background**

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

30 Project activities in Yemen were carried out by Bioversity and national partners such as the
31 Agricultural Research and Extension Authority (AREA) and the Ministry of Agriculture. Yemen is one of
32 the poorest countries in the world with 45% of the population living with less than US\$2 per day and 80%
33 of the poor located in rural zones (UNDP, 2007). The harsh conditions of the poor are worsened by scarce
34 and diminishing water resources, and by an oil-led growth of the economy which mainly benefits the

1 urban population. The use of Medicinal and Aromatic plant (MAPs) species in Yemen goes back
 2 thousands of years and forms an important part of the Yemeni culture. Although many species have fallen
 3 into disuse, some still play an important role especially in the health and body care system. In Yemen
 4 there are about 273 endemic plant species most of which are of medicinal, cosmetic and aromatic use (Al-
 5 Nassiri, 2005).

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

14 Several constraints for the conservation and use of MAPs were identified and a set of activities was
 15 thus tailored to the Yemeni context and implemented in 13 communities among three different ecological
 16 zones: the Highlands, divided into Northern, Central and Southern area; the Coastal zone, divided in
 17 eastern, western and southern areas; and the Eastern Plateau, a semi-desert area. Specifically interventions
 18 in order to offset the lack or loss of germplasm and traditional knowledge of target species were
 19 implemented identifying constraints and opportunities for their better use. Through the introduction of *ex*
 20 *situ* and on-farm conservation agronomic practices the project aimed at creating and securing the
 21 conservation of selected species as well as promoting their use. A Seed Supply System was established
 22 and seeds were purified and conserved in genebanks and then planted out for multiplication and
 23 distribution to farmers and the private sector. Pilot farmers produced certified seeds that were cleaned,
 24 sorted and distributed to a larger number of farmers to establish a seed bank and to sell seeds through
 25 cooperatives. Fertilization trials were carried out under farmers' management in Central Highlands by
 26 using organic matter (manure) and chemical fertilizers (NPK) and the result was an increase in the yield
 27 of target crops by almost double (table1).
 28

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

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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
<ul style="list-style-type: none"> - 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. 	<ul style="list-style-type: none"> - Seed supply communities established; - Improved planting material produced and distributed to farmers; - <i>Ex situ</i> 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. 	<ul style="list-style-type: none"> - 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. 	<ul style="list-style-type: none"> Raising income through securing and exploiting the full potential of the genetic diversity contained in NUS.

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Assessing the impact of the project

The impact assessment of a research 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

1 intervention. A major consideration for impact evaluations is the counterfactual, which is the change that
2 would have occurred without the intervention. Thus, the approach attempts to measure the outcome of a
3 programme in isolation of other possible interventions and effects not caused by the programme (Rossi
4 and Freeman, 1993; Backer, 2000). Other confounding factors may have contributed to the magnitude and
5 distribution of the outcomes, and is thus necessary to establish the causal relationships between the
6 intervention and the outcome.

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

1 application of this framework (Maredia *et al.*, 2000) thus alternative quantitative methods of analysis are
 2 applied focusing specifically on the first step indicated by Caliendo and Hujer (2006).

3

4 **Data and methods of analysis**

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

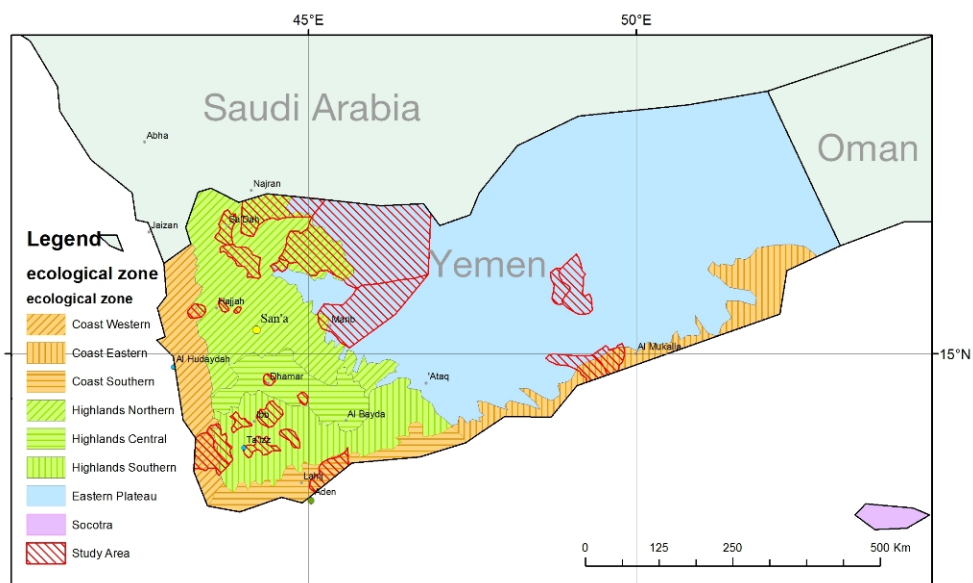
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Table 3 | **Distribution of questionnaires in different designated project areas**

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	
	Shebam	0	4	4	-Traaning on marketing opportunities	
	Assm	5	8	13	-Establishing farmers Genbank	
	Maaber	7	8	15	-Establishing farmer school for NUS(use ,constraints and opportunity)	
Central	Rusabah	6	9	15	-studing agricultural practices for targeted NUS (nigella, cumin and coriander)	
	Anis	4	1	5	-Training farmers on marketing opportunities and some practices on value chain -Formulation farmers groups for production and marketing NUS	
	Kitab	6	11	17	-Testing new varieties of coriander and nigella .	
Southern	AlSaddah	4	8	12	-Collection and documentation of Indigenous knowledge on traditional medicinal use.	
Coastal		19	27	46		31.1%
Southern	Lahj	11	5	16	- On farm conservation of henna - Testing new Henna varieties	
	Abian	1	4	5	- Studying Agriculture practices on henna cultivation - Post harvest technology of henna	

					- Marketing opportunities
	Kail Bawazeir	6	14	20	- On farm conservation of henna - Testing new henna varieties - Studying Agriculture practices on henna cultivation
Eastern	Al-Mukalla	1	4	5	- Post harvest technology of henna - Marketing opportunities of henna. - organizing Farmer groups for production and marketing henna
Plateau		2	3	5	-
	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	

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



5
6 Figure 1: Project sites distribution

7

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

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

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

26
$$Participation = f(\text{livestock assets; age; education; region; farm land size; tractor owner;}$$

27
$$\text{producers of MAPs; producers of other crops; availability of irrigation; agricultural capital}$$

28
$$\text{assets}).$$

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

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

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

4
 5
 6 Additional model details are provided in Annex 1. The presence of ‘livestock asset’ has been chosen
 7 as instrument variable; the rationale behind this choice is that this variable is correlated with the
 8 endogenous regressor (household participation) but it should not be directly correlated with the perceived
 9 yields increase of MAPs and other crops.

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

- 12 1. There is a direct causal relation between the project participation (y_1) and the increase of yields
 13 in growing MAPs (y_2) and other crops (y_3) through the estimation of parameter δ_2 and δ_3 (the
 14 scalar parameters).
- 15 2. There is a correlation due to the independent variables (\mathbf{Z} , \mathbf{X} and \mathbf{W} , specifying households’
 16 socio-demographic characteristics) that influence both the project participation and the increase
 17 of yields.
- 18 3. There is a correlation due to the unobserved characteristics of the household ($\varepsilon_1, \varepsilon_2, \varepsilon_3$).

20 Results and discussion

21 As shown in Table 4, the average household size is 8 members, but noteworthy differences are found in
 22 the Northern Highlands, with an average of 13 members per household, and the Eastern Coast and
 23 Southern Highlands where average household size is the lowest. This is reflected in the household
 24 dependency ratio which is low on the Eastern Coast and high in Central Highlands¹.

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

1
2 Household decision making with regard to financial matters and expenditures is mainly a male
3 prerogative (Table 5), as the husbands are the main cash earners. However, the farmers who answered the
4 gender section of the survey (66%) stated that women have a predominant role in the production of
5 MAPs. Women are highly involved in MAP weeding, harvesting and cleaning, in different food
6 preparations and in selling fresh products in local markets, especially for coriander. Women's condition in
7 Yemen is among the worst in the world: the legal framework itself accentuates gender inequalities
8 restraining women from access to resources and entrepreneurship, leaving them to the only alternative of
9 unpaid labor in agriculture (World Economic Forum, 2008). Therefore this priority role and the fact that
10 women participate in group decision making concerning MAPs, deciding upon strategies towards farm
11 improvements, is relevant for conservation strategies and gender empowerment warranting further
12 research. Authors such as Nussbaum (2000) and Dreze and Murthi (2001) sustain that households where
13 women take cash spending decisions perform better in terms of nutrition, health, education and overall
14 well-being of the family.

15

Table 5 | Gender Roles in Household Decision Making

Gender Role	HH Member Making Decisions				Total (N=98)
	Wife	Husband	Together	Other	
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%

16
17 Positive changes in women's roles in handling minor crops were also reported by many authors in
18 Benin, Ethiopia, Kenya and Nigeria (Rahman and Ibrahi 2007; Ogato *et al.* 2009; Gotor and Irungu 2010;
19 Ogunniyi and Ajao, 2010; Umar *et al.* 2010; Ayoola *et al.* 2011; Dansi *et al.* 2012) therefore further
20 research should be conducted in order to promote a sustainable production of MAPs and upscale women's
21 roles in handling cash generated .

22 Land use varies across the regions based on the agroclimatic conditions (90% in the Highlands and
23 70% in the Coastal regions). Table 6 reports the percentage of farm area under different cultivation in
24 2002 and 2007, and farmers' perceived yields.

1

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 (<i>Catha edulis</i> <i>F</i>)	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

2

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

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

16

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%

17 *1,000 YER = 4.5 \$US

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

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

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

18

Table 8 Descriptive statistics of the variables used in the model – (n = 148)			
Variable	Variable label	Average	Std. Dev
Participation	<i>Whether households participated in the program</i>	.426	.496
Livestock Assets	<i>Whether households have livestock</i>	.860	.350
Yield Incl. MAPs	<i>Whether households have had an increase of MAPs yields</i>	.392	.491
Yield Incl. Other	<i>Whether households have had an increase of other crop yields</i>	.426	.496
Farm size	<i>Number of Ha</i>	3.40	4.49
Irrigation	<i>Whether households have irrigation system</i>	.322	.469
Location	<i>Project site</i>	6.55	3.58
Age	<i>Age of the head of the household</i>	49.55	14.63
Education	<i>Number of years in school</i>	5.02	6.01
Agr.assets	<i>Number of agricultural capital assets of the household</i>	19.03	7.94
Tractor	<i>Whether households have a tractor</i>	.135	.343
Other Producer 02	<i>Household producer of Other Crop in 2002</i>	.579	.495
MAPs Producer 02	<i>Household producer of MAPS in 2002</i>	.344	.476

19

20 The system estimation results are listed in Table 9. Overall, the model shows a good explanatory capacity.
 21 Indeed, prediction indexes, which measure the relation between Y values correctly determined and total Y
 22 values observed are 68.2, 76.3 and 72.3 respectively for equation 1, equation 2 and equation 3 of the

1 system². The first equation of the model with response variable ‘whether household is from treatment
 2 group or not’ shows that participation in the project does not depend on the household socio-economic
 3 characteristics or on the farm size. However the project has attracted mainly households with past
 4 experience in growing MAPs and other crops.

5
 Table 9 | **Regression results from the multivariate probit**

Equation	Participation		Increased MAPs yields		Increased Yields Other Crops	
	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
<i>Observation</i>	148	$\rho(\text{Part./ Y. Other})$		-0.668***	$\text{Prob}>\chi^2$	0.000
<i>LogLikelihood</i>	-239.13	$\rho(\text{Y.MAPs./ Y. Other})$		-0.005	$L.R \chi^2 (d.f)$	7.20(3)
$\rho(\text{Part./ Y. MAPs})$	-0.473**	$\text{Wald } \chi^2 (d.f)$		178.3(30)	$\text{Prob}>\chi^2$	0.065

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

7
 8 The above results are also confirmed by the computed marginal effects reported in Table 10, which
 9 demonstrate and quantify the role of participating in project activities in the three equations of analysis.

10
 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

11
 12 Table 10 shows the effect of our covariates reported in rows on our three dependent variables reported
 13 in columns. As reported in Table 9, in our first equation the fact that households were producing both
 14 MAPs and other crops is significant as a determinant of project participation at 5% level. This means that

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

3 Table 9 also shows that in our second and third equation, project participations (used as a covariate) is
4 significant as a determinant for MAPs or other crops yield increase at 5% level. Therefore, a household
5 participating in project activities has a propensity of almost 36% to increase its MAPs' yield and of
6 35.7% to increase the yield of other crops compared to those that do not participate. It is interesting to
7 note that having an irrigation system increases the probability of growing MAPs by 27.1%, while it does
8 not appear to be significant for other crops. On the contrary, owning agricultural assets increases the
9 propensity of incrementing other crops' yield by 1% but does not seem to be significant for MAPs
10 yields. The presence of agricultural assets and farm size coefficients has been deemed not significant in
11 increased MAPs yields. This result is attributed to poorer households owning or cultivating less land than
12 richer ones, but owning a smaller or less capital-intensive farm does not significantly differ from zero.

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

18 19 20 **Conclusion**

21 In this paper we have analyzed the impact at the outcome level of a research project, lead by
22 Bioversity and its partners in Yemen, aimed at increasing NUS conservation and use to improve people's
23 livelihoods. The project has attracted small- scale farmers mainly with past experience in growing MAPs
24 and other crops. Participants were trained in various activities including introduction of new varieties,
25 plant protection, fertilizer application, irrigation and better post harvest practices. Access to material
26 conserved in the newly established genebank in Sana'a increased significantly as awareness on MAPs and
27 the introduced Seed Supply System grew. Meetings, informative fairs and national workshops further
28 developed stakeholders' awareness of the opportunities connected with MAPs. In order to assess the
29 impact of project participation on the cultivation of MAPs and ultimately on rural livelihoods, we
30 developed a simultaneous multivariate probit framework. Results show that project participation
31 positively impacts the probability of observing an increase in yields both of MAPs and other crops. The
32 increase in perceived yield is likely to have an impact in terms of income generation and in improving
33 people's wellbeing thanks to the increased self consumption and marketing opportunities generated as a
34 result of project participation. This direct causal relation between project participation and increased

1 yields shows that the project was successful in transferring knowledge and providing information on
2 better agronomic practices and opportunities related to growing MAPs. These results also support
3 findings from Anderson and Hazell 1989, Ceccarelli *et al.* 1992, Cleveland 1993, Cooper *et al.* 1992,
4 Pimentel *et al.* 1992, which recognize the contribution of agrodiversity to yield stability in agricultural
5 systems. The generated benefits incentivized farmers to continue to apply the interventions beyond the
6 lifetime of the project ensuring thus a sustainable process in which exogenous interventions, once adopted
7 by farmers become integrant part of farmer's agronomic practices.

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

15 These findings should stimulate further research on tailoring knowledge transfer and encourage the
16 development of projects aimed at improving rural livelihoods through greater knowledge transfer and use
17 of local agrobiodiversity, while supporting the conservation of important genetic resources. If sustainable
18 agriculture is defined as optimizing long-term diversity and stability (Cleveland *et al.*, 1994) and long
19 term stability is achieved by locally diverse and specific management strategies (Cleveland 1991, Ghera
20 *et al.* 1994, Richards 1986) that take into consideration indigenous knowledge (NRC 1992, Thurston
21 1992) and the rights of small-scale farmers to control their crop and farm resources (Cooper *et al.* 1992,
22 Soleri *et al.* 1994) we can ultimately appreciate the important role played by NUS for the achievement of
23 sustainable agriculture.

24

25 **Notes**

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

30

31

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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:

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

with

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

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

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

and \mathbf{X} , \mathbf{Z} , \mathbf{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:

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

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

$$\int_{-\infty}^{-\mathbf{X}\boldsymbol{\beta} - (\mathbf{Z}'\boldsymbol{\gamma} + \boldsymbol{y}_1\delta_2)} \int_{-\infty}^{-\mathbf{W}\boldsymbol{\chi} + \boldsymbol{y}_1\delta_3} \int_{-\infty}^{\phi_3(\boldsymbol{\varepsilon}_1, \boldsymbol{\varepsilon}_2, \boldsymbol{\varepsilon}_3, \rho_{12}, \rho_{13}, \rho_{23})} d\boldsymbol{\varepsilon}_3 d\boldsymbol{\varepsilon}_2 d\boldsymbol{\varepsilon}_1 \quad (5)$$

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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