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What Prompts Agricultural Innovation in Rural Nepal: A Study Using the Example of Macadamia and Walnut Trees as Novel Cash Crops

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Abstract: Agricultural innovations are important, especially as climatic conditions around the world have been subject to increasing change over the past decades. Through innovation, farmers can adapt to the changing conditions and secure their livelihoods. In Nepal, 75% of the population depends upon agriculture, which is impacted by climate change, migration, and feminisation. In this context, it is important to understand what drives a household to start agricultural innovation to increase its economic benefits and resilience in the face of multiple pressures. We sought a comprehensive understanding of these drivers by investigating the determinants of rural innovation, using macadamia and walnut trees as examples of novel, potentially commercialised cash crops. After conducting an in-depth household survey that divided farmers into those who cultivate nuts and those who do not, we analysed the socio-economic and cultural characteristics of each category using statistical tests and a multiple logistic regression. Our results show that the individual variables of ethnicity, wealth and "years of experience with fruit trees" correlate significantly with nut cultivation. The results of the multiple regression suggest that "years of experience with tree cultivation" and "having an income through fruit trees" most influence nut cultivation. Overall, we conclude that nut cultivation is an accepted and promising cash crop mostly grown by wealthier households, and that, for poor, landless, or female-headed households to benefit, alternative business models and new policies must be explored and developed. We further suggest that this is also true for other nut or other cash crop trees that have gained recent attention in Nepal such as almond, hazelnut, or pecan farming.

Keywords: agriculture; innovation; livelihood; macadamia; Nepal; walnut

1. Introduction

Agricultural practices have been subject to transformation and adaptation throughout human history, as farmers successfully innovate in response to environmental and socio-economic challenges [1]. The great growth in yields and increased agricultural productivity in the second half of the 20th century was obtained as a result of many factors, including the extensive mechanization of operations and use of fertilisers [2,3]. This "green revolution" has heavily shaped agriculture: the introduction of modern varieties of different crops led to higher yields that have helped ease global food shortages, among other benefits, but not all innovations have had purely positive results: some have led to increased pressure on soils and the environment through the extended use of chemicals [3,4].

As we show below, agriculture in Nepal has been somewhat untouched by this "green revolution" and many farmers still farm only for subsistence or to turn only a modest profit [4]. We set out to investigate how Nepalese agriculture currently operates, and whether innovative crop choices and growing methodologies could help farmers adapt to the pressures of local climate changes and labour changes. We chose to focus on nut tree cultivation, which is a relatively new, innovative crop that holds potential to help farmers adapt and thrive in the new climate.

In the past decades, farmers have increasingly had to adjust to the additional variable of global climate change. These changes have local impacts, including a shift in the elevation and extent of climate zones, which impacts the type of crops that farmers can expect to grow each season and affects the long-term viability of tree crops [5–8]. In Nepal, maximum temperatures have been increasing since 1960 and precipitation patterns have shifted in combination with a decrease in in the summer period [9]. The effects are expected to be both negative (e.g., loss of useful growing land due to drought or floods or temperature shifts) and positive (e.g., warming of previously unusable or less-usable lands allowing farmers to plant crops that previously would not have survived); however, depending on the locality, people who will be exposed to the worst of the impacts are usually those least able to cope with the associated risks [10–12].

Therefore, there is an increasing urgency for a stronger focus on adapting agriculture to future climate changes to avoid food scarcity [13]. Inadequate income and inadequate food sources are main components of poverty, which also leads to political instability [14,15]. In recent years, tensions between the urban and rural areas were created in part through poverty, which was one of the drivers for the civil war in 1996–2006 [14]. Agricultural innovations can increase the well-being of the rural areas and could form the basis of a stable political situation [14]. Both technical and institutional innovations are needed in agriculture to ensure self-sufficiency and adequate incomes in rural areas under the expected climate changes [16–18]. In Nepal, over 75% of the population depends upon agriculture for self-sufficiency and income [19]. The most commonly cultivated crops are rice, maize, and millet; the specific crop choice usually depends upon the elevation of the farm in question [6,8].

Farmers have started to adopt different strategies to earn a livelihood as they adapt to some changes already (e.g., changes in temperature or a shift in precipitation patterns) [7–9]. These strategies include abandoning traditional crops, delaying sowing, leaving land fallow, and migrating, in addition to seeking temporary opportunities further away [20–24]. Male-out migration, the most popular off-farm livelihood strategy, especially for deprived households, increases financial flows into rural areas and improves food security on a short-term basis [25–28]. At the same time, the missing labour also undermines food sovereignty in the agriculture-based economy: the lack of adequate labour to produce labour-intensive subsistence crops has resulted in a growing dependence on food imports, as some communities and households are unable to meet their own food needs [26,28,29]. This threatens the access of food to the poor, especially to nutritious food, and is also of concern to overall economic stability [25–30].

Some agricultural innovation is already occurring in Nepal. Vegetable cultivation in areas with market access has increased markedly; Brown and Kennedy [31] show that selling vegetables has a gross margin that is 10 times higher than that of selling staple crops. Additionally, as part of the complex farming systems on Nepalese hillsides, enhanced agroforestry has improved livelihoods [32–34]. Farmers have increased the volume of plantations of fruit trees, especially those of high-value crops such as coffee [35–38]. Nut trees are also playing an increasingly important role in agroforestry, and offer additional benefits when compared to fruit and coffee trees: besides producing a nutritious ready-to-eat food, nut trees crops are non-perishable, robust, low-volume, high-value, easy to handle, and in high demand [39,40]. Because of their benefits and potential to meet nutritional and commercial needs, we chose to investigate this aspect of agricultural innovation.

Different authors have determined that a variety of economic and social factors drive the adoption of agroforestry systems globally and in Nepal [41–44]. Aase et al. [45] explored innovation in different geographical Himalayan settings, finding that natural and individual resources and networks of

organisations support innovation across the regions. Other studies focus on general adaptive practices such as multiple cropping, water management or income diversification through off-farm work [46–48]. Present research does not, however, discuss the specific motivations and specific variables that impact the farmers' decisions to choose or not to choose agricultural innovations and livelihoods. With this paper, we aim to bridge this gap by investigating the cultivation of macadamia and walnut trees as an example of the ways by which Nepalese farmers adopt new crop systems; the cultivation of nut trees is considered representative of innovation and adoption of rural livelihood strategies in general.

We chose to focus on nut crops in Nepal as they are relatively new to farmers there and represent an innovative livelihood strategy where they are grown. Macadamia and walnut are the most widespread of the different nut trees in Nepal [5]. According to our observations, the commercialisation of both value-chains is in its infancy as both nuts only gained popularity in recent years [5]. Understanding the motivation for and success of this new strategy of nut cultivation was a major motivation for the Helvetas project, to which this study is linked, as there is missing research specifically on nut cultivation in Nepal [5]. Macadamia (*Macadamia integrifolia*) are newcomers and were introduced to Nepal in 1970 by a joint project of the Food and Agriculture Organization of the United Nations, and the Australian and Nepalese governments. The most suitable areas for growing macadamia in Nepal are the tropical and sub-tropical zones at a mean elevation of 60–1700 m [5,49,50]. In the temperate and cold zones at an elevation of 1200–3000 m, two types of walnuts (*Juglans regia* L.) are present: the indigenous hard-shell walnut tree and the soft-shell walnut tree, which was introduced to Nepal and is comprised mainly of cultivars and populations selected for crop production [51,52]. There is no clear history about the introduction of soft-shell walnuts to Nepal. During our survey, several farmers said that their grandfathers introduced the well-producing Kashmiri walnut when they came back from working in India.

Our research project consisted of four parts. First, we conducted an extensive, semi-structured household survey in the field to characterise those farmers who cultivate tree nuts ("nut growers") and those householders who do not ("non-nut growers"). Secondly, the quantitative data, collected from closed-answer questions and other observations (see below) was analysed using statistics and a multiple logistic regression analysis to identify the factors and variables that drive farmers to choose walnuts or macadamia nuts within their respective growing regions. Thirdly, we conducted in-depth analyses of the farmers' answers to open-ended questions and their stories in order to add commentary and details to the statistical results. Finally, we use the insights and data collected above to derive recommendations for future nut cultivators, development partners and policymakers.

2. Materials and Methods

2.1. The Study Areas

The field-based study was conducted in different districts of Nepal and focuses on the cultivation of two cash-crops, macadamia and walnuts. The locations of macadamia and walnut growers do not overlap; the two nuts require different growing conditions and therefore are found in different climatic settings [5]. Walnuts occur across most of the temperate and cold zones of Nepal: we had many districts to choose from for our field study. We chose to focus on the Jumla district, in the Mid-Western Development Region, as representative of a walnut-growing region, because, in our pre-visit, we had found enough farmers who were growing walnuts over the whole district, who had more than one tree. Also, the local governmental research centre had also initiated their own small-scale research activities with walnuts and had therefore shown interest in our study [5]. We were able to obtain 144 interviews there. Macadamia are less common but are found in locations across the sub-tropical zone of Nepal; in order to obtain a similar number of interviews, we identified five different districts that had the most macadamia nut growers and obtained a total of 135 interviews (Figure 1).

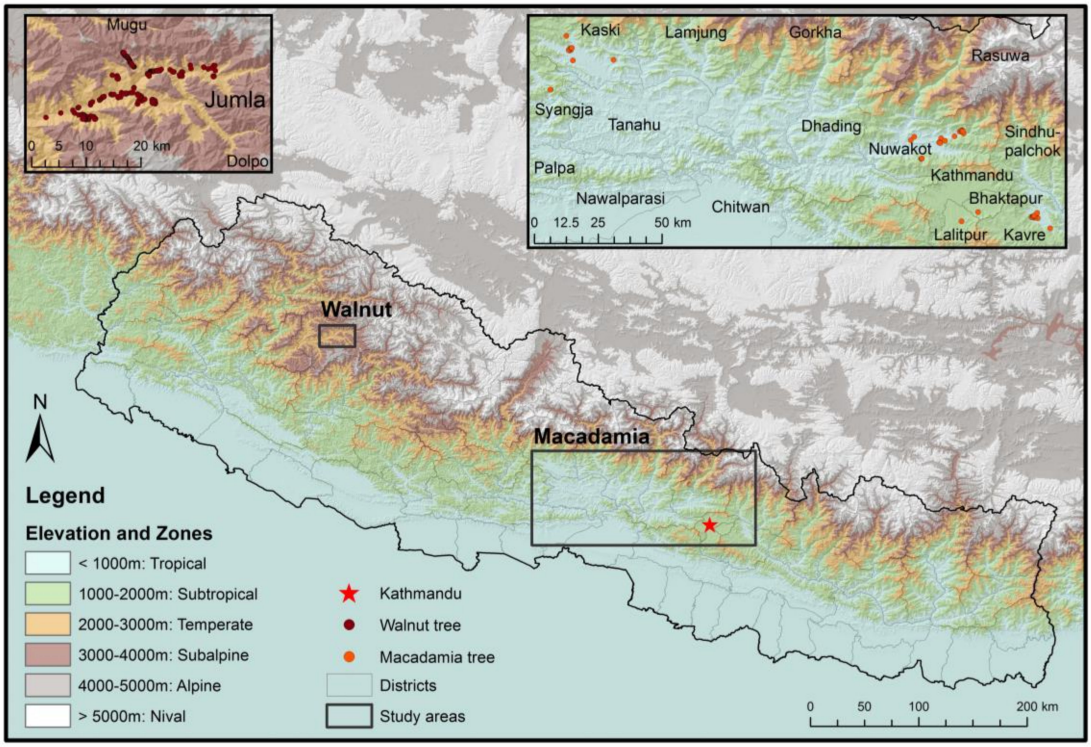

Figure 1. Overview of study areas in Nepal.

2.2. Data Collection

We designed and pre-tested a semi-structured interview based upon on the rural livelihood system approach and the nine-square Rural Livelihood System mandala [53–55]. We also ensured that statistically significant answers and results from similar surveys on the adaptation of agricultural innovations were integrated into our survey [41,42,45,46]; we sought to understand if variables known to impact decisions about agricultural practices in other contexts also applied in Nepal, and with regards to nut cultivation.

The survey was carried out from November 2014 to May 2016, and was paused for two months after April 2015 due to the series of strong earthquakes that struck Nepal. We found the participants by beginning the study in known nut-growing villages, and then following referrals from farmers to others who were growing nuts nearby. We chose one person from each household, usually the head (often, but not always, male), to interview. In total, we interviewed 279 household heads that we divided into four groups: (1) walnut growers (n = 89), (2) macadamia growers (n = 69), (3) non-walnut growers (n = 55), and (4) non-macadamia growers (n = 66). The first two categories, which we referred to collectively as "nut growers", represent farmers "adopting a new livelihood strategy". The latter two categories represented farmers "not adopting a new livelihood strategy" and are collectively referred to in this paper as "non-nut growers".

The extensive survey that we created consisted of three parts that in turn focused on specific elements of a household that are known to be relevant and/or could be statistically significant factors in agricultural innovation. Each section included open and closed questions that allowed for descriptive statistics and the extraction of qualitative information from the participants' narratives.

Section 1 was the collection of general information on households regarding educational, financial and social background (characterisation of households, 50 questions).

Section 2 consisted of questions considering direct questions about the specifics of nut cultivation (36 questions).

Section 3 focused on questions regarding the emotional context of the respondent and his or her family (44 questions).

To allow for a precise analysis of the responses, we divided the answers into quantitative and qualitative variables, and the latter included data on emotional aspects of decision-making. The quantitative answers revealed characteristics that were indicative of the interviewees and their households. The qualitative answers are descriptive. To constitute the dataset on emotional aspects, we asked the household heads questions around themes such as which needs had to be met for their happiness, what worried them, and what they were aspiring for in their lives.

2.3. Data Analysis

We took our survey data and divided it into three parts for analysis: (1) the characterisation of the household, (2) the drivers for growing nuts, and (3) the narratives. For the whole analysis, we used R, a language and environment for statistical computing and graphics [56,57].

For the first part, we analysed the characteristics of the households using general statistical functions: the standard of deviation for non-categorical variables and a two-tailed Fisher's exact test to determine whether there was a dependence between the first and the second variable, the first variable being "nut grower" and the second being "non-nut grower". We then applied a two-tailed Fisher's exact test to determine if there was a non-random association between a pair of variables e.g., the variable "nut grower" and "non-nut grower" and the variable gender ("man" and "woman"). This distribution was then used to compute the p-value as "the probability of observing more extreme data than the actually-obtained data", where "extreme" means that the probability of each of these possible values is smaller than the observed one. The null hypothesis is then rejected if the p-value is smaller than a pre-specified significance level. Most authors accept 0.05 as the significance level and it is marked as "*", while 0.01 is marked with "**", and 0.001 with "***" [58].

For the second part, addressing the drivers that prompt farmers to adopt nuts, we applied a multiple logistic regression analysis to determine the effect of the variables on the dependent nominal variable to grow nuts [56]. In our study, this was the degree of relationship between the driver's influence such as ethnicity, age, land size, and the decision of the farmers to become a nut grower (i.e., adopt a new livelihood strategy). The model is specified as follows: let Y_i be the response variable which indicates whether individual i has cultivated nuts ($Y_i = 1$) or not ($Y_i = 0$), for $i = 1, 2, \ldots, n$, where n is the number of farmers interviewed. Let p_i be the probability that $Y_i = 1$ (and therefore the probability that $Y_i = 0$ is $1 - p_i$) for individual i. The k explanatory variables are denoted by $x_{i1}, x_{i2}, \ldots, x_{ik}$ for individual i, where k represents the number of variables in the dataset studied. The logistic regression model is therefore:

$$\log\left(\frac{p_i}{1-p_i}\right) = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_k x_{ik} + \varepsilon_i, \quad (1)$$

for $i = 1, 2, \ldots, n$, where $\beta_0, \beta_1, \ldots, \beta_k$ are the regression coefficients and ε_i is an error term.

The goal of the following analyses was to study which variables influenced the production of nuts. From the quantitative set of variables, gender, ethnicity, poverty rating, growing fruit trees, and growing fodder trees, were treated as categorical variables, which means that the answers of respondents were summarised and represented as categories rather than numbers. The quantitative variables were called quantitative as they expressed answers on an ordinal scale, i.e., number of school years, numbers of fruit trees planted, number of poverty rating—with the exception of gender, which is nominal.

In the qualitative set of variables, all the variables were binary except for the variable: "Shared decision for big investment (man/woman)", which was treated categorically (the three possible answers were "the man", "the woman", or "shared decision making"). The qualitative variables were further divided into a set of data focused on variables related to emotional characteristics; we felt that a question such as "what do you need for happiness?" differed from "how do you get your income?" or

"what do you know about nuts?" The emotional variables focused on three aspects of the respondents, as mentioned in Section 2.1, that is, the needs for happiness, their worries in life, and their aspirations. Each set of qualitative variables was treated individually and independently of the others.

The third part, the narratives, was extracted from the individual interviews. These were selected according to their usefulness in contributing to the overall understanding of the motivation for nut cultivation. They reflected the opinions of individual farmers that either perished in the statistical analysis or that were given as additional, qualitative reflections during the survey.

2.4. Limitations

The multiple logistic regression analysis encountered two limitations: the limited number of surveys taken compared to the number of variables present, and the fact that some variables were categorical. Moreover, only the variables without any missing values could be consulted for multiple logistic regression, due to the limited number of surveys taken. These variables were chosen by careful analysis, considering all the other variables with missing values, to ensure that no important information was missed with this step.

Additionally, with the topography of Nepal ranging from accessible, flat plains to deeply-fissured, mountainous terrain, the social complexity in Nepal is immense, and the respondents of our five ethnic backgrounds were divided into 14 sub-groups. Combined, these factors made it impossible to select a group of farmers that truly represented the whole population of Nepal. The answers of respondents might also have been influenced by their expectations when a research team was visiting. We were aware of this fact and used common sense to investigate answers that did not match the context. Additionally, the different perspectives of each of the research team members, given their own experience, ethnic backgrounds and education, may have influenced the answers obtained; by using such a thorough survey, we reduced these risks to a minimum. Finally, the team members' skills in translating the local language into English may have influenced the results, and therefore careful assessment of each answer and its translation was a requirement prior to the statistical analyses.

3. Results and Discussion

3.1. Characterisation of the Households (Results of Part 1 of the Data Analysis)

The socio-economic characteristics of the households are depicted below for walnut and non-walnut growers and macadamia and non-macadamia growers (Table 1).

These characteristics of the households are expected to influence the decision-making around new livelihood strategies. To derive the influences, we looked at each variable individually (Table 1). Since no adjustment was performed for multiple testing, one should be careful with the interpretation of the individual *p*-values. Overall, there were three main significance finds: (1) The ethnic groups called Dalits were least likely ($p < 0.001$) and Brahmin were most likely to grow nuts ($p < 0.01$). (2) A wealthy farmer was very likely to grow nut trees ($p < 0.001$), while a very poor farmer was not likely ($p < 0.01$) to grow nut trees. (3) Finally, there were significantly more farmers who grew nut trees in combination with fruit trees than growing them without fruit trees ($p < 0.001$).

The result that Dalits were less likely to grow nuts is no surprise: Dalits are often less wealthy with less land and smaller incomes. This context does not allow them to take the necessary risks to invest time and money into a new, possibly uncertain, livelihood strategy. In comparison, Brahmins in our study area were more likely to grow nuts, which can be explained by the sufficient financial assets available to them that increase their tolerance of failure. This is also linked to the quality and nature of the land that they farm. Although it would have been too complicated to quantify differences in land type, Brahmins tend to own better, more fertile land on which there are pockets suitable for tree cultivation, whilst Dalits (who are not traditionally farmers) tend to own or farm less productive, more marginal land. Lastly, nut growers rely most often on their experience with fruit trees to help them cultivate nuts, as the third results shows.

Table 1. Characteristics of households (standard deviation in brackets).

	Variable	Walnut Growers	Non-Walnut Growers	Pr (>|z|)	Macadamia Growers	Non-Macadamia Growers	Pr (>|z|)	Tot Nut	Tot Non-Nut	Pr (>|z|)
	Total growers	89	55	-	69	66	-	158	121	-
	Men	63	49	0.01	53	44	0.25	116	93	0.58
	Women	26	6	0.01	16	22	-	42	28	0.58
	Age	44.5 (13.9)	35 (13.7)	-	52.6 (14.9)	48.2 (17.2)	-	48.1 (14.9)	42.2 (17)	-
Ethnicity *	Brahmin-Hill	25	3	0.00	28	18	0.15	53	21	0.00
	Chhetri	58	31	0.30	10	11	0.81	68	42	0.18
	Dalit	3	21	0.00	1	5	0.11	4	26	0.00
	Janajati	3	0	0.29	30	30	0.86	33	30	0.47
	Giri	0	0	1	0	2	0.24	0	2	0.19
	School years	5.5 (4.4)	5.4 (4.5)	-	6.4 (4.2)	5.2 (4.4)	-	5.9 (4.3)	5.3 (4.4)	-
	Number of people in the household	6.2 (2.3)	5.9 (2.9)	-	5.7 (2.9)	5 (2.3)	-	5.9 (2.6)	5.4 (2.6)	-
	Migration to district of close family members	0.5 (1)	0.3 (0.6)	-	0.4 (0.9)	0.3 (0.7)	-	0.5 (1)	0.3 (0.6)	-
	Migration to country of close family members	0.1 (0.3)	0.1 (0.3)	-	0.5 (0.7)	0.4 (0.6)	-	0.3 (0.5)	0.3 (0.5)	-
	Available men working on land	1.2 (0.8)	1.3 (1.1)	-	1.6 (1.2)	1.4 (0.8)	-	1.4 (1)	1.3 (0.9)	-
	Available woman working on land	1.5 (0.8)	1.5 (1)	-	1.7 (1)	1.6 (0.7)	-	1.6 (0.9)	1.6 (0.8)	-
	Land size (ha)	1.5 (2.1)	0.6 (0.5)	-	0.9 (1.2)	0.6 (0.5)	-	1.2 (1.7)	0.6 (0.5)	-
Poverty rating	Very poor	8	19	0.00	0	1	0.49	8	20	0.00
	Poor	35	23	0.86	9	18	0.05	44	41	0.30
	Medium	43	13	0.00	36	42	0.22	79	55	0.47
	Wealthy	3	0	0.29	23	4	0.00	26	4	0.00
	Very wealthy	0	0	1	1	1	1	1	1	1
	Farmer grows fruit trees	80	34	0.00	65	59	0.36	145	93	0.00
	Farmer grows fodder trees	12	0	0.00	51	48	1	63	48	1
	Years of experience with trees	15.2 (8.1)	3.7 (5.1)	-	15.9 (7.3)	12.5 (8.2)	-	15.5 (7.8)	8.5 (8.2)	-

* Nepal has 126 caste/ethnic groups reported in 2011 [9]. Chhetri is the largest group 16.6% of the total population of 26,494,504, followed by the Brahman-Hill (12.2%). Dalits, Janajati and Giri make less than 1% of the population.

3.2. Analysis of Drivers for Growing Nuts as a Novel Livelihood Strategy (Results of Part 2 of the Data Analysis)

The aim of the logistic regression was to deduce the variables that influenced the decision by a farmer to grow nuts. The results of the multiple logistic regression are presented in Table 2. Pre-results including all variables (without adjusted *p*-values) are given in the supplementary material (Tables A1 and A2).

Table 2. Result logistic regression with adjusted *p*-values.

	Variable	*p*-Values Adjusted	Significance Code
Quantitative	Years of experience with trees	0.0000	***
Qualitative	Income through fruit trees	0.0000	***
Emotional	Need for happiness: Financial	0.0350	*
	Need for happiness: Religion/Spirituality	0.0001	*
	Future aspiration: Social reputation	0.0129	*

* Most authors accept 0.05 as the significance level and it is marked as "*", while 0.01 is marked with "**", and 0.001 with "***".

In the quantitative set of variables, "years of experience with tree cultivation" had a significant impact on nut production, since the adjusted *p*-value was below the significance value ($p < 0.001$). The outcome of the qualitative set of variables showed that "having an income through fruit trees" had an influence on whether a farmer cultivates nuts ($p < 0.001$). Looking at the emotional set of variables, "financial means" and "spiritualty/religion" (factors needed for a happy life) and "gaining social reputation" (an aspiration) had a positive influence on tree cultivation ($p < 0.05$).

Due to the small size of the sample, the outcomes must be interpreted carefully. These *p*-values give an idea as to which variables might influence whether a farmer grows nuts; however, they cannot be combined, as the three datasets were tested independently. The quantitative result "years of experience with trees" could be interpreted that farmers who grow any cash crop tree, and may even have an income from it, trust their ability to cultivate nut trees successfully and therefore choose to grow them. The result from the qualitative data set "having an income through fruit trees" supports this interpretation: fruit farmers have positive experiences with other tree crops and are therefore more likely to opt for the new but similar livelihood strategy. "Financial means" or "religion/spirituality", as a way to happiness, and "social reputation" as an aspiration (the results of the emotional data set) are significant on a lower level, and were therefore not interpreted further. Moreover, although ethnicity, poverty ranking, and "years of experience with tree growing" in general may influence the decision-making process, as the simple statistical pairwise analysis shows in Table 1, these were not detected in the result of the multiple logistic analysis. This could be an objection to the suitability of approach of the logistic regression or it can be attributed to the small number of respondents. With more observations, we could test the variables jointly and hope to obtain stronger conclusions. We therefore suggest that the results of the logistic variable be treated with care and that the results of the simple statistical evaluation and the narratives be consulted for additional insights.

The answers of the logistic regression are not completely reflected in similar publications. The recent study of Cedamon et al. [44] for example finds that household income, migration and caste have an influence on the adaptation of agroforestry practices, while Dhakal et al. show in their study in the Terai plains, that institutional support and infrastructure development promote agroforestry while farm size, labour force and farming inputs are restraining factors [59]. Soft variables such as needs for happiness, worries or aspirations were not tested in other comparable studies to the best of our knowledge.

3.3. Narratives about the Motivation for Nut Cultivation (Part 3 of the Data Analysis)

The aim of the narrative was to get more individual, detailed insights into the nut cultivation and to discuss the results of the statistical analyses above. The narratives were given by each household

head during the interviews as extra explanations for a closed question or as answers to open questions. We analysed the narrative answers only after the statistical assessment was complete, and did so in order to illuminate those results. In Table 3, we summarise the motivation expressed by the nut growers to cultivate nuts. "Curiosity/trial", "financial motivation" and "own consumption" were mentioned the most. Non-nut growers said that they are not aware of nuts' economic value and that they do not have the knowledge needed and/or available land.

In Jumla district, where apple cultivation is promoted by the government, walnut is mostly grown in combination with apple trees. Farmers expressed that "I have walnuts to diversify my income. If my apple trees get damaged due to hail, I still have walnuts" and "Walnuts are less susceptible to certain diseases and pests". Other farmers stated that the "Walnuts will sell all year around due to its non-perishability" and "I planted my first tree so that my children [will] stop climbing to the trees of my neighbours to take nuts".

Table 3. Motivation to grow nuts or not to grow nuts.

Motivation to Grow Nuts	Walnut (%)	Macadamia (%)	Total (%)
Curiosity/Trial	41.6	82.6	59.5
Finance	61.8	23.2	44.9
Own consumption	14.6	56.5	32.9
Low labour	15.7	8.7	12.7
Robustness	1.1	13	6.3
Copy from neighbour	9	1.4	5.7
Intercrop	1.1	10.1	5.1
Culture/Religion	2.2	0	1.3
Motivation not to Grow Nuts			
Unaware of economic value	32.7	57.6	46.3
Missing knowledge	20	65.2	44.6
Missing land	36.4	21.2	28.1
Land unsuitable	10.9	9.1	9.9
No finance	12.7	4.5	8.3
No quality sapling	9.1	7.6	8.3
Missing labour	1.8	3	2.5
Long gestation period	1.8	0	0.8

In the macadamia districts, farmers said: "Now my neighbours have asked me for small trees as they see that my tree is bearing nuts". Another farmer reported, "My wife has seen how much our neighbours gets paid for one kilo of nuts; therefore, she went to the nursery and worked in return for a small macadamia tree". However, macadamias are sometimes liked too much: "I planted some trees close to the road to school hoping that the school children stop climbing up my trees on my land but rather climb the ones along the road", and, "Two years ago, some of my newly planted macadamia trees were taken out of the ground during the night. Now I have planted them all in sighting distance of my house or the temple to discourage people stealing them".

A handful of older farmers from both areas expressed: "I'm getting old. Soon, I will not be able to work physically hard. With nut trees, I will only have to pick the nuts. Therefore, the nut trees will be my pension". A farmer from Syangja reported: "Many young men have left our village to find work abroad. We are short in labour, which lead to more barren fields. Therefore, our community has bought 200 macadamia trees and planted them last year instead of finger millet. Once planted, there will be very little physical labour required".

Regarding the feminisation of agriculture that is caused by the male-out migration, over eighty percent of the farmers agreed that: "If the woman has knowledge, there is no problem for her to cultivate nuts". The reality showed that the domestic work burden of women (unpaid care) often hampers their engagement in income-generating farm tasks. Instead of this being a barrier to nut cultivation, however, men planning to migrate could plant the trees before they go. Our interviews and

research showed that nuts appeared to require little labour once they were established. Women and other householders who were left behind could focus on other farm and domestic tasks, only requiring assistance with the nuts in harvest time and perhaps with pruning. Nuts represent a nutritious, sustainable and low-labour crop to many households.

4. Conclusions and Recommendations

Nepal faces climate challenges, including shifting climate zones, and economic changes, such as migration from the rural areas to cities. Cultivation of certain nuts and other cash crops, provides a potential way to adapt agricultural practices to meet these and other challenges [60]. As Barrueto et al. [5] have shown, the climate of Nepal is suitable for both macadamia and walnut value-chains at present and under projected climate change scenarios even though growing zones will undergo a regional and elevational shift, as introduced above.

According to the Government of Nepal [61], the national agricultural strategy emphasises supporting farmers to move from subsistence to commercial farming. The commercialisation of walnuts could lead to the substitution in the markets of locally-produced walnuts for those that are currently imported from neighbouring countries [62]. The commercialisation of macadamia has the potential to supply both local and international markets [60]. Moreover, land can be used more efficiently: macadamia growers reported that they have started to intercrop macadamia with coffee. This is a promising strategy, as income is diversified between two crops and coffee is expected to give higher yields [63,64]. We recommend further applied research to explore the best conditions for the intercropping of coffee with macadamia and other cash crops in Nepal.

Furthermore, with this investigation, we have shown that nut cultivation is a novel livelihood strategy that represents the first steps by farmers into crop commercialisation in the areas of Nepal that we studied. Nut production is already an accepted livelihood strategy for men and women, which diversifies and stabilises incomes. Curiosity, economic benefits, own consumption, and low labour are the most commonly mentioned reasons for starting nut cultivation; nuts provide a good source of food and potential income to farmers, and requires minimal continuous labour (in contrast to labour-intensive crops such as millet). Nut cultivation could also lead to the increased resilience of rural communities, as poverty is reduced and nutrition increased.

Barriers to production remain. Our research also revealed that women, poor, and landless farmers do not have the financial means, risk-bearing capacity, land to grow trees, or skills needed to assess the risks and benefits of this crop. This is in line with research from Aase et al. [45] who found that farm size influences the agricultural innovation, as well as water availability and active national nongovernmental organisations. Oli et al. [42] also found that land size was one apparent determinant for whether a farmer grows trees; in their research gender, neither [potential] income nor ethnicity were significant influences on farmers' decisions.

Many farmers also appear to lack knowledge about the benefits of their involvement in these value-chains. Several pilot projects and workshops to teach farmers to grow macadamia nuts have already been done, with some success. We therefore recommend that development partners and policymakers explore inclusive business models, i.e., models that pay heed to weaker members of the rural communities, such as those mentioned above (women, poor, and/or landless). Such models could also benefit from the involvement of the private sector in the promotion of these value-chains, and in the creation of an environment that enables an inclusive commercialisation of these promising crops: walnuts and macadamia could be produced both for local and international markets, and for home consumption [65]. They would provide a reliable, sustainable source of subsistence for farmers with the possibility of additional income from sales. Finally, we suggest that additional research be conducted into the suitability of other nuts (almonds, pecans, hazelnuts) for production in Nepal. Together, these nuts could fulfil the dual purpose of increasing income and food security for rural areas in Nepal under present and future climatic conditions.

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Appendix A

Table A1. Pre-result logistic regression after using command drop1 in R (ETH Zurich, Zurich, Switzerland).

Quantitative Set of Variables	*df*	Deviance	Pr(>Chi)	Significance Code
Gender	1	276.37	0.665383	
Age	1	276.86	0.412642	
Ethnicity	4	288.6	0.014537	*
School years	1	276.23	0.831959	
Number of people in the household	1	278.72	0.111377	
Migration to district of close family members	1	276.22	0.851546	
Migration to country of close family members	1	278.75	0.109039	
Available men working on land	1	276.19	0.971917	
Available woman working on land	1	279.01	0.092608	
Land size (ha)	1	283.85	0.005615	**
Poverty of the respondent	4	288.53	0.014938	*
Farmer cultivates fruit trees	1	276.19	0.964421	
Farmer cultivates fodder trees	1	278.63	0.117849	
Years of experience with trees	1	301.67	0.000000	***
Qualitative Set of Variables				
Income through Cereals	1	309.36	0.273575	
Income through Legumes	1	316.5	0.003881	**
Income through Potatoes	1	314.23	0.013766	*
Income through Vegetables	1	316.05	0.004979	**
Income through Fruits	1	342.68	0.000000	***
Income through Dairy (Milk, Ghee, Eggs)	1	308.3	0.70245	
Income through Chicken	1	309.12	0.327879	
Income through Livestock	1	311.81	0.055848	
Income through Remittance	1	309.48	0.250627	
Income through Pension	1	308.27	0.734097	
Income through Widow/War allowance	1	308.95	0.374114	
Income through off farm income	1	308.57	0.521749	
Income through medical plants	1	308.95	0.374887	
Practice of work load share (man/woman)	1	310.08	0.165634	
Knowledge regarding health benefits of nuts	1	313.54	0.02037	*
Shared decision for big investment (man/woman)	2	318.27	0.006359	**
Emotional Set of Variables				
Nature of Needs for Happiness				
Financial	1	291.74	0.0018421	**
Religion/Spirituality	1	303.3	0.0000040	***
Health	1	282.26	0.6383081	
Social acceptance	1	284.01	0.1600214	
Family	1	283.97	0.1651355	
Education of children	1	287.59	0.0184484	*
Land	1	282.53	0.4855336	

Table A1. *Cont.*

Quantitative Set of Variables	*df*	Deviance	Pr(>Chi)	Significance Code
Worries				
Financial worries	1	282.79	0.3876948	
Wellbeing of children	1	282.19	0.6947026	
Lack of food	1	282.07	0.8653194	
Not having enough when old	1	284.66	0.1054408	
Sickness/injuries	1	290.86	0.002983	**
Natural hazards	1	282.34	0.5838167	
Aspirations for Future				
Spiritual	1	282.64	0.2196014	
Financial	1	283.55	0.4393164	
Education of children	1	285.43	0.0655168	
Health	1	282.13	0.7619857	
Family	1	284.07	0.1537966	
Social reputation	1	293.68	0.0006454	***
Career	1	284.34	0.1291161	
Acquire skills / knowledge	1	288.42	0.0115337	*

* Most authors accept 0.05 as the significance level and it is marked as "*", while 0.01 is marked with "**", and 0.001 with "***".

Table A2. Full Result logistic regression with adjusted *p*-values.

Quantitative Set of Variables	Adjusted *p*-Value	Significance Code
Gender	1	
Age	1	
Ethnicity	0.18456	
School years	1	
Number of people in the household	1	
Migration to district of close family members	1	
Migration to country of close family members	1	
Available men working on land	1	
Available woman working on land	1	
Land size (ha)	0.05987	
Poverty of the respondent	0.18456	
Farmer cultivates fruit trees	1	
Farmer cultivates fodder trees	1	
Years of experience with trees	0.000013	***
Qualitative Set of Variables		
Income through Cereals	1	
Income through Legumes	0.058216	
Income through Potatoes	0.165195	
Income through Vegetables	0.069711	
Income through Fruits	0.0000000675	***
Income through Dairy (Milk, Ghee, Eggs)	1	
Income through Chicken	1	
Income through Livestock	0.558478	
Income through Remittance	1	
Income through Pension	1	
Income through Widow/War allowance	1	
Income through off farm income	1	
Income through medical plants	1	
Practice of work load share (man/woman)	1	
Knowledge regarding health benefits of nuts	0.224073	
Shared decision for big investment (man/woman)	0.082672	

Table A2. *Cont.*

Quantitative Set of Variables	Adjusted *p*-Value	Significance Code
Emotional Set of Variables		
Nature of Needs for Happiness		
Financial	0.035000	*
Religion/Spirituality	0.000084	*
Health	1	
Social acceptance	1	
Family	1	
Education of children	0.295174	
Land	1	
Worries of Respondents		
Financial worries	1	
Wellbeing of children	1	
Lack of food	1	
Not having enough when old	1	
Sickness/injuries	0.053694	
Natural hazards	1	
Aspirations for Future		
Spiritual	1	
Financial	1	
Education of children	0.982753	
Health	1	
Family	1	
Social reputation	0.012907	*
Career	1	
Acquire skills / knowledge	0.1960731	

* Most authors accept 0.05 as the significance level and it is marked as "*", while 0.01 is marked with "**", and 0.001 with "***".

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