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Ecosystem-based Adaptation (EbA) strategies for reducing climate change risks and food security of forest-dependent communities in Iran

Strategien zur ökosystembasierten Anpassung (EbA) zur Reduzierung der Risiken des Klimawandels und der Ernährungssicherheit von waldabhängigen Gemeinden im Iran

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Schlüsselbegriffe: Agroforstsystem, Ökosystembasierte Anpassung (EbA), Iran, Lebensunterhalt, NTFPs

Abstract

The livelihood of forest-dependent communities in many developing countries is very vulnerable to the impacts of climate change due to their high dependence on ecosystem services and their low capacity to reduce climate-related impacts. Ecosystem-based adaptation (EbA) strategies may contribute positively to combat climate change risks (*i.e.*, food security) in Iran. This study aims to identify strategies that can be applied in practice to improve the economic conditions of local communities and identify ways to decrease poverty within the Arasbaran biosphere reserve of Iran. We used data collected with interviews and field observations on the communities' knowledge and expectations about future ecosystem services, awareness of climate

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change, its impacts on livelihoods and strategies for adaptation to climate change. Four EbA strategies were identified: (1) changing croplands into sumac (Rhus coriaria) woodlands, (2) establishing agroforestry systems, (3) changing cropping patterns, and (4) collecting Non-Timber Forest Products (NTFPs). Sumac and NTFPs contribute up to 29% and 27% towards total household income, respectively. A majority of households (91%) were involved in agroforestry systems with fruit trees, including walnut (*Juglans regia*), cornelian cherry (*Cornus mas*), and mulberry (*Morus alba*), being the most common trees used within an agroforestry system. In the studied villages, 33% of farmers reported that they had replaced their crops for potentially more drought-resistant crops such as saffron and lentil, depending on the annual rainfall. Results showed that 14 NTFPs-providing species were present in the study area. Lastly, adaptation projects should be contextualized according to the communities and ecosystems around them. The study concludes that the incorporation of the diverse ecosystem-based approaches in different thematic areas can promote the sustainable livelihoods of rural communities. Training programs for agroforestry managers and the development of safe economic strategies are key solutions to promote sustainable agroforestry systems.

Zusammenfassung

Der Lebensunterhalt waldabhängiger Gemeinschaften in Entwicklungsländern ist aufgrund ihrer hohen Abhängigkeit von Ökosystemleistungen und ihrer geringen Fähigkeit, die Auswirkungen zu verringern, sehr anfällig für die Auswirkungen des Klimawandels. Strategien zur Anpassung an das Ökosystem (EbA) können einen positiven Beitrag zur Bekämpfung von Risiken des Klimawandels wie der Ernährungssicherheit im Iran leisten. Diese Studie zielt darauf ab, Strategien zu identifizieren, die in der gesamten Landschaft in der Praxis angewendet werden, um die wirtschaftlichen Bedingungen der lokalen Gemeinschaften zu verbessern und Wege zu finden, um ihre Armut im Biosphärenreservat Arasbaran im Iran zu verringern. Wir sammelten Daten mithilfe von Interviews und Feldbeobachtungen über das Wissen und die Erwartungen der Gemeinden über die zukünftigen Ökosystemleistungen, das Bewusstsein für den Klimawandel und seine Auswirkungen und Lebensgrundlagen sowie über lokale Schwachstellen und Anpassungsmöglichkeiten gesammelt. Es wurden vier EbA-Strategien identifiziert: (1) Umwandlung von Ackerland in Sumachwälder (*Rhus coriaria*), (2) Einrichtung von Agroforstsystemen, (3) Änderung der Anbaumuster und (4) Sammeln von Nichtholz-Waldprodukten (NTFP). Es zeigt sich, dass Sumach als marktfähiges und hochwertiges Produkt und NTFP bis zu 29 % bzw. 27 % zum Gesamteinkommen der Haushalte beitragen kann. Ein Großteil der Haushalte (91 %) war an Agroforstsystemen beteiligt. Obstbäume wie Walnuss (*Juglans regia*), Kornelkirsche (*Cornus mas*) und Maulbeere (*Morus alba*) waren die häufigsten Bäume in den Agroforstsystemen im Iran. In den untersuchten Dörfern ersetzten 33 % der Landwirte ihre Pflanzen durch potenziell dürreresistente Pflanzen wie Safran und Linsen, abhängig vom jährlichen Niederschlag. Die Ergebnisse zeigten, dass sich 14 NTFP-liefernde Arten im Untersuchungsgebiet befanden. Schließlich sollten

die Anpassungsprojekte entsprechend den Gemeinschaften und Ökosystemen um sie herum kontextualisiert werden. Die Studie kommt zu dem Schluss, dass die Einbeziehung der verschiedenen ökosystembasierten Ansätze in verschiedene Themenbereiche eine nachhaltige Existenzgrundlage für ländliche Gemeinden fördern kann. Schulungsprogramme für Agroforstmanager und die Entwicklung sicherer Wirtschaftswege sind Schlüssellösungen zur Förderung nachhaltiger Agroforstsysteme.

Introduction

Climate change is the gradual change in climate and physical geography associated with an increase in the Earth's temperature (Chan, 2018) and is one of the biggest challenges facing the Earth (Chan, 2018; Morid and Massah Bavani, 2010). Responding to this challenge requires that different players (*e.g.*, governments, communities, institutions, and individuals) recognize the urgency of addressing the social, environmental, and economic effects of climate change (Muthee *et al.*, 2017). Climate change affects human well-being and food security in most parts of the world (Jamshidi *et al.*, 2019; Muthee *et al.*, 2017). Its impact on agricultural activities in developing countries has increased dramatically. Understanding how farmers perceive climate change and how they adapt to it is very important to the development and implementation of effective policies to ensure agricultural and food security (Fadina and Barjolle, 2018). Food security is inherently interlocked with other recent global challenges of the economy and climate change (Kattumuri *et al.*, 2017). Reducing the risks posed by climate change on food security is one of the main challenges of today (Campbell *et al.*, 2016; Gohari *et al.*, 2017). On the other hand, there is an urgent need to expand food production due to an increase in population over the next few decades (Mesgaran *et al.*, 2017).

Climate change increases the odds of worsening droughts occurring in many parts of the world. Although short-term global droughts have remained relatively constant across the world, many intense or long-term droughts have been observed in arid and semi-arid regions since the 1970s. For instance, in the last 50 years, Iran has experienced 27 drought events that led to the loss of agricultural production, food shortages, and inadequate socio-economic entitlements while exacerbating the vulnerability of rural households. The negative impacts of drought are further intensified by the threat of climate change that is projected to increase the frequency, duration, and severity of droughts in many arid and semi-arid regions (Keshavarz *et al.*, 2017). Rural communities are particularly vulnerable due to their high reliance on natural systems because of the type of activities in which they are engaged (*e.g.*, farming) (Doswald *et al.*, 2014). Throughout history, rural households and smallholder farmers have adapted to and coped with climate change risks (Kattumuri *et al.*, 2017; Keshavarz *et al.*, 2017). In Brazil, family farmers are responsible for about 70% of the food consumed by the Brazilian population. At the same time, smallholder farmers living in semi-arid Brazil are considered to be the most vulnerable sector of Brazilian society due to the impacts of climate change (Burney *et al.*, 2014). An effective adaptation strategy is needed in order to develop accurate mitigation scenarios (Gohari *et al.*, 2017; Pramova *et al.*, 2012). Many smallholder farmers rely on rainfall as a source of water for their agricultural activities. About 41% of the arable land (6.2 million ha) in Iran is a rainfed farming system (Emadodin *et al.*, 2012) and this system is more vulnerable to drought impacts compared to irrigated farming (Morid and Massah Bavani, 2010). For this reason smallholder farmers in developing countries are one of the most vulnerable social groups to the changing climate (Jamshidi *et al.*, 2019; Lasco *et al.*, 2014). As a result, climate change and changing precipitation patterns can have an especially disproportionate impact on agricultural productivity and food security. In order to mitigate the negative impacts of climate change on local people, increasing their adaptive capacity is imperative (Keshavarz *et al.*, 2017).

Over the years, different adaptation strategies designed to enhance rural communities' ability to adopt adaptation and sustainable livelihood programs have emerged, including Ecosystem-based Adaptation (EbA), which seeks to promote societal resilience via ecosystem management and conservation (Chong, 2014). EbA recognizes the centrality of ecosystems in the adaptation process. Ecosystems maintain, strengthen, and enrich different elements of life and livelihood on the planet. EbA includes the use of biodiversity and ecosystem services as part of an overall adaptation strategy designed to help people adapt to the adverse effects of climate change (Nalau *et al.*, 2018). EbA approaches include sustainable management, conservation, and restoration of ecosystems for the purpose of providing services to help people adapt to climate change impacts (Naumann *et al.*, 2011). Specifically for forest communities, EbA may include interventions of conserving or restoring forest on slopes to reduce landslides or extreme losses of water (Pramova *et al.*, 2012); or developing diversified agroforestry to deal with climate change (Thorlakson and Neufeldt, 2012), or conservation of agrobiodiversity to conserve specific gene pools of crops or livestock to better adapt to climate change. EbA is considered to be a nature-based method for climate change adaptation that addresses food security by strengthening and maintaining natural systems with providing goods and services (McVittie *et al.*, 2018; Naumann *et al.*, 2011). It has gained currency over the past few years (Girot *et al.*, 2012). EbA is a new issue defined as the dependency on the ecosystem services as part of an overall adaptation strategy to help people adjust to the harmful effects of climate change (Girot *et al.*, 2012; Munang *et al.*, 2013). Recent research has focused on the potential for EbA to help mitigate climate change risks in arid and semi-arid regions (Campbell *et al.*, 2016; Chan, 2018; Girot *et al.*, 2012; Kattumuri *et al.*, 2017; Reid, 2016). Local coping strategies form the basis for reducing long-term climate change risks, including adaptation initiatives adopted by local communities (Kattumuri *et al.*, 2017). Local communities, especially in rural areas, heavily depend on the natural resource strategies to help them achieve global food security while meeting livelihood needs (Scarano, 2017).

EbA covers a wide range of actions to maintain and strengthen ecosystem services that underpin agricultural productivity and resilient food production. One of the specific EbA approaches that contribute to agricultural productivity is agroforestry systems (Lasco *et al.*, 2016). About 30% of the rural population of the world at 46 percent of total farmlands use trees in this system (Lasco *et al.*, 2014). Agroforestry has real potential to simultaneously tackle food insecurity and climate change (Catacutan *et al.*, 2017; Swamy and Tewari, 2017). The use of sustainable land-management practices such as agroforestry (using trees and shrubs in pastures and croplands) can increase farmers' resilience to climate change through sustaining or increasing food production (Jones *et al.*, 2012). Tree-based agricultural systems are currently being promoted in many parts of the World and its economic importance has been emphasized in different regions (Catacutan *et al.*, 2017; Jones *et al.*, 2012; Kattumuri *et al.*, 2017; Mbow *et al.*, 2014).

EbA strategies for enhancing biodiversity are designed as a bio-infrastructure that enhance the supply of ecosystem services and provide many long-term benefits to local communities, especially through access to natural resources and livelihood opportunities (Roberts *et al.*, 2012; Scarano, 2017). Local communities with access to forest resources usually follow a livelihood strategy that is highly dependent on forest extraction (Soltani *et al.*, 2012). Forests provide them with food, timber and non-timber products, ecosystem services, and employment opportunities that help them reduce their poverty (Ghanbari *et al.*, 2014; Sunderlin *et al.*, 2005). However, living in rural forest areas means being heavily dependent on natural-resources that are becoming increasingly unstable due to environmental changes like land degradation and climate change (Gentle and Maraseni, 2012). NTFPs, as a major forest products, are considered to be an important source of dependency on the forest ecosystem (Amiri *et al.*, 2015; Ghanbari *et al.*, 2020; Salehi *et al.*, 2010). NTFPs, as an adaptation strategy, constitute important safety nets and are sources of income diversification for many rural people facing increased climate hazard risks (Pramova *et al.*, 2012). Many researchers report that rural households depend more on NTFPs for coping with livelihood problems during famines. For example, by analyzing 54 case studies in the different parts of the World, Vedeld *et al.* (2007) showed that these products averagely have contributed 22% in total household income. Other studies have emphasized that NTFPs played a major role in supporting rural livelihoods in Iran (Ghanbari *et al.*, 2014; Ghanbari *et al.*, 2011; Keyvan Behju *et al.*, 2017; Khosravi *et al.*, 2017; Mahdavi *et al.*, 2009), Africa (Heubach *et al.*, 2011; Mamo *et al.*, 2007), Asia (Dash and Behera, 2016; Fu *et al.*, 2009; Mahapatra and Tewari, 2005), Europe (Lovrić *et al.*, 2020; Weiss *et al.*, 2020), America (Chamberlain *et al.*, 2018) and the World (Sheppard *et al.*, 2020).

Arasbaran forests (one of the five main vegetation regions of Iran (Sagheb-Talebi *et al.*, 2014)) has experienced many challenges including high dependency of local communities on forest resources (Ghanbari *et al.*, 2014; Ghanbari *et al.*, 2020), over exploitation and cutting of trees for fuel wood and overgrazing (Ghanbari et al., 2015; Sagheb-Talebi *et al.*, 2014). While some researchers have begun to focus on adaptation strategies designed to combat the impacts of climate change in this region (Gohari *et al.*, 2017; Karimi *et al.*, 2018; Keshavarz and Karami, 2016; Keshavarz *et al.*, 2014; Morid and Massah Bavani, 2010), the role of EbA adaptation strategies have not been studied in the

Arasbaran forest region, Iran. This study aims to identify strategies for improving the economic conditions of local communities and find ways to decrease poverty in the Arasbaran biosphere reserve of Iran. Data were collected by interviews and field observations regarding the communities' knowledge and expectations about future ecosystem services, their awareness of climate change, and its impacts on livelihoods besides local vulnerabilities and identify options for promoting adaptation.

Methods and Materials

Study area

Arasbaran forests are characterized by a high diversity of plant species, including more than 84 woody plants (Sagheb-Talebi *et al.*, 2014). Arasbaran forests cover a land area of 153,000 ha. The forest type is classified as broad-leaved deciduous. This region is situated along the border of Armenia and Azerbaijan between 38° 35′ N – 39° 00′ N latitude and 45° 45′ E – 47° 05′ E longitude (Figure 1). The climate is semi-humid and in some regions is semi-arid with an average annual temperature of 14°C and an average annual rainfall of 400 mm. The population is approximately 15,200, the population density is relatively low, and the main ethnic group is Azeri. The main livelihoods are from agriculture (wheat and barley) where the farming system consists of alternating cycles of cultivation and fallows. The East Azerbaijan province includes six percent of the total farmland in Iran and produces 3.5 percent of the total agricultural production (Shanavazi, 2014). The share of agriculture value added to total value added of the agriculture sector was estimated to be four percent in 2013 (Organization EAMAP, 2014). High value trees are preserved on croplands and grazing by cattle, sheep, and goat herds are extensive. In the semi-arid region of this area, sumac is planted at sloped lands by local farmers and cornelian cherry (*Cornus mas* L.) and walnut (*Juglans regia*) are integrated within the agroforestry systems.

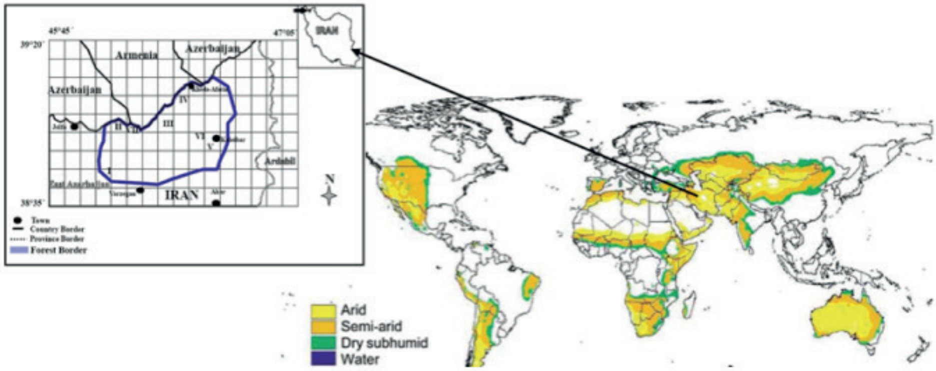

Figure 1: Distribution of arid and semi-arid region in Iran and study area in Northwest of Iran.

Abbildung 1: Verteilung der ariden und semi-ariden Region im Iran und des Untersuchungsgebiets im Nordwesten des Iran.

Data collection and analysis

Step 1: identification of the adaptation strategies

Data were collected using a socio-economic survey. The socio-economic survey included various methods including, field observations, informal discussions, focus group discussions (FGD) and implementation of a household survey. We identified four adaptation strategies through field observations which included, changing croplands into sumac woodlands, agroforestry, changing cropping patterns, and collecting Non-Timber Forest Products (NTFPs).

Step 2: Data collection

Regarding the changing croplands into sumac woodlands adaptation strategy, we observed that local farmers are changing croplands into sumac woodlands. We also observed that farmers are planting cornelian cherry and walnut to increase the flow of financial revenues from agroforestry systems. To assess the use of the first three strategies, we conducted a household survey consisting of 76 sample households from five villages (Kalaleh Ulya, Aghbiraz, Kalaleh Sofla, Mollalu, and Tabestanagh). The sample households were purposively selected using the following criteria: converting low yield croplands to sumac woodlands and employing agroforestry systems (Dejene *et al.*, 2013; Kar and Jacobson, 2012). Initial surveys and informal discussions were conducted to collect essential background information to be incorporated into the semi-structured questionnaire for the household interviews. The semi-structured questionnaire was designed to obtain information on the history of land use, the motivation of local people for converting farming systems, cropland ownership size, types of cultivated crops, area of cropland converted to sumac woodland, the quantity of sumac collected from woodlands, cost and price of inputs and outputs of production and selling constraints, and the function of planted trees within the agroforestry systems. For estimating tree yields in both strategies, the mean stem density per hectare and annual yield per tree/year were estimated (Mahapatra and Tewari, 2005). Annual tree yield was computed by multiplying the mean stem density per hectare with the mean yield per tree (kg/tree/year) (Dejene *et al.*, 2013; Mahapatra and Tewari, 2005). The yield of trees was obtained through focused group discussions (FGDs) with three different local groups of 4–5 individuals/group in each village (Damnyag *et al.*, 2011). To estimate annual crop yield per hectare, the farm size of the sample households was obtained through interviews. The quantity of the harvest was divided by the plot size (ha) to estimate annual crop yield per ha. The total monetary values of the outputs or inputs per hectare and year basis were calculated by multiplying the quantity of inputs and outputs per hectare with the corresponding unit price of each of the input and output, respectively. The market price for these products at the village level was used to estimate the prices of inputs and outputs, based on a direct survey of the market for prices and costs of outputs and inputs, respectively (Dash and Behera, 2016; Dejene *et al.*, 2013). In addition, the value addition of sumac before and after processing was computed and compared. To determine the profitability of processing activities, the processing efficiency was determined by subtracting the raw fruit weight from the processed fruit weight (Ghanbari *et al.*, 2014).

An NTFP-based adaptation strategy is another important strategy that can be employed to mitigate climate change risks. In order to evaluate the importance of NTFPs as an adaptation strategy, we conducted field surveys to develop product inventories as well as conducting interviews with households to determine their dependency on NTFPs (Henareh Khalyani *et al.*, 2014). NTFPs were fully inventoried in the six sampled villages and a biological inventory of all fruit-providing trees was carried out within the 2,700 hectares of the study area. The number of edible fruit trees was counted to facilitate the calculation of the number of each fruit-providing species per hectare (Ghanbari *et al.*, 2020). We also collected socio-economic data from the sampled villages through interviews with the heads of household (Soltani *et al.*, 2012). The surveyed households were randomly sampled within the selected villages (Henareh Khalyani *et al.*, 2014) and the number of questionnaires required was estimated based on Cochran's formula (Soltani *et al.*, 2012). In total, 90 questionnaires were completed by the participating households. At the household level, a comprehensive questionnaire was used to collect information on key socio-economic elements including household size, education, size of landholdings, occupation, sale and consumption of NTFPs, processing of NTFPs, and income earned from NTFPs and other types of activities (Cai *et al.*, 2011; Mamo *et al.*, 2007). In order to identify the dependence of households on NTFPs, NTFP dependency was measured as the contribution that the income derived from NTFPs provided relative to the total household income (relative NTFP income) (Heubach *et al.*, 2011). Other sources of household income included animal husbandry, farming, beekeeping, and off-farm employment. We employed a number of strategies to try to get an accurate estimate of household income. First we explained the aim of the research regarding climate change and the role of ecosystem services in combating climate change. In addition, we used different questions to help estimate household income. In order to estimate the annual household income from each type of livelihood, we asked questions about the number of livestock, the number of hives in beekeeping, farmland areas per household, and income from off-farm employment. We also asked questions about the income derived from, and the cost associated with, each activity during the past production period for each activity. Using this information, we estimated the annual household income from different sources of livelihood. Based on total NTFPs collected annually by the household and the market price of each species, the income derived from each NTFP was calculated and the total income from NTFPs was estimated by summing up the income from each individual NTFP (Schaafsma *et al.*, 2014).

Several factors may influence household utilization of freely available NTFPs. Some of these concern household characteristics while others are contextual. Larger households are able to clear more forest both because they have more workers and because they have more mouths to feed. Educated individuals may be in a better position to tap into income flows from natural stocks. A higher level of education makes fuelwood collection increasingly unprofitable due to the higher opportunity costs of labor (Adhikari *et al.*, 2004). Total household income (and wealth) is often found to have a nonlinear relationship with forest resource extraction. On the one hand, improved off-farm employment opportunities and better access to credit may reduce forest clearing as a revenue-filling activity. On the other hand, better natural resource asset endowments allow households the ability to exploit more forest resources. While (Escobal and Aldana, 2003) found that the demand for forest resources increased with income level, (Godoy *et al.*, 1997) found that the relationship between total income and forest clearance resembled an inverted U-shape. This argument seems to suggest that the relationship will remain linear and positive in poor communities.

Several factors have been found to influence the household collection of NTFPs including household size, education level of the head of household, household wealth, fruit prices, opportunity costs, and NTFP yields. The expected relationships between key household factors and NTFP collection are summarized in Table 1 with reference to previous research. In order to analyze the relationship between NTFP collection and the characteristics and external factors of households, we conducted an ordinary least square (OLS) regression of the NTFPs collection data against these variables using SPSS.

Table 1: NTFPs collection against household characteristics and external factors.

Tabelle 1: Sammlung von NTFP anhand der Haushaltsmerkmale und externer Faktoren.

Factor	Exp. Sign	Assumption	References
Household size	+	More people; more labor accessed; higher opportunity for collecting NTFPs	(Kamanga et al., 2009; Mamo et al., 2007)
Education of household head	–	High-educated households have more access to a wider range of income opportunities; low dependency on collection of NTFPs	(Coulibaly-Lingani et al., 2009; Heubach et al., 2011; Kamanga et al., 2009; Mamo et al., 2007)
Household wealth	–	More wealth, less need for collection of NTFPs and vice versa	(Heubach et al., 2011; Kamanga et al., 2009; Vedeld et al., 2007)
Fruit price	+	High price of fruits; high collection of NTFPs	(Adam et al., 2013; Mahapatra and Tewari, 2005)
Opportunity cost	–	High opportunity cost of households; low collection of NTFPs	(Coulibaly-Lingani et al., 2009; Illukpitiya and Yanagida, 2010)
Yield in the distribution areas	+	Higher yield of fruit-providing species in the distribution areas; easy access and greater collection of the products	(Coulibaly-Lingani et al., 2009; Schaafsma et al., 2014)

Results

The empirical and field evidence of adaptation strategies being employed by local people provides the basis and knowledge to design policies and actions for enhanced adaptation to climate variability for the region. The results are based on the households in the region who reported that were applying each strategy. Details of the strategies adopted in the Arasbaran regions as reported by the local people are described below.

I. Changing croplands into sumac woodlands as an adaptation strategy

Changing croplands into sumac woodlands is one of the most commonly adopted strategies for coping with climate change in the arid and semi-arid regions. In this region which is relatively semi-arid, sumac is planted on the sloped lands by local farmers. Farmland area (ha) was an opportunity for sumac planting, especially on the sloped farmlands. The mean farmland area was 5.9 ha per household and we found that each household has converted about one-hectare of farmland into sumac stands. Most of the households of the six villages (82%) were found to be involved in intensively planting sumac. All interviewed households reported that they had engaged in the collection and sale of sumac. This high importance of sumac was reflected in its contribution to household revenues. We found that sumac income contributed about 29% to total household income (Figure 2), followed by livestock activity (24%). Local people also recognize the importance of sumac in contributing to total household income and one survey participant emphasized that "sumac income play the main role for our livelihood."

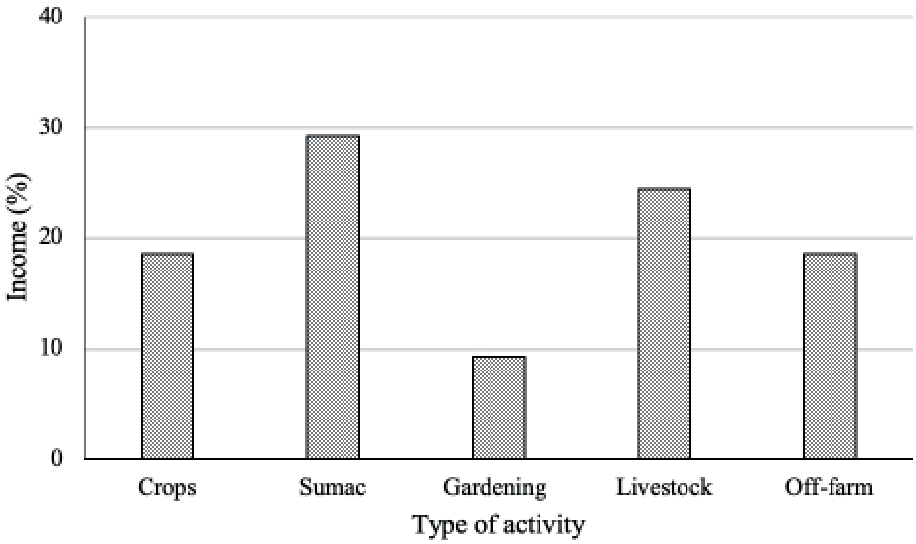

Figure 2: Share of income by income sources.

Abbildung 2: Einkommensanteil nach Einkommensquellen.

There are a number of external factors that influence the collection of these products. In order to determine the main factor influencing sumac income, we performed a correlation analysis between the various socio-economic characteristics. Sumac income was found to have a positive and non-significant correlation with education and the number of animals owned per household and was found to be significantly correlated with attendance at training workshops about the forest (table 2).

Table 2: Correlation analysis between socio economic characteristics and household sumac income.

Tabelle 2: Korrelationsanalyse zwischen sozioökonomischen Merkmalen und Haushaltssumach-einkommen.

Variable	Household size	Education of household head	Training workshops	Farmland area	Animal number per household	Total household income
Correlation Coefficient	-0.046	0.149	0.273*	-0.099	0.22	0.122

Local people considered sumac processing to be an important method of increasing household food security and nutrition. It generated additional employment and income, offered opportunities for processing enterprises and improving marketing channels. Sumac processing appears to be a profitable commercial activity for sumac harvesters and traders. Local people reported that "because the processing of sumac increases household income, it increases our motivation for processing." Another respondent said that "although processing creates employment opportunities and income, it needs more investment for providing equipment." Sumac processing increased the processing benefit by 10.5 USD per kg. The value addition of these products through semi-processing, drying, and grading can increase local people's income substantially (Avocèvou-Ayisso *et al.*, 2009; Saha and Sundriyal, 2012). The fruits obtained by collecting and drying reddish blackberry and sumac were sold in the market. In contrast, fruits of cornelian cherry and pomegranate were sold fresh in the local markets at lower prices. Several other researchers have noted the importance of processing in value addition (Avocèvou-Ayisso *et al.*, 2009) and this activity has been considered to be an important potential source of employment and income for poor people.

II. Agroforestry-based adaptation strategies

Traditionally, agroforestry has been an important land-use option for sustaining agricultural productivity and livelihoods of farmers by providing an alternative source of income (Swamy and Tewari, 2017). Our research found that the vast majority of households (91%) were involved in some type of agroforestry. In agroforestry, the tree species used is usually determined based on financial revenue and its effectiveness in adapting to climate change. Different tree species were planted in the agroforestry system (figure 3). Some households have grown one tree species and some other mixed species such as the composition of poplar and walnut or cornelian cherry.

Farmers practicing agroforestry did so as an additional source of additional income. They indicated that the income derived from agroforestry helped to meet their socio-economic needs and sustain their livelihoods in the face of declining productivity of agricultural crops. Walnut, cornelian cherry, and mulberry (*Morus alba*) were the most common trees planted for subsistence and the generation of supplemental income for households. In recent years, planting poplar has been decreased because of this tree species high demand for water. In contrast, the planting of adapted species such as cornelian cherry and Russian olive has been increasing. Cornelian cherry has a high market demand and this has provided additional motivation of local farmers in the cultivation of this species within the agroforestry landscape.

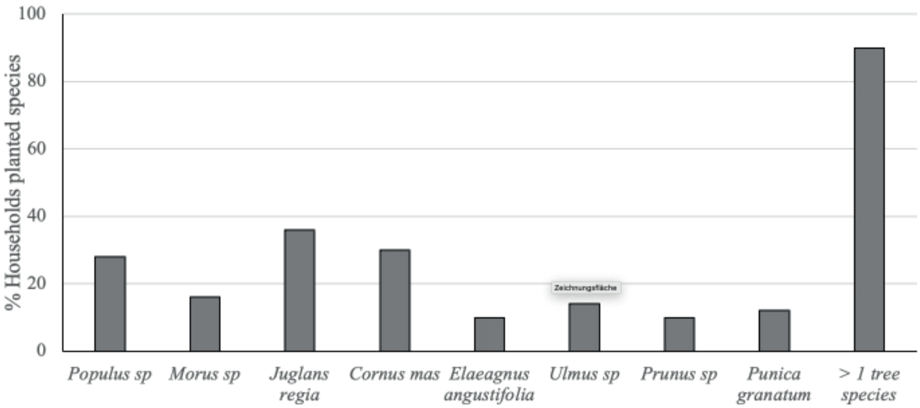

Figure 3: Tree species planted by households in agroforestry to adopting climate change.

Abbildung 3: Baumarten, die von Haushalten in der Agroforstwirtschaft gepflanzt wurden, um den Klimawandel zu übernehmen.

According to the results of this research, the eight trees planted within the agroforestry landscape provided different functions. All trees in this type of system performed a shade function. Other important functions were as follows: poplar (timber and windbreak), mulberry (animal fodder and fruit), Russian olive (fruit and nitrogen fixation), elm (timber), walnut, cornelian cherry, plum, and pomegranate (fruit). Mulberry leaves were used also for sericulture. Similar benefits to farm households have been mentioned by some other researchers (Lasco *et al.*, 2016; Swamy and Tewari, 2017). Lasco *et al.* (2016) identified 7 tree species planted within agroforestry systems in Bohol, Philippines. Swamy and Tewari (2017) reported that farmers take advantage of the benefits of agroforestry to help buffer against the effects of climate change in arid and semiarid regions. In South Benin, agroforestry has been identified as the most promising strategy for farmers, the environment and future generations (Fadina and Barjolle, 2018), who reported that the growing of perennial plants such as oil palm, citrus trees and teak trees are the most popular perennial species cultivated by farmers as a way of increasing farm income. In agroforestry, the species and diversity of tree species is critical in influencing not only income, but also for adapting to climate variability. The potential of agroforestry will only expand once the barriers to its implementation have been addressed through more efficient solutions. The recognition of agroforestry as a mitigation strategy under the Kyoto Protocol has improved its recognition as an adaptation strategy that can be employed by local communities (Hernández-Morcillo *et al.*, 2018).

III. Changing cropping pattern as an adaptation strategy

Changing cropping patterns by planting of drought-resistant varieties of crops was found to be another important adaptation strategy. The emphasis on planting more drought-resistant crops in arid and semi-arid regions could help in reducing vulnerability to climate change. Generally, there has been a shift from water-intensive to less water-intensive crops. A similar practice was adopted by the farmers of the Barind region of Bangladesh who have cultivated a drought-tolerant rice variety to in response to climate changes (Hossain *et al.*, 2016). Further, this shift was mostly from lower economic yielding crops (*i.e.*, wheat, barley, and rice) to crops that provide higher economic returns (*i.e.*, saffron and lentils). Changing cropping patterns has been noted as an adaptation strategy by Morid and Massah Bavani (2010) in Isfahan, Iran and Hossain *et al.* (2016) in the Barind region of Bangladesh. In addition, Kattumuri *et al.* (2017) reported that farmers in the semi-arid regions of Karnataka in India adopted shifting cropping pattern practices to adapt to climate risks. Some researchers suggest that it may be the best possible strategy to mitigate the negative impacts of climate change (Morid and Massah Bavani, 2010).

Previously, planting saffron was limited to the eastern region of Iran including Khorasan and Kerman but it has expanded in other parts of Iran especially Azerbaijan and their villages where are faced with water deficiency. In the sampled villages, 33% of farmers reported that they had replaced their crops with potentially more drought-resistant crops such as saffron and lentils depending on the annual rainfall. Although the farmland areas converted to saffron were low, the use of drought-resistant crop varieties such as saffron is being tried by some farmers as pilot farms. They considered saffron to be an effective adaptation method to climate change in the studied villages. Over the past ten years, the saffron farmland area has been increased from 65 ha to 143 ha in the research area. In addition to providing resistance to climate change and drought, it has high income generating potential. The interview results showed that the annual average income derived from the sale of saffron was about 3,000 USD per hectare. Other researchers have noted that changing cropping patterns is seen as one of the most commonly adopted practices for coping with climate variability in agriculture especially with small and marginal farmers (Kattumuri *et al.*, 2017).

IV. Non-Timber Forest Products (NTFPs) based as an adaptation strategy

Non-Timber Forest Products (NTFPs) is one of the main economic benefits derived from forest regions and a majority of local people in the sample villages reported that they depended on these products.

The results of this research showed that 14 NTFP-providing species were identified in the study area, although the three species of cornelian cherry, plum and walnut had a higher density than other species. Other NTFPs-providing species included raspberry (*Rubus* sp.), dog rose (*Rosa canina*), pear (*Pyrus* sp.), hawthorn (*Crataegus* sp.), wild apple (*Malus orientalis*), pomegranate (*Punica granatum*), pistachio (*Pistacia mutica*), medlar (*Mespilus germanica*), barberry (*Berberis* sp.), sumac (*Rhus coriaria*), and hazelnut (*Corylus avellana*) (table 3). The high diversity of NTFPs-providing species reported in Arasbaran is considered as having a large potential to empower local people and increase their ability to combat climate change. Arasbaran forests with about 1,334 different plant species (Sagheb-Talebi *et al.*, 2014) can easily play this role in supporting the livelihood of local people. The United Nations' Convention on Biological Diversity notes that the most widely adopted method is the use of biodiversity and ecosystem services (BES) as part of an overall strategy to help people to adapt to the adverse effects of climate change (Scarano, 2017).

Table 3: The potential production on NTFPs-providing species.

Tabelle 3: Die potenzielle Produktion auf NTFP-liefernden Arten.

Variable	Cornelian cherry	Walnut	Plum	Other species
Number of trees	2628	545	1785	7418
Total production (Kg)	2872	21743	8075	9403
Income per household (USD)	298	295	27	147

Local households typically collected the fruits of these species from July through November. Plum was collected by 60% of households and a large proportion of households were engaged in the collection of cornelian cherry (42%) and walnut (33%). One of the respondents said," fruit derived from forests creates food security during a time of drought season and when we have not enough crops for meeting food needs". Another respondent said, "Although climate impacts on NTFPs, some years is drought season and some others is rainy but variations are NTFPs is lower than other products." Figure 4 shows the share of different activities relative to total household income. The average share of NTFPs to total household income was 27% (comparable to that derived from farming), while animal husbandry, farming, and beekeeping were the other sources of household income (Figure 4). Developing a diversity of income sources can help to offset the risks associated with climate change. Khosravi *et al.* (2017) estimated that the dependency of local people on NTFPs was between 10% and 21% among different income groups in the Zagros forests of Iran. Other researchers in the Zagros forests have estimated this ratio to be about 30% (Salehi *et al.*, 2010) and 33% (Soltani *et al.*, 2012).

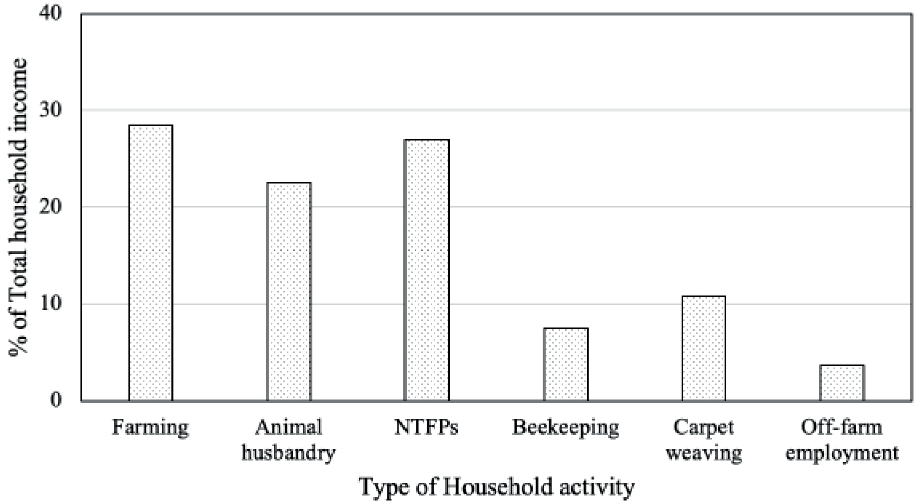

Figure 4: The contribution of different household activities in total household income.

Abbildung 4: Der Beitrag verschiedener Haushaltsaktivitäten zum Gesamteinkommen der Haushalte.

An OLS regression analysis showed that NTFP collection was significantly and negatively correlated with the level of education of the household head and opportunity cost ($p<0.05$), and household wealth ($p<0.001$). The collection of NTFPs was positively and significantly related to fruit price and yield in the distribution area ($p<0.001$) (table 4).

Table 4: OLS regression of household collection of NTFPs against socio-economic characteristics. R2 = 0.818; R2 adj = 0.803; F = 52.569; p<0.001.

Tabelle 4: OLS-Regression der Haushaltssammlung von NTFP versus sozioökonomische Merkmale.

Factor	Coeff.	SE	t-value	*p*-value
Intercept	-1.83	24.5	-0.075	0.94
Household size	0.258	1.39	0.185	0.854
Education of household head	-0.575	0.269	-3.57**	0.037
Household wealth	-0.0001	$-5*10^{8}$	-0.271*	0.001
Fruit price	+0.004	0.001	4.23*	0.000
Opportunity cost	-0.001	0.0002	-2.42**	0.08
Yield in the distribution areas	+0.09	0.006	15.02*	0.000

Several factors influence the dependency of local households on NTFPs. The larger the household size in our study area, the higher the likelihood of NTFP collection. The influence of household size on NTFP collection was in line with other studies, where NTFP collection was found to be positively related to household size (Kamanga *et al.*, 2009; Khosravi *et al.*, 2017; Mamo *et al.*, 2007). Large families have more workers and greater opportunities to carry out labor intensive activities. Households with higher education levels often have more external sources of income. In previous studies, higher levels of education have been shown to reduce dependency on forests and NTFPs (Khosravi *et al.*, 2017; Mamo *et al.*, 2007). A higher level of education provides a wider range of employment opportunities while making NTFPs collection less lucrative due to the higher opportunity costs of collection. This result is similar to findings by Mamo *et al.* (2007) and Kamanga *et al.* (2009) which concluded that education is a major determinant of access to NTFPs. The finding related to household wealth is supported in these research results. Households with medium and upper-income levels were much less engaged in the collection of NTFPs. These results showing a stronger dependency on NTFPs among households with lower wealth are consistent with the findings of Kamanga *et al.* (2009) and Khosravi *et al.* (2017), while contrasting the results of Heubach *et al.* (2011) which found wealthier households generate more cash income from NTFPs than poorer ones. Fruit price is one of the most important factors in increasing a forest's economic value. The growing demand for organic products has been reported in many developed countries (Cai *et al.*, 2011). This can create a new market opportunity for the export of NTFPs to these countries. In our study area, most of the products were not traded in markets. Thus, a lack of market information and market access limit the economic benefits obtained from NTFPs for these communities. Also, Soltani *et al.* (2012) have emphasized the importance of developing new markets as an opportunity for increasing the income of rural households. Our research showed that there was a low number of species being sold in local markets, while these products can be exported to national and international markets (Ghanbari *et al.*, 2014). Other scholars have also found that these factors influence the trading of NTFPs (Saha and Sundriyal, 2012). Although trade relationships are currently limited by international sanctions on Iran, NTFPs are not included on the sanctioned products list. Thus, there is a new opportunity to expand markets and increase income by exporting these products. To increase NTFPs income significantly, it is recommended to export them in a processed form. Our results showed that the fruit price was statistically significant and positively correlated with NTFP collection by households. This was consistent with other recent studies on the relationship between fruit price and NTFP collection (Adam *et al.*, 2013; Mahapatra and Tewari, 2005). Due to the increasing price of fruit, the demand for the collection of NTFPs is likely to increase and therefore fruit-providing species are highly prone to overexploitation (Heubach *et al.*, 2011; Mahapatra and Tewari, 2005).

Conclusions

Adaptation to climate change is a two-step process that requires that rural communities first perceive climate change and then respond by adopting an adaptation strategy (Asrat and Simane, 2018). To better manage climate change impacts on the food security of forest dependent communities, it is important that these communities identify the magnitude of climate trends and also identify suitable strategies to respond to climate changes. EbA strategies as local coping strategies are one option for responding to long-term climate change risks. In addition, the goals of ecosystem-based adaptation may overlap with economic development in rural areas through the improvement of nature-based livelihoods. In other words, by better harnessing the resources to respond to climate variation and improve rural livelihoods, EbA has the potential to alleviate poverty for rural communities that are threatened by adverse climate change impacts. However, consistent with other research, EbA affects different social-economic groups differently depending on how differentiated capacities (*e.g.* income, education, access to land) may limit the adoption of EbA strategies to manage risk (Duan, 2017).

In this research, we identified four strategies for mitigating climate change risks; converting croplands into sumac woodlands, agroforestry, changing cropping patterns, and NTFP-based resource extraction as adaptation initiatives by local communities. Identifying these strategies can help to mitigate climate change impacts in semi-arid regions. All identified strategies are interconnected with ecosystem services directly and indirectly but some strategies such as agroforestry and NTFPs are more directly related to ecosystem services. The first strategy, changing croplands into sumac woodlands can be useful for other sloped lands in other arid and semi-arid regions of Iran. Despite its high potential, agroforestry has not yet been adopted on a large scale as a mitigation or adaptation mechanism and its uptake is growing slowly due to several socio-economic and technical challenges (Hernández-Morcillo *et al.*, 2018). Agroforestry is an integrated land-use system that can provide an important add-on option to the conservation of both flora and fauna, mitigating CO_2, and improving livelihood resilience to climate variability and change (Mulatu and Hunde, 2019). Swamy and Tewai (2017) mentioned that local communities have developed tree-based systems to reduce climate change risks. The tree component in agroforestry serves an important role in the conservation of fauna diversity, provision of ecosystem services (*e.g.* provision of food, fuel wood, improve crop productivity, increase cash income, etc.) including climate regulation services (Mulatu and Hunde, 2019). NTFP-based strategies can increase the resilience of local communities in forest regions. Many of these local communities recognize that climate change risk impacts their livelihoods and has incentivized them to adopt adaptation strategies for food security. Nevertheless, the present research can help governmental and non-governmental organizations to make suitable decisions to prioritize actions related to reducing climate change risks and provide inputs for policy formulations and implementation. Thus, it will help to decrease climate change risks at both the local and national levels (Hossain *et al.*, 2016). In addition, climate change education can be incorporated into school and university curricula to help people to understand this issue and also teach people how to better cope with climate change (Ghanbari *et al.*, 2019; Hossain *et al.*, 2016). This information is important for planners, extension agents, and NGOs in identifying and adopting more effective responses to help mitigate climate change risks. Lastly, adaptation projects should be contextualized according to the communities and ecosystems around them. This research suggests that the incorporation of the diverse ecosystem-based approaches in different thematic areas can promote sustainable livelihoods for rural communities. Training programs for agroforestry managers and the development of safe economic routes are key solutions to promote sustainable agroforestry systems.

Climate change risks impact rural people. It has increased rural migration dramatically due to farmer's inability to sustain their livelihoods due to climate change. Within the current context of this research, the ratio of the rural population to urban population has changed from seventy percent to thirty percent over the past forty years and has led to some problems in the policy-making programs for rural areas. Recently in order to decrease the migration rate from rural to urban areas, the government has begun supporting local people by working to create employment opportunities and increase income and also by improving the farming and irrigation methods by providing low interest bank loans. Further research is needed to consider the effects of governmental policies in supporting rural areas for decreasing migration and supporting local communities in increasing the adoption of climate change adaptation policies. Developing a successful understanding of the potential of agroforestry requires awareness by decision-makers and the public and support for landowners in terms of technical know-how and access to and choice of appropriate planting species and management.

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