Farmers' vulnerability to global change in Navarre, Spain: large-scale irrigation as maladaptation.

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Abstract Agricultural landscapes are dynamic environments which change in response to cropping and trade opportunities, available technologies, and climatic conditions. In this article, we investigate farmers' vulnerability to climate related stressors and crop price volatility in rural Navarre, Spain. Specifically, we analyse the extent to which livelihood differences and vulnerability can be partly explained by the development of a large-scale irrigation project promoted by the Spanish and regional governments. Grounded on qualitative and quantitative data gathered across 22 villages, we demonstrate that small-scale diversified farmers appear the most vulnerable and least able to adapt to climate related stressors and crop price volatility. In contrast, more market-driven, large-scale intensive farmers, who participate in the irrigation project, are the least vulnerable to these stressors. We argue that the irrigation project has increased the short-term adaptive capacity of irrigation adopters while establishing the institutional conditions for the displacement of small-scale farming. Therefore, we suggest that farmers' vulnerability in Navarre can be explained by maladaptive irrigation policies designed to favour large-scale and market-driven agriculture.

Keywords: social vulnerability; large-scale irrigation; global change; sensitivity; adaptive capacity; exposure

Introduction

Historically, agricultural landscapes are subject to changes in ecological, social and cultural conditions (García-Martín et al., 2018). Agrarian systems are subject to rapid change at shorter time horizons due to a combination of multiple drivers, such as shifting agricultural markets, increased climate variability, new policies and technological development, in addition to slower underlying changes in demographics and socio-cultural values (Borras and Franco, 2011). Over the last few decades, agricultural intensification has been a key driver of agricultural change (Foley et al., 2005; Tilman et al., 2011), resulting in higher available food, fibres and biofuels but also in reductions of agricultural biodiversity (Dirzo and Raven, 2003) and of regulating ecosystem services (Foley et al., 2005; Rasmussen et al., 2018). Agricultural intensification has often been spurred by land privatization policies and industrial-scale production processes (Murgida et al., 2014), which have led to land property concentration and large scale technological lock-in, via the introduction of 'improved' seed varieties or large-scale irrigation infrastructures (Andreas and Zhan, 2016).

It becomes pertinent to investigate which and to what extent farmers are vulnerable to these multiple and often co-existing processes of change, and in doing so shed light on which farming livelihoods might benefit the most and which agricultural landscapes might emerge as a result (Turner et al., 2003; Smit and Wandel, 2006; Adger, 2006; Notenbaert et al., 2013). Drawing on Adger (2006) we understand vulnerability as the expression of a condition that reflects people's ability to deal with the range of processes and stressors that underpin social-ecological changes. Here we aim to contribute to the operationalization of vulnerability in agrarian landscapes by connecting it to farming livelihood typologies. Moreover, we expect to shed light on how farming livelihoods are affected by large-scale irrigation projects, which underpin agricultural intensification strategies and are often presented as a climate change adaptation strategy (Maleksaeidi et al., 2016; Varela-Ortega et al., 2016).

Large-scale irrigation projects have been highly contested (Berbel and Mateos, 2014; Cabello et al., 2015; Tarjuelo et al., 2015), particularly on the grounds of mixed empirical evidence (Garrote et al., 2015; Dumenu and Obeng, 2016). The institutional changes associated with large-scale irrigation often entail new property and water management rules that transform existing power relations and decision-making processes, often to the detriment of the least empowered and endowed farmers (Hara and Backeberg, 2014; Andreas and Zhan, 2016). Furthermore, large-scale irrigation and its accompanying policies are designed to collude with the interests of powerful actors (Smith and Stirling, 2010), and they tend to foreclose alternative development pathways (Partelow and Winkler, 2016). Large-scale irrigation aims at optimizing economic growth through technological change at the expense of the 'sustainability' of broader actor constituencies (Partelow and Winkler, 2016), particularly of those who cannot lobby to continue using public and communal goods for their own private benefit (M. D. McGinnis and Ostrom, 2014).

In this article, we investigate how a large-scale irrigation project in rural Navarre, Spain, affects farmers' vulnerability and adaptive capacity. We use a farmer-focused survey to develop a vulnerability index, and we complement the index results with insights from interviews and focus groups. We show that the project is increasing the adaptive capacity of large-scale irrigation adopters to climatic and market stressors, but also enhancing the vulnerability of small-scale farmers. We suggest that the irrigation project can thus be understood as a maladaptive practice that may undermine adopters' adaptive capacity in the long-term and we discuss why this is the case (Barnett and O'Neill, 2010). The findings also illustrate why agricultural policy should pay more attention to its negative effects on the most vulnerable farmers and why it should increase its support to such farmers in their attempt to pursue their livelihood in the context of global economic and environmental changes.

Case study and methods

Background to the study area and the irrigation project

To understand how large-scale irrigation affects farmers' vulnerability to global change, we analyse the deployment and adoption of an irrigation project known as the *Itoiz-Canal de Navarra,* which involved the construction of a dam and a water irrigation channel across the *Zona Media* and *Ribera Alta* of Navarre in the Ebro River watershed (Figure 1). The governments of Spain and Navarre promoted and funded the large-scale irrigation project creating a public society called *Canal de Navarra S. A.* (CANASA), with 60% and 40% of public funding from each government, respectively. The project was planned in two phases. Here, we focus on the first development phase of the project (2006-2014), which involved a water channel of 119 kilometers and the irrigation of 37.445 hectares through water canals, distributed across rainfed and traditionally irrigated lands managed by approximately 3600 farmers.[1] The land affected is characterized by a flat topography, fertile soils and a mild Mediterranean climate. Traditionally, cereals like winter wheat and barley have been grown in the area, alongside vineyards for high quality wine production. Olive trees can also be found and fruit trees and vegetables plots are located along the margins of the Ebro river (Larragueta, 2012).

Figure 1. Location of Navarre province and Phase 1 of the Itoiz-Canal de Navarra irrigation project

Before the *Itoiz Canal de Navarra* project was developed, some villages in the studied region had a traditional irrigation system inherited from the Arab period; which captured water from the river, transported it through irrigation ditches (*acequias*), and flooded agricultural plots through a gravity-fed system. Water in *acequias* was considered common property, and compliance with community obligations was required for an individual to maintain their individual water rights. Despite this system persisting in these villages for centuries, most farmers have now adopted large-scale irrigation, partly in response to agricultural development policies, an increasing focus on markets and competitiveness (Cox, 2014), and by the high costs involved in maintaining and fixing the *acequias*. Farmers who got involved in the large-scale irrigation project have had a 40% to 50% share of their investment costs (approx. 3900 euro/hectare) covered by the Navarre government. Furthermore, communal land decrees and laws, have also been modified to facilitate large-scale irrigation affecting land access.[2]

Pressure sprinklers are now the most common irrigation tool and a drip irrigation system is also installed when appropriate (e.g. with crops such as vegetables, vineyards or trees). Large-scale irrigation technology has also entailed changes in the types of crops grown, being corn (*Zea mays*) and forage the predominant crops that have been introduced. Most farmers have abandoned traditional crops with high labour costs such as asparagus, peppers and fruit trees, which compete with imports from countries like China or Peru. Such a trend has also offered new opportunities for the production of biofuel (De Vries, A, and Garcia M., 2012).

The large-scale irrigation project has also changed the way water consumption is measured and credited. The former is reflected on a meter located next to the hydrants, and farmers pay for water consumption and the maintenance and conservation work carried out by CANASA. This shift in water management, from local communities to private enterprise, has implied a major break with traditional Spanish collective irrigation management institutions (Sanchis-Ibor et al., 2017). Irrigators have lost power an

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[1] When the project is concluded, the channel is expected to run for 177 km and to have irrigated 57,700 hectares of farming land.

[2] Communal land decrees refers to Foral Law 6/1986 -repealed by Foral Law 6/1990. Likewise, councils transforming communal lands can get a higher subsidy for the installation of irrigation technology if such councils prioritise full time farmers rather than other kind of farmers when allocating communal lands among the neighbouring farmers (Foral Order 186/2011 and Foral Order 185/2015).

authority in favour of CANASA, which now monitors water consumption, influences water pricing and establishes sanctions in case of non-payment.

The irrigation project has also affected land property and local institutions through a process known as *concentración de tierras*, which requires farmers to bundle at least 5 hectares of farming land. Such bundling is aimed at facilitating the cost-effective installation of the new irrigation system and the improved use of heavy machinery and spread of synthetic fertilisers and pesticides. Consequently, average yields have increased. For example, winter-wheat yields increased on average 5900 Tm/hectare between 2013 and 2014 in the whole Ribera Alta region as a result of irrigation-driven intensification (Gobierno de Navarra, 2016).

The *Itoiz-Canal de Navarra* project has been controversial since its design phase in 1987, and has faced considerable opposition from some farmers and civil society organisations (Beaumont, 1997; Diario de Noticias de Navarra, 2016, 2018). These have often argued that the project would result in severe environmental degradation, and the loss of traditional crops and related cultural practices (Diario de Noticias de Navarra, 2016). However, other farmers and organisations, including INTIA — the regional government's agency dedicated to providing technical and market services to rural farmers throughout the region — have argued that large-scale irrigation would promote agricultural development and improve rural livelihoods (INTIA, 2016).

Methods

A randomized and semi-structured household survey was carried out from October 2013 to January 2014 in order to identify farming profiles and develop a vulnerability index. The survey targeted 381 farmers across 22 villages affected by the irrigation project.[3] Probability sampling and proportionality in each of the affected villages was applied. For the sake of brevity, we do not develop in the results below how we identified the four farming profiles that emerged from the survey (for details see Albizua et al., 2016). Nevertheless, it is important to note that we found four types of farmers in the study area, which differed in the way they managed land and mobilized assets, including irrigation water and technology.

As Table 1 informs, s*mall-scale diversified* farmers hold a more diversified economy encompassing part time and retired farmers. They grow vegetables and woody crops, such as olive and almond trees for self-consumption in small plots (0-1 hectares). They are not interested in market-focused, higher-value and higher-yielding crops, and they have not adopted large-scale irrigation. *Medium-scale organic* cultivate cereals and vineyards mostly under rainfed systems and who use organic fertilisers in farms up to 10 ha. Although some of these farmers are involved in the irrigation project, watering practices involve drip-irrigation with comparatively low water consumption levels. *Medium-scale intensive* farmers mostly grow maize in land tracks of about 5-50 ha, using large-scale irrigation and conventional fertilization methods. Finally, *large-scale intensive* farmers tend to be older and cultivate larger tracks of land (>50 ha) of rainfed as well as irrigated cereals, using both conventional and organic fertilisers (see Table 11 in Supplementary material for more detail). S*mall-scale diversified* farmers are more prevalent in the northern villages, *medium-scale organic* farmers in *Zona Media* villages and large-scale *intensive* farmers in the southern villages (see Table 12 in Supplementary material).

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[3] Questions with too many missing values were removed before data analysis. When there were few missing values (e.g. <ten missing data) it was retained, but respondents with missing values were removed from the analysis of such particular variable. Thus, the results rely on 364 respondents of the 381 total surveys performed.

Table 1. Summary of farmers' livelihoods

Livelihood type	**Description**
Small-scale diversified farmers (N=125)	Small-scale farmers hold a more diversified economy encompassing part time and retired farmers. They hold plots of 0-1 hectares of "other" crops (vegetables, fruit trees). They do not use sprinklers and do not cultivate the main commercial crops (maize, vineyards and biofuels)
Medium-scale organic farmers (N=22)	Younger farmers who cultivate cereals and vineyards mainly under rainfed systems or under drip irrigation systems who use organic fertilisers in farms up to 10 ha.
Intensive farmers, both medium and large-scale (N=217)	Full-time farmers, mostly growing maize and other cereals in land plots between 5 and >50 ha, who have adopted large-scale irrigation and mainly conventional fertilisation methods.

Using a snowball sampling method (May-July 2013) we conducted 29 key informant semi-structured interviews with farmers, representatives of farming cooperatives, policy-makers, scientists and NGOs across the study area, as well as with those who had been involved in the design and implementation of the irrigation project. We carried out 19 additional and purposive interviews with farmers from the four different livelihood profiles (May-June 2015). The first round of interviews aimed to reveal perceptions of the large-scale irrigation project and, in the case of farmers, at better understanding the assets that influenced their sensitivity and adaptive capacity to the stressors identified through the survey. The second round of interviews aimed to validate the survey results and understanding in further depth existing vulnerabilities. Interviewees in both rounds were asked for consent to participate and to tape-record the interviews.

Survey and interview data were complemented with additional qualitative information from a focus group discussion used to further discuss the factors influencing farmers' vulnerability and adaptive capacity. The discussion was held in December 2014 in Miranda de Arga, one of the villages affected by the irrigation project. Participants were recruited using purposive sampling based on farmers' livelihood profiles, but not all those who initially agreed to participate attended. The group consisted of a local environmental activist, an owner who refused to participate in the irrigation project, an INTIA technician, and two members of the traditional irrigation community (eventually members of the large-scale irrigation project and representing medium-scale intensive farmers). The discussion lasted 6 hours and was recorded and transcribed involving three project researchers.

Measuring vulnerability

We drew on Hahn et al. (2009) to develop our vulnerability index. Each of the three vulnerability components (exposure, sensitivity and adaptive capacity) is made up of a set of subcomponents at different levels (Levels 3 and 4 in Figures 2 and 3), in turn associated with physical, natural, human, social and financial capital assets, as well as with socio-demographic variables. To calculate climate variability, we used a data series of 89 years (1920-2009). We selected data from seven meteorological stations and assigned farmers to the closest station where each interviewee lived and worked. We calculated the average standard deviation of the maximum and minimum monthly temperatures and monthly precipitation (Ahmed et al., 2009; Hahn et al., 2009) (Level 3 of Figure 2). For estimating drought, we subtracted evapotranspiration from the average rainfall (Figure 2). We acknowledge that different crops have diverse growing and maturation periods, but annual averages were best suited to analyse the four assessed crops simultaneously.

In order to assess farmers' exposure to price volatility, we compiled regional data on prices and yield production, using data provided by the Department of Agriculture of Navarre. The standard deviation for each crop for the period 1995-2013 was calculated. Also collected in the survey were selected sub-components of adaptive capacity and sensitivity, such as income diversification or the subsidies, respectively, through a review of the literature on sustainable livelihood assessments (SLA) (Ifejika Speranza et al., 2014; Notenbaert et al., 2013). During our interviews and the final focus group, we also discussed the influence of such components on households' sensitivity and adaptive capacity.

Figure 2. Categorisation of analytical variables, components and contributing factors from the interpretation of vulnerability by the IPCC (2007) for climate connected stressors

Figure 3 Categorisation of analytical variables, components and contributing factors from the interpretation of vulnerability by the IPCC (2007) for crop prices connected stressors

We quantified adaptive capacity based on a number of variables. For human capital, we included knowledge in the form of academic curricula or years of working experience. We accounted for socio-demographic variables, such as age, gender and number of family members working on the same farm. We considered financial status through the percentage of owned and rented land, the subsidies perceived (CAP, modernisation and irrigation) and the number and type of agrarian insurances bought (integral, for hail only, others). Physical assets included internet use and the participation in the project and the subsequent installation of large-scale irrigation technology (i.e. sprinklers), while social networks referred to farmers' participation in specific organisations as an important means for information exchange.

We measured sensitivity by assessing the current state of the household and the stressors' effect on the agro-ecological system. Indicators included the level of crop diversification, the number of economically dependent family members, and the hectares of cultivated maize – a crop that is more dependent on irrigation than others in the region are.

Following Hahn et al. (2009) we used a balanced weight approach in the calculation of the vulnerability index, where each sub-component contributes equally to the overall index, despite each major component being comprised of a different number of sub-components. Once we had selected all the variables (sub-components) classified by each component, we normalised them as an index: Y = (value - min)/(max. – min.), where Y denotes an indicator of vulnerability (Hahn et al., 2009; Yagiz and Gokceoglu, 2010; Albizua et al., 2015). Having standardised the sub-components, the same weight was given to each of the components:

$$\mathrm{CF} = \sum_i^n WMiMi \ / \ \sum_i^n WMi \qquad (1)$$

CF is the IPCC-defined contributing factor (exposure, sensitivity, or adaptive capacity). Mi is the major components index. W is the weight of each component, and n is the number of major components in each contributing factor. Once exposure, sensitivity, and adaptive capacity were calculated, the three contributing factors were combined using the following equation:

$$\mathrm{VI(i)} = (\mathrm{E} - \mathrm{AC}) * \mathrm{S} \qquad (2)$$

VI(i) is the vulnerability index where (i) is the subscript denoting each farmer.

Results

Locally perceived stressors and farming vulnerabilities

During the first round of key informant interviews, farmers mentioned three main stressors on their livelihoods. These were crop price volatility in agricultural markets; climate variability and drought;

and lack of institutional support. During the survey, when asked to evaluate these stressors on a scale from zero to five (zero as insignificant and five as extremely important), farmers highlighted that climate variability and drought, as well as their lack of control over crop prices were the most critical.

Eighty-two percent of the sampled farmers assigned the highest importance to not having control over their crops' selling price. Based on secondary data by the Department of Agriculture of the Government of Navarre (Gobierno de Navarra, 2015), the price volatility of the dominant crops in the study area was higher during the 2000-2010 decade than in the previous two decades. In addition, 60% of the surveyed farmers considered climate variability and drought an important stressor, but response variance was higher. This can be explained by differences in memory recall and by the fact that the *Zona Media* is usually wetter than *Ribera Alta*.

Finally, 45% of the respondents believed that institutional support from formal organisations, such as Navarre government, was insufficient and that such organisations did not provide enough subsidies to make most farming livelihood economically viable. All participants in the focus group agreed that small-scale farms were disappearing, mostly as a result of decreasing institutional support. In the words of a farmer, "I wonder why another type of development has not been favoured" (Miranda de Arga neighbour, sustainable fluvial manager and member of Urbizi NGO: FG1-3). A high standard deviation when rating such stress might be explained by distinct understandings of "institutional support" during the survey and, for this reason, we decided to exclude this stress from the analysis below.

Zooming into farming typologies

As Figure 4-a illustrates, climate related stressors affect farmers differently. The vulnerability index for climate related stressors is on a scale from -0.10 (least vulnerable) to 0.24 (most vulnerable). The analysis shows that *small-scale diversified* farmers (VI_climate = 0.035) and *medium-scale rainfed organic* farmers (VI_climate = 0.015) are the most vulnerable groups to climate related stressors, whereas *medium-scale intensive* farmers (VI_climate = 0.007) and *large-scale intensive* farmers (VI_climate = 0.005) are less vulnerable. Figure 4-b illustrates the three dimensions of vulnerability when farmers are exposed to crop price volatility. It is on a scale from -0.48 (least vulnerable) to -0.062 (most vulnerable).[4] The analysis shows that *small-scale diversified* farmers (VI_price = -0.20) and *large-scale intensive* farmers (VI_price = -0.24) are the most vulnerable groups to price volatility related stressors, whereas *medium-scale rainfed organic* farmers (VI_price = -0.27) and medium-scale intensive farmers (VI_price = -0.27) are less vulnerable.

Figure 4-a Vulnerability to climate stressors (climate variability –i.e. precipitation and temperature- and shock –i.e. drought). Figure 4-b Vulnerability to crop price volatility

The disaggregation of the vulnerability index is useful to identify and further understand the underlying factors of vulnerability across farmer typologies. Figure 5-a identifies the contribution of each factor to the index, when considering climate related stressors (i.e. temperature and precipitation variability and drought). Similar results are obtained when assessing vulnerability to crop price volatility (Figure 5-b).

Figure 5 Disaggregated components of vulnerability to climate variability (panel a) and crop price volatility (panel b) for the four types of farmer groups.

Small-scale diversified farmers (N=125)

According to the values of the vulnerability index, *small-scale diversified* farmers face the greatest exposure to climate related stressors whereas their adaptive capacity is much lower compared to other

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[4] Check the development of the index in the methods section and supplementary material. VI can take negative values when adaptive capacity (AC) values are higher than exposure (E) values.

farmers. Their human capital assets are the lowest among all farmer groups, and their lack of access to physical assets (e.g. large-scale irrigation), financial (e.g. subsidies and insurance) and social assets (e.g. belonging to agrarian cooperatives) constrain their adaptive capacity.

The non-adoption of large-scale irrigation by small-scale farmers affects their access to natural, financial, human and social assets. First, most[5] interviewees and participants in the focus group explained that most farmers who were not able or willing to participate in the irrigation project decided to sell or rent their arable lands to those who did join. As a focus group participant explained: "The high investment required to participate in the large-scale irrigation project means that land is allocated to very few people; many were forced to sell their lands since they were not willing to invest so much money" (Miranda de Arga neighbour, sustainable fluvial manager and member of Urbizi NGO: FG1-3). When accessing an internal list of land ownership held by an irrigator in Miranda de Arga, we indeed noted that the number of landowners in the village had decreased by 23% between 2013 and 2014 (i.e. 80 farmers had sold their lands to larger farmers).

Second, the substitution of the traditional irrigation system by the large-scale irrigation system promoted through the *Itoiz-Canal de Navarra* project suggests that public policies undervalue the traditional rights to water held by all farmers in the past, and by *small-scale diversified farmers* in particular. Consequently, the latter group has now seen how their access to communal land and irrigation water has been compromised, since normative allocating communal land favours those adopting large-scale irrigation and the denial of small-scale farmers to adopt this approach has supposed their loss of traditional irrigation rights. Third, their lack of involvement in the large-scale irrigation project also constrains their access to the large-scale irrigators' community, which is further influenced by the fact that small-scale farmers are rarely members of local cooperatives. In comparison to the other farming groups, their lack of social capital has resulted in a low level of access to subsidies, information, labour-sharing opportunities and land borrowing practices.

Medium-scale organic farmers (N=22)

As Figure 5 shows, *medium-scale organic* farmers are the second most vulnerable to climate variability. These farmers have adopted large-scale irrigation, but they often use drop irrigation systems in medium size plots. Their vulnerability to climate related stressors is mostly explained by a relatively high sensitivity (i.e. a high level of family member financially dependent) and low levels of key assets that support adaptive capacity. The vulnerability index reflects that these farmers have the financial options to adapt to both stressors and shocks, but their lack of ties with mainstream organisations (e.g. local agrarian cooperatives) reduces their adaptive capacity in comparison to *intensive* farmers (below).

The decomposition of the vulnerability index shows the relative lower exposure of *medium-scale organic* farmers to crop price volatility, mostly due to the type of crops grown and their relative smaller plots (compared to those of *intensive* farmers). Some interviewees noted that these farmers often sell their crops directly to specific clients, with whom they negotiate their future selling price to minimize risk and to buffer themselves against potential price fluctuations. This differentiates them from the intensive farmers involved in the global market who are more subject to fluctuations in crop prices.

The agricultural model followed by organic farmers is notably different from the agro-industry model followed by other large-scale irrigation adopters. They hardly use the mineral fertilisers and pesticides sold and distributed by farming cooperatives, and largely invest in the maintenance and expansion of their vineyards, which exposes them to significant financial risks (Dwiartama and Rosin, 2014). As a focus group participant pointed out: "I would like that someone explained to me why rural incentives are oriented towards producing higher quantity [of produce] instead of better quality" (Miranda de Arga neighbour, sustainable fluvial manager and member of Urbizi NGO: FG1-3). Interviews with organic farmers also revealed that they have little influence over regional rural strategies and policies.

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[5] 'Few', 'some', 'many' and 'most' are used consistently to mean less than 25 per cent, up to 50 per cent, up to 74 per cent and 75 per cent or more of the corresponding sample, respectively.

Intensive farmers, both medium and large-scale (N=217)

Large-scale intensive farmers manage the largest areas of crops and they are therefore highly exposed to crop price volatility and climate variability. This makes them relatively vulnerable to these stressors (i.e. they are the second most vulnerable group to crop price volatility, after the *small-scale diversified* farmers). Figure 5 shows that the two groups of intensive farmers – *medium-scale and large-scale intensive farmers* – have relatively good access to capital assets, which translates into a higher adaptive capacity compared to the other farmer groups.

The decomposition of the vulnerability index, combined with qualitative information from interviews, suggests that there is a strong correlation between being a large-scale intensive farmer and accessing agricultural subsidies.[6] The vulnerability index reveals that these subsidies represent a stable income stream, which buffers them against fluctuations in other income sources. Additionally, most of the large-scale farmers interviewed confirmed that their affiliation to cooperatives and farming unions allowed them to acquire discounts for insurance, oil and fertilisers. Consequently, there is a positive feedback loop between the improved financial situation of the new irrigators (intensive farmers) and the latter's ability to influence the agricultural policies underpinning irrigation development. Our analysis also makes evident that the direct selling of crops (thus circumventing intermediaries) and out-grower schemes[7] are a common feature among intensive farmers.

Trade-off between sensitivity and adaptive capacity

Figure 5 also suggests that *medium- and large-scale intensive* farmers and *medium-scale organic* farmers are the most sensitive groups to external stressors and have a higher level of adaptive capacity, explained by their better access to physical, financial and human assets. This finding partly explains the existence of a trade-off between sensitivity and adaptive capacity. The more intensive farmers are typically dedicated to large-scale agriculture, which is often characterised by crops with a high demand for water and other inputs. These farmers have been able to counter climate related hazards such as drought by participating in the irrigation project, optimizing their strategies to access all available subsidies, acquiring insurance and using cooperative networks services. By contrast, *small-scale diversified* farmers are more vulnerable in comparison to other farming groups, due to a relatively lower access to physical, financial, social and technical knowledge-related assets. However, their sensitivity is also lower which may edge against climatic risks and crop price volatility in the long term.

Discussion

The results above demonstrate that in the context of an agrarian transformation driven by a large-scale irrigation project, *intensive* farmers are less vulnerable to climate related stressors and crop price volatility than other farmers. Specifically, the results show that the large-scale irrigation project affects *small-scale diversified* farmers negatively by making them more vulnerable to climate change and global market fluctuations and by displacing them from the traditional agrarian landscape.

We argue that such displacement is an unintended effect of the agricultural modernisation agenda driving agricultural policy in Navarre, and Spain more broadly, particularly since the 1960s. The Spanish and Navarre governments consider the *Itoiz-Canal de Navarra* irrigation project a platform to revitalize and "modernise" agriculture in the studied area. Policy makers promote large-scale irrigation based on the premise that new farming generations should become highly skilled and capitalized if they are to thrive in global agricultural markets. Regardless of how questionable such assumption might be, our analysis demonstrates that the public investment and subsidies accompanying irrigation functions

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[6] A personal communication of an NGO technician revealed that those participating in the large-scale irrigation project accessed most of the available subsidies and received higher subsidies.

[7] Also known as *contract farming*. Through these contracts, the farmers' crop harvest will be sold to large-scale agribusinesses (German et al., 2011). Farmers and future buyers agree on a price for the harvest, which may be either above or below future market price, so farmers may either lose or win money. They accept the potential loss because they are guaranteed the purchase of the harvest.

as an active modernizing agent, if anything, concentrate land in fewer hands and mostly benefit large-scale intensive farmers, reinforcing the idea of "water control as a new business opportunity" (Sanchis-Ibor et al., 2017).

The simultaneous increase in the adaptive capacity of *large-scale intensive* farmers and in the overall vulnerability *of small-scale diversified* farmers observed in our study echoes observations made in other contexts where communities try to adapt to climate change, agricultural intensification, or other drivers of agrarian change (Ford et al., 2006; Cinner et al., 2018). The exclusion and enhanced vulnerability of *small-scale* farmers and, to a lower extent, of *organic* farmers is not surprising either. These farmers are not politically active nor organized, which limits their ability to influence the rules and deployment of the large-scale irrigation project (Calvário et al., 2016), and to ensure that their cultural values and land management practices fit into such project (Smith and Stirling, 2010). Taken together, these observations suggest that agrarian change inevitably results in winners and losers, as well as that changes in water governance through large-scale irrigation is due to and further entrenches existing power structures in agrarian landscapes.

Our findings also show that the large-scale irrigation project facilitates intensive farmers' response to climate variability and price volatility, but also increases their exposure to present and future climate and market shocks because of larger cropping areas, and higher water consumption levels and financial burdens. In line with other studies (Ford et al., 2006), we argue that the large-scale irrigation project in Navarre might constitute a form of maladaptation, particularly if climate change leads to reduced precipitation levels in the Mediterranean watersheds, water use and extraction continues to increase, potentially rising costs, and subsidies for irrigation decrease. In the future, crop productivity levels might decrease, water stress increase, and farmers' ability to maintain their irrigation-led farming system might be compromised (Schröter et al., 2005; Huber García et al., 2018). Furthermore, the fact that the large-scale irrigation project involves the displacement of traditional farming and the adoption of new practices guided by external agents (e.g. INTIA technicians) also suggests that farmers may lose autonomy and control over their productive resources over time (Sanchis-Ibor et al., 2017). This, in turn, may undermine their ability to respond to novel circumstances in the future (Berkes et al., 1994; Ford et al., 2006).

Finally, our findings also reflect the strengths and weakness of using a vulnerability index approach to understand the response of farming livelihoods to agrarian change. There are at least two important benefits of using such index. First, the index contributes to the operationalisation of vulnerability theory by taking into account the interdependencies between global stressors and local assets and mechanisms (Lin and Polsky, 2015). An index-based approach can be useful to understand both the impacts and the social capabilities for anticipatory or reactive modes (adaptive capacities) to reduce farmers' sensitivity and exposure to exogenous threats (Eakin and Bojórquez-Tapia, 2008; Hahn et al., 2009; Lin and Polsky, 2015). Second, the vulnerability index approach can result in policy-relevant insights, grounded on recognising farmers' exposure to global stressors and shocks and the need for context-sensitive policy action (O'Brien et al., 2004a). In our case study, the results of the vulnerability index reveal the existence of trade-offs between sensitivity and adaptive capacity in a rural environment characterised by agricultural market fluctuations and climate variability amidst a large-scale irrigation project promoted by public institutions and driven by a "modernisation" agenda. We have shown that the large-scale irrigation project allows intensive farmers to benefit from their political clout in agrarian development policy, as well as in collateral impacts, for example the increased sensitivity of such *intensive* farmers and the displacement or even disappearance of small-scale farming livelihoods.

However, we acknowledge that the vulnerability index approach has also some limitations. For example, we have not included in the index a specific indicator reflecting the level of indebtedness across farming groups, which might have increased the vulnerability of *intensive* farmers. Questions about debt were not included in the survey because we considered them too intrusive. Another limitation is that the index developed is both time and scale specific, thus precluding explicit dynamic features of vulnerability (O'Brien et al., 2004b). Capturing the longer-term evolution of farmers' vulnerability in the study area would require the collection of panel data and the subsequent calculation and comparison of index values over time.

Conclusion

Agricultural intensification is a worldwide phenomenon (Campbell et al., 2014), even across European agricultural landscapes where such intensification co-exists with rural abandonment and afforestation processes (Rivera-Ferre, (2008). In many places, intensification is resulting in a decrease of farming systems' diversity, and specifically in the loss of small-scale farming. In Navarre, Spain, the large-scale *Itoiz-Canal de Navarra* irrigation project has been rolled-out to promote agricultural development and improve rural livelihoods as well as a climate change adaptation measure. However, our research shows that the project has made some farmers more vulnerable to market and climatic stressors than others, and it has changed both present and potentially future patterns of sensitivity to these stressors.

The farmers who have most engaged with the irrigation project (i.e. *large scale intensive* farmers) are benefiting from a large suite of subsidies associated with the irrigation project, greater social networks, and increased access to land and water, arbitrated by local and national institutions. These greater assets generated partly by the irrigation project explain their lower vulnerability in comparison to other groups, but also their relatively acute sensitivity to climatic variability and crop price volatility. In turn, the farmers who have willingly or unwillingly not adopted irrigation appear more vulnerable to such stressors, but they are also less sensitive. These findings suggest that the large-scale irrigation project might be a masked form of maladaptation: whenever the institutional support for the large-scale irrigation projects weakens, or the climatic and market conditions radically shift, the relative vulnerability levels across farming groups could change, potentially making more vulnerable those who now appear the least. As suggested elsewhere (Barnett and O'Neill, 2010; Collof et al., 2017), the studied large-scale irrigation project is a maladaptive option for agriculture because it obscures the effects of long-term environmental change and it downplays alternative development and adaptation options.

In conclusion, this research demonstrates that the benefits of a large-scale irrigation project in a context of a changing climate and fluctuant markets flow unevenly, and that the project affects farmers' vulnerability in ways that deepen existing inequalities in access to land and water. Furthermore, it suggests that the ongoing transition towards larger-scale and intensified farming livelihoods is likely to make the social-ecological system less adaptive and more vulnerable to future climatic and institutional shocks. To counteract this trend, we believe that agricultural public policies should refrain from subsidising and supporting large-scale irrigation and focus instead on supporting smaller-scale and more diverse farming systems.

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References

Adger, W.N., 2006. Vulnerability. Resil. Vulnerability Adapt. Cross-Cut. Theme Int. Hum. Dimens. Programme Glob. Environ. Change Resil. Vulnerability Adapt. Cross-Cut. Theme Int. Hum. Dimens. Programme Glob. Environ. Change 16, 268–281. https://doi.org/10.1016/j.gloenvcha.2006.02.006

Ahmed, S.A., Diffenbaugh, N.S., Hertel, T.W., 2009. Climate volatility deepens poverty vulnerability in developing countries. Environ. Res. Lett. 4, 034004.

Albizua, A., Pascual, U., Corbera, E., 2016. Social-ecological impacts of agrarian intensification: The case of modern irrigation in Navarre.

Albizua, A., Williams, A., Hedlund, K., Pascual, U., 2015. Crop rotations including ley and manure can promote ecosystem services in conventional farming systems. Appl. Soil Ecol. 95, 54–61. https://doi.org/10.1016/j.apsoil.2015.06.003

Andreas, J., Zhan, S., 2016. Hukou and land: market reform and rural displacement in China. J. Peasant Stud. 43, 798–827. https://doi.org/10.1080/03066150.2015.1078317

Barnett, J., O'Neill, S., 2010. Maladaptation. Glob. Environ. Change 2, 211–213. https://doi.org/10.1016/j.gloenvcha.2009.11.004

Beaumont, M.J., 1997. El embalse de Itoiz, la razón o el poder. Bakeaz.

Berbel, J., Mateos, L., 2014. Does investment in irrigation technology necessarily generate rebound effects? A simulation analysis based on an agro-economic model. Agric. Syst. 128, 25–34. https://doi.org/10.1016/j.agsy.2014.04.002

Berkes, F., Folke, Carl, Gadgil, M., 1994. Traditional Ecological Knowledge, Biodiversity, Resilience and Sustainability, in: Perrings, C.A., Mäler, K.-G., Folke, C., Holling, C.S., Jansson, B.-O. (Eds.), Biodiversity Conservation: Problems and Policies. Papers from the Biodiversity Programme Beijer International Institute of Ecological Economics Royal Swedish Academy of Sciences, Ecology, Economy & Environment. Springer Netherlands, Dordrecht, pp. 269–287. https://doi.org/10.1007/978-94-011-1006-8_15

Borras, S.M.B., Franco, J.C., 2011. Global Land Grabbing and Trajectories of Agrarian Change: A Preliminary Analysis. J. Agrar. Change 12, 34–59. https://doi.org/10.1111/j.1471-0366.2011.00339.x

Cabello, V., Willaarts, B.A., Aguilar, M., del Moral Ituarte, L., 2015. River basins as social-ecological systems: linking levels of societal and ecosystem water metabolism in a semiarid watershed. Ecol. Soc. 20. https://doi.org/10.5751/ES-07778-200320

Campbell, B.M., Thornton, P., Zougmore, R., van Asten, P., Lipper, L., 2014. Sustainable intensification: What is its role in climate smart agriculture? Curr. Opin. Environ. Sustain. 8, 39–43. https://doi.org/10.1016/j.cosust.2014.07.002

Cinner, J.E., Adger, W.N., Allison, E.H., Barnes, M.L., Brown, K., Cohen, P.J., Gelcich, S., Hicks, C.C., Hughes, T.P., Lau, J., Marshall, N.A., Morrison, T.H., 2018. Building adaptive capacity to climate change in tropical coastal communities. Nat. Clim. Change 8, 117–123. https://doi.org/10.1038/s41558-017-0065-x

Colloff, M.J., Martin-Lopez, B., Lavorel, S., Locatelli, B., Gorddard, R., Longaretti, P.-Y., Walters, G., van Kerkhoff, L., Wyborn, C., Coreau, A., Wise, R.M., Dunlop, M., Degeorges, P., Grantham, H., Overton, I.C., Williams, R.D., Doherty, M.D., Capon, T., Sanderson, T., Murphy, H.T., 2017. An integrative research framework for enabling transformative adaptation. Environ. Sci. Policy 68, 87–96. https://doi.org/10.1016/j.envsci.2016.11.007

Diario de Noticias de Navarra, 2018. Canal de Navarra: sin agua para 21.500 nuevas ha. [WWW Document]. URL http://www.noticiasdenavarra.com/2018/03/23/opinion/tribunas/canal-de-navarra-sin-agua-para-21500-nuevas-ha (accessed 5.16.18).

Diario de Noticias de Navarra, 2016. La segunda fase del Canal "es desproporcionada y de alto coste". [WWW Document]. URL http://www.noticiasdenavarra.com/2016/02/20/economia/la-segunda-fase-del-canal-es-desproporcionada-y-de-alto-coste (accessed 2.22.16).

Dumenu, W.K., Obeng, E.A., 2016. Climate change and rural communities in Ghana: Social vulnerability, impacts, adaptations and policy implications. Environ. Sci. Policy 55, 208–217. https://doi.org/10.1016/j.envsci.2015.10.010

Dwiartama, A., Rosin, C., 2014. Exploring agency beyond humans: the compatibility of Actor-Network Theory (ANT) and resilience thinking. Ecol. Soc. 19. https://doi.org/10.5751/ES-06805-190328

Eakin, H., Bojórquez-Tapia, L.A., 2008. Insights into the composition of household vulnerability from multicriteria decision analysis. Glob. Environ. Change 18, 112–127. https://doi.org/10.1016/j.gloenvcha.2007.09.001

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N., Snyder, P.K., 2005. Global Consequences of Land Use. Science 309, 570–574. https://doi.org/10.1126/science.1111772

Ford, J.D., Smit, B., Wandel, J., 2006. Vulnerability to climate change in the Arctic: A case study from Arctic Bay, Canada. Glob. Environ. Change 16, 145–160. https://doi.org/10.1016/j.gloenvcha.2005.11.007

García-Martín, M., Plieninger, T., Bieling, C., García-Martín, M., Plieninger, T., Bieling, C., 2018. Dimensions of Landscape Stewardship across Europe: Landscape Values, Place Attachment, Awareness, and Personal Responsibility. Sustainability 10, 263. https://doi.org/10.3390/su10010263

Garrote, L., Iglesias, A., Granados, A., Mediero, L., Martin-Carrasco, F., 2015. Quantitative Assessment of Climate Change Vulnerability of Irrigation Demands in Mediterranean Europe. Water Resour. Manag. 29, 325–338. https://doi.org/10.1007/s11269-014-0736-6

Gobierno de Navarra, 2015. Registro de explotaciones agrarias [WWW Document]. Obs. Agrar. URL http://www.navarra.es/home_es/Temas/Ambito+rural/Vida+rural/Observatorio+agrario/Agricola/Informacion+estadistica/Registro+de+explotaciones.htm

Hahn, M.B., Riederer, A.M., Foster, S.O., 2009. The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique. Glob. Environ. Change 19, 74–88. https://doi.org/10.1016/j.gloenvcha.2008.11.002

Hara, M.M., Backeberg, G.R., 2014. An institutional approach for developing South African inland freshwater fisheries for improved food security and rural livelihoods. Water Sa 40, 277–286. https://doi.org/10.4314/wsa.v40i2.10

Huber García, V., Gampe, D., Ludwig, R., 2018. Estimating future water scarcity in two European river basins under different integrated climate, land use and water management scenarios. Presented at the EGU General Assembly Conference Abstracts, p. 2848.

Ifejika Speranza, C., Wiesmann, U., Rist, S., 2014. An indicator framework for assessing livelihood resilience in the context of social–ecological dynamics. Glob. Environ. Change 28, 109–119. https://doi.org/10.1016/j.gloenvcha.2014.06.005

INTIA, 2016. PREGUNTAS CLAVE SOBRE EL EMBALSE DE ITOIZ Y EL CANAL DE NAVARRA [WWW Document]. URL http://www.intiasa.es/es/comunidad-de-regantes/areas-de-interes/itoiz-canal-de-navarra.html

Larragueta, 2012. Sector primario en Navarra.

Lin, K.-H.E., Polsky, C., 2015. Indexing livelihood vulnerability to the effects of typhoons in indigenous communities in Taiwan. Geogr. J. 182, 135–152. https://doi.org/10.1111/geoj.12141

Maleksaeidi, H., Karami, E., Zamani, G.H., Rezaei-Moghaddam, K., Hayati, D., Masoudi, M., 2016. Discovering and characterizing farm households' resilience under water scarcity. Environ. Dev. Sustain. 18, 499–525. https://doi.org/10.1007/s10668-015-9661-y

McGinnis, M., Ostrom, E., 2014. Social-ecological system framework: initial changes and continuing challenges. Ecol. Soc. 19.

McGinnis, M.D., Ostrom, E., 2014. Social-ecological system framework: initial changes and continuing challenges. Ecol. Soc. 19. https://doi.org/10.5751/ES-06387-190230

Murgida, A.M., Gonzalez, M.H., Tiessen, H., 2014. Rainfall trends, land use change and adaptation in the Chaco salteo region of Argentina. Reg. Environ. Change 14, 1387–1394. https://doi.org/10.1007/s10113-013-0581-9

Notenbaert, A., Karanja, S.N., Herrero, M., Felisberto, M., Moyo, S., 2013. Derivation of a household-level vulnerability index for empirically testing measures of adaptive capacity and vulnerability. Reg. Environ. Change 13, 459–470. https://doi.org/10.1007/s10113-012-0368-4

O'Brien, K., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H., Javed, A., Bhadwal, S., Barg, S., Nygaard, L., West, J., 2004a. Mapping vulnerability to multiple stressors: climate change and globalization in India. Glob. Environ. Change 14, 303–313. https://doi.org/10.1016/j.gloenvcha.2004.01.001

O'Brien, K., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H., Javed, A., Bhadwal, S., Barg, S., Nygaard, L., West, J., 2004b. Mapping vulnerability to multiple stressors: climate change and globalization in India. Glob. Environ. Change 14, 303–313. https://doi.org/10.1016/j.gloenvcha.2004.01.001

Partelow, S., Winkler, K., 2016. Interlinking ecosystem services and Ostrom's framework through orientation in sustainability research. Ecol. Soc. 21. https://doi.org/10.5751/ES-08524-210327

Rasmussen, L.V., Coolsaet, B., Martin, A., Mertz, O., Pascual, U., Corbera, E., Dawson, N., Fisher, J.A., Franks, P., Ryan, C.M., 2018. Social-ecological outcomes of agricultural intensification. Nat. Sustain. 1, 275–282. https://doi.org/10.1038/s41893-018-0070-8

Rivera-Ferre, M.G., 2008. The future of agriculture. EMBO Rep. 9, 1061–1066. https://doi.org/10.1038/embor.2008.196

Sanchis-Ibor, C., Boelens, R., García-Mollá, M., 2017. Collective irrigation reloaded. Re-collection and re-moralization of water management after privatization in Spain. Geoforum 87, 38–47. https://doi.org/10.1016/j.geoforum.2017.10.002

Schröter, D., Cramer, W., Leemans, R., Prentice, C.I., Araújo, M.B., Arnell, N.W., Bondeau, A., Bugmann, H., Carter, T.R., Gracia, C.A., Vega-Leinert, A.C. de la, Erhard, M., Ewert, F., Glendining, M., House, J.I., Kankaanpää, S., Klein, R.J.T., Lavorel, S., Lindner, M., Metzger, M.J., Meyer, J., Mitchell, T.D., Reginster, I., Rounsevell, M., Sabaté, S., Sitch, S., Smith, B., Smith, J., Smith, P., Sykes, M.T., Thonicke, K., Thuiller, W., Tuck, G., Zaehle, S., Zierl, B., 2005. Ecosystem Service Supply and Vulnerability to Global Change in Europe. Science. https://doi.org/10.1126/science.1115233

Smit, B., Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. Glob. Environ. Change, Resilience, Vulnerability, and Adaptation: A Cross-Cutting Theme of the International Human Dimensions Programme on Global Environmental Change 16, 282–292. https://doi.org/10.1016/j.gloenvcha.2006.03.008

Smith, A., Stirling, A., 2010. The Politics of Social-ecological Resilience and Sustainable Socio-technical Transitions. Ecol. Soc. 15. https://doi.org/10.5751/ES-03218-150111

Tarjuelo, J.M., Rodriguez-Diaz, J.A., Abadía, R., Camacho, E., Rocamora, C., Moreno, M.A., 2015. Efficient water and energy use in irrigation modernization: Lessons from Spanish case studies. Agric. Water Manag. 162, 67–77. https://doi.org/10.1016/j.agwat.2015.08.009

Tilman, D., Balzer, C., Hill, J., Befort, B.L., 2011. Global food demand and the sustainable intensification of agriculture. Proc. Natl. Acad. Sci. 108, 20260–20264. https://doi.org/10.1073/pnas.1116437108

Turner, B.L., Kasperson, R.E., Matson, P.A., McCarthy, J.J., Corell, R.W., Christensen, L., Eckley, N., Kasperson, J.X., Luers, A., Martello, M.L., Polsky, C., Pulsipher, A., Schiller, A., 2003. A framework for vulnerability analysis in sustainability science. Proc. Natl. Acad. Sci. 100, 8074–8079. https://doi.org/10.1073/pnas.1231335100

Varela-Ortega, C., Blanco-Gutierrez, I., Esteve, P., Bharwani, S., Fronzek, S., Downing, T.E., 2016. How can irrigated agriculture adapt to climate change? Insights from the Guadiana Basin in Spain. Reg. Environ. Change 16, 59–70. https://doi.org/10.1007/s10113-014-0720-y

Vincent, K., 2004. Creating an index of social vulnerability to climate change for Africa. Tyndall Cent. Clim. Change Res. Work. Pap. 56, 41.

Wilhelmi, O.V., Wilhite, D.A., 2002. Assessing Vulnerability to Agricultural Drought: A Nebraska Case Study. Nat. Hazards 25, 37–58. https://doi.org/10.1023/A:1013388814894

Yagiz, S., Gokceoglu, C., 2010. Application of fuzzy inference system and nonlinear regression models for predicting rock brittleness. Expert Syst. Appl. 37, 2265–2272.

Figure 1. Location of Navarre province and Phase 1 of the Itoiz-Canal de Navarra irrigation project

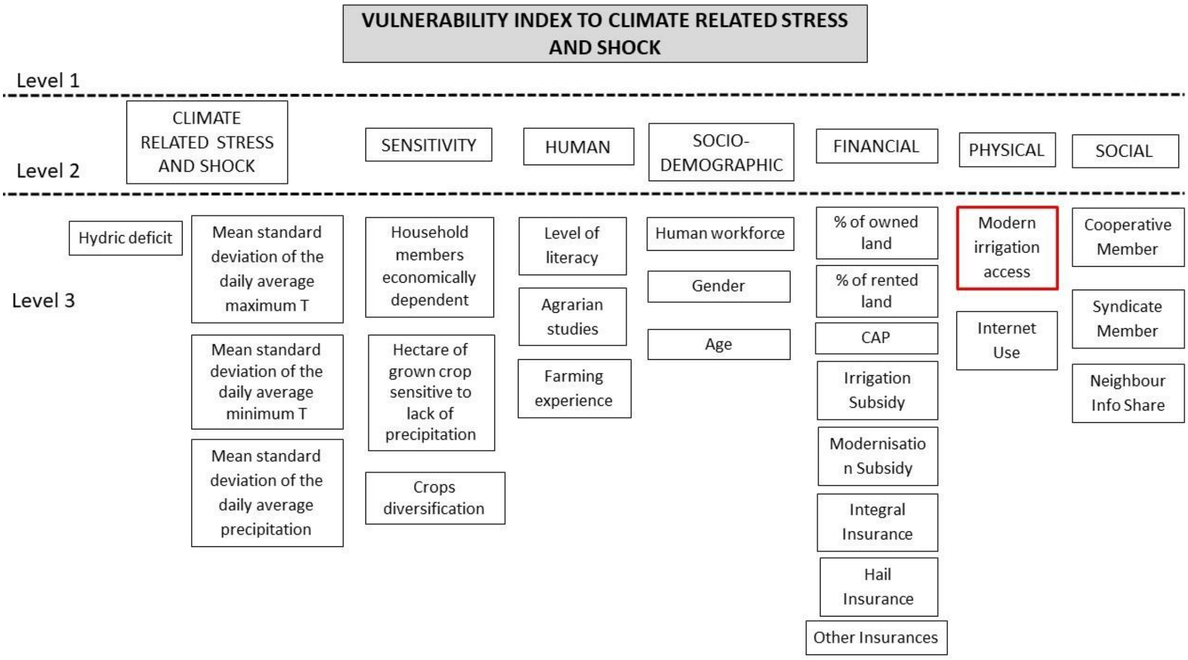

Figure 2. Categorisation of analytical variables, components and contributing factors from the interpretation of vulnerability by the IPCC (2007) for climate connected stressors

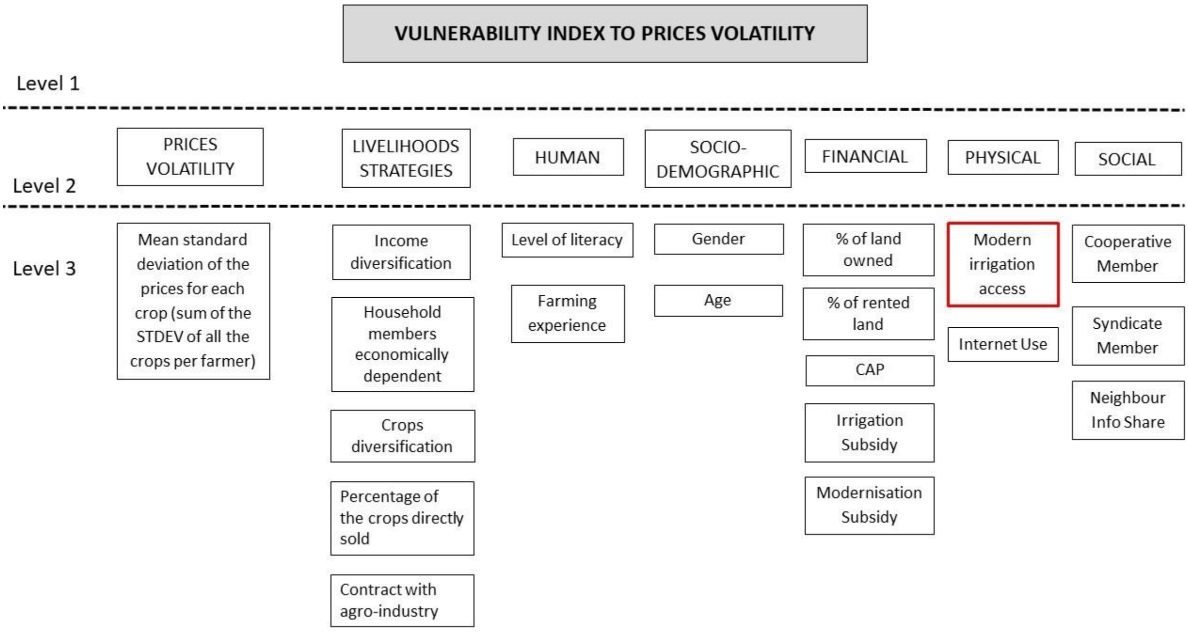

Figure 3 Categorisation of analytical variables, components and contributing factors from the interpretation of vulnerability by the IPCC (2007) for crop prices connected stressors

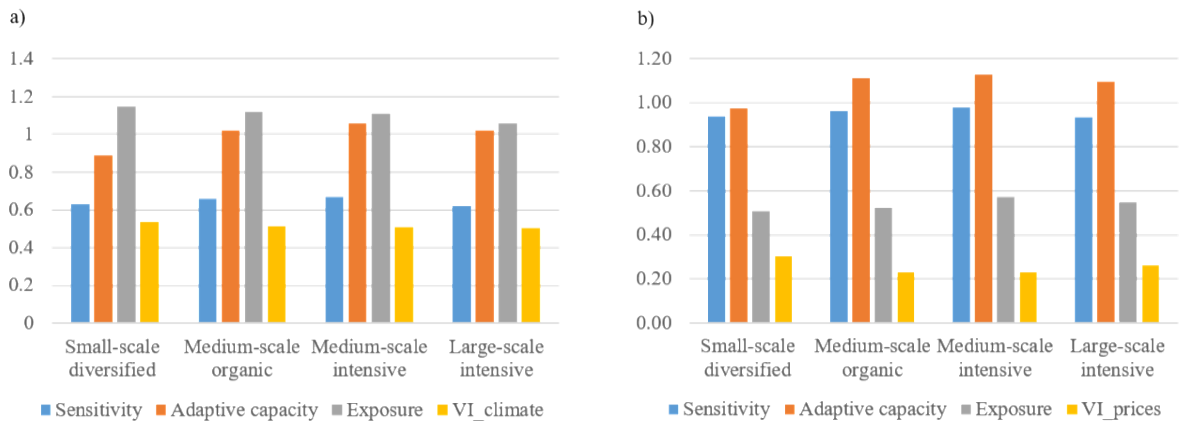

Figure 4-a Vulnerability to climate stressors (climate variability –i.e. precipitation and temperature- and shock –i.e. drought). Figure 4-b Vulnerability to crop price volatility

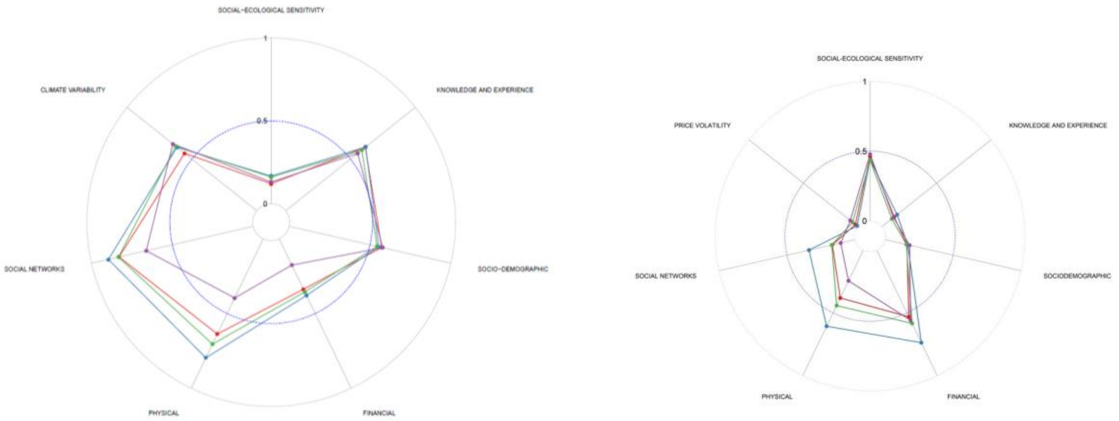

Figure 5 Disaggregated components of vulnerability to climate variability (panel a) and crop price volatility (panel b) for the four types of farmer groups.