HOW DOES MODERN IRRIGATION INFLUENCE FARMERS' VULNERABILITY TO EXTERNAL STRESSORS? THE CASE OF ITOIZ-CANAL DE NAVARRA

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According to the Fifth Assessment Report of Intergovernmental Panel on Climate Change, climate change is likely to result in an increased reduction in water availability from rivers and groundwater sources. The combination of increased water demand (e.g. irrigation, energy and industry, domestic use) and reduced water drainage and runoff due to increased evaporation, can result in several risks for many countries and economic sectors worldwide, but particularly in southern Europe.

This evidence, however, was not obvious in the case study of Itoiz-Canal de Navarra, an area affected by modern irrigation transformative project, where the majority of farmers (66%) manifested a lack of concern about future water availability and, in fact, were in favour of endorsing modern irrigation to increase water consumption and increase their competitiveness, regardless of potential investment for the long term.

Likewise, there is no consensus in the literature over the efficiency of modern irrigation or to which extent it reduces or increases rural households' vulnerability to drought. In this context, we hypothesise that modern irrigation in Navarre might negatively impact the livelihoods of some farmers and jeopardise the capacity to adapt to external stressors such as climate and market changes. Further we also hypothesise that modern irrigation installation might instead lead farmers to mal-adaptation – i.e. when a short term response inadvertently leads to an increase in future vulnerability.

The case study of Itoiz-Canal de Navarra

The introduction of modern irrigation has been quite controversial and it faced the opposition of certain groups of farmers due to the loss of their traditional irrigation rights, environmental impacts of the project and other cultural related concerns whereas other groups of farmers support such technological transformation under the idea of increased yields and farms profitability.

We distinguished four groups of farmers holding uneven rural livelihoods. Their livelihoods differences are mainly based on their land management practices and the different ways farmers mobilize assets, including irrigation water and technology. We found contrasting small-scale diversified, medium-scale rainfed organic, large-scale intensive and medium-scale intensive livelihood strategies.

In this research, farmers' vulnerability is assessed with respect to two locally identified stressors, climate variability (drought) and crop prices fluctuations. We examine if the access to modern irrigation increases or decreases farmers and landowners' vulnerability to external stressors and shocks, answering the following research question: Which livelihoods are more vulnerable to (1) climate variability and drought and (2) to crop price volatility and why this may be the case?

Key points

- *Small-scale diversified farmers are doubly vulnerable to climate variability and crop prices volatility*
- *Small-scale diversified farmers' adaptive capacity is much lower than the rest of farmers groups'. However, their sensitivity is lower than those intensive groups adopting modern irrigation*
- *Intensive farmers' adaptive capacity to climate and market increases the vulnerability of small-scale diversified farmers since their access to irrigation water and communal land gets worse.*
- *Strengths and limitations of using a Vulnerability Index for vulnerability assessment*
    a. *Powerful because connect science with policy*
    b. *Empirical data value*
    c. *Limited framing of financial assets*
    d. *No consideration of uncertainty about government's maintenance of subsidies and water low quotas; no inclusion of trades*

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Data source	Demographic	Purpose
Qualitative interviews	29 interviews randomly selected including farmers, scientists, policy-makers, NGOs, cooperative workers, consumer groups and water management companies' officers	Identification of perceived rural stressors faced by farmers in the last decade and other contextual information
Quantitative household survey	381 households randomly selected from the 22 villages affected by *Itoiz-Canal de Navarra* project (95% of confidence level)	Analysis of the weights farmers attributed to the previously mentioned factors of stress and identification of the assets that composite households sensitivity and adaptive capacity - components of the vulnerability indexes
Qualitative interviews	19 stratified sample of farmers in the village of Miranda de Arga	Analysis of farmers' perceptions about the importance of assets influencing their own vulnerability and adaptive capacity
Focus group	5 individuals intentionally selected: farmers and landholders from Miranda de Arga, a local environmental activist, and an INTIA technician	Analysis of farmers' perceptions about the importance of assets influencing their own vulnerability and adaptive capacity

Table 1 Summary of the data sources used for the analysis of farmers' vulnerability

Applied theories about exposure, sensitivity and adaptive capacity

Exogenous factors, such as the changing costs of production inputs and the uncertainty of weather, pests, and plant diseases, act as factors that can influence the phases of the agricultural cycle. These latter risks might intensify with anthropogenic climate change and globalisation-induced price volatility.

To analyse exposure to climate variability and drought, climatic station data were used. In order to assess farmers' exposure to price volatility, data was used from official sources examining the primary crops produced and their prices in the study area, i.e. cereals (wheat and barley), maize and vineyards.

Sensitivity can be described as the degree to which a system (e.g. social, economic) is affected by or is responsive to external stimuli. Generally, a household's sensitivity to a given stressor is a function of combined factors, including the household's structure (e.g. the number of family members who are economically dependent) and the existence of a broader livelihood portfolio – i.e. the availability of alternative off-farm income as complementary strategies to buffer vulnerability. Additionally, the sensitivity of rural households to different stressors is influenced by the type of crop, the level of farmers' income diversification, which determines farmers' bargaining power and exposure to risk among other factors.

Finally, the capacity of the households to access and put their assets into action will determine their ability to adapt, anticipate or react. Therefore, a household's capacity to address the risks of multiple stressors has been described as a function of indicators measuring various types of capitals. These capitals can include access to information, technology, wealth and finance, and institutional resources such as subsidies or other forms of external support..

Measuring vulnerability through an index

In line with other scholars, this research assumes vulnerability as a function of three main components: exposure, sensitivity and adaptive capacity. Each of these, in turn, has a set of components (Figure 1, level 3) and sub-components (Figure 1, level 4) that bring together the analytical variables corresponding with the five types of capitals and other socio-demographic variables (extracted from the survey performed to farmers in the area). Sensitivity encompasses three analytical variables that differ from those used when referring to vulnerability to market prices stressors. Adaptive capacity encompasses five components: human, socio-demographic (e.g. gender, age), financial, physical and social (at level 3). A Vulnerability Index (VI thereafter) has been derived based on the elements of Table 1 and following the approach of Hahn et al [1.]

1. 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

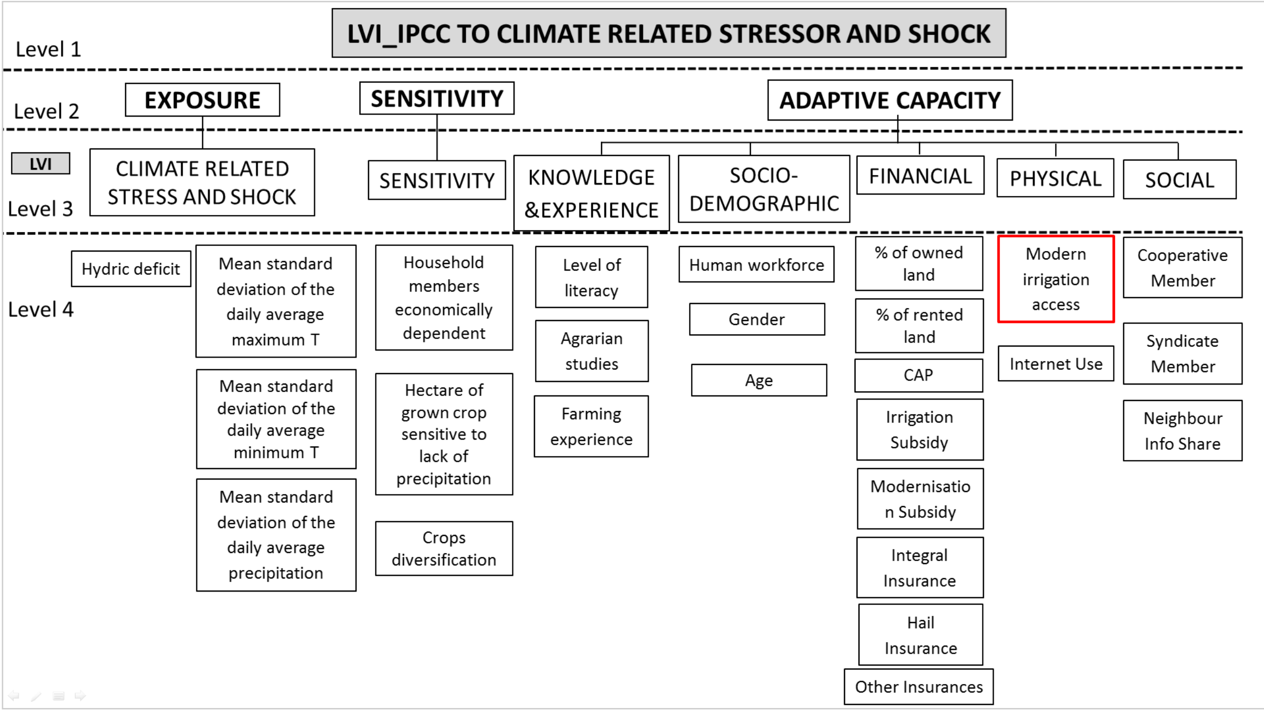

Figure 1. Categorisation of analytical variables, components and contributing factors from the IPCC vulnerability definition for climate connected stressors and shocks

Vulnerability to rainfall variability and to price volatility

This section calculates the Vulnerability Index (VI) to analyse farmers' vulnerability to climate variability and drought and prices. As expected, with regards to climate variability, this shock affects the case study farmers differently (Figure 2)[2] .

Overall, the VI_climate analysis shows that small-scale diversified farmers (0.035) and medium-scale rainfed organic farmers (0.015) are the most vulnerable groups, whereas intensive farmers (0.007 and 0.005) are less vulnerable.

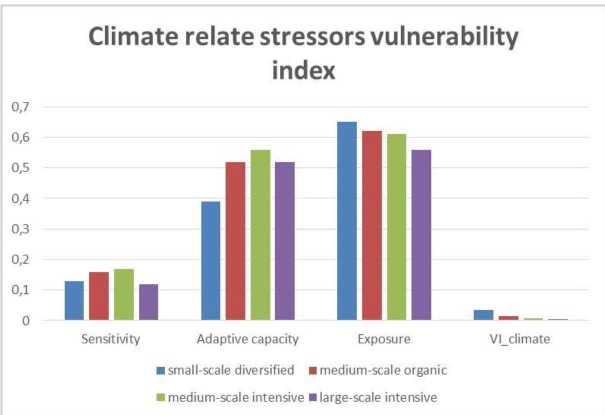

Figure 2. Vulnerability to climate stressors. The VI to climate variability and drought (VI_climate) is on a scale from -0.10 (least vulnerable) to 0.24 (most vulnerable). These values were the minimum and maximum results of VI_climate for each household.

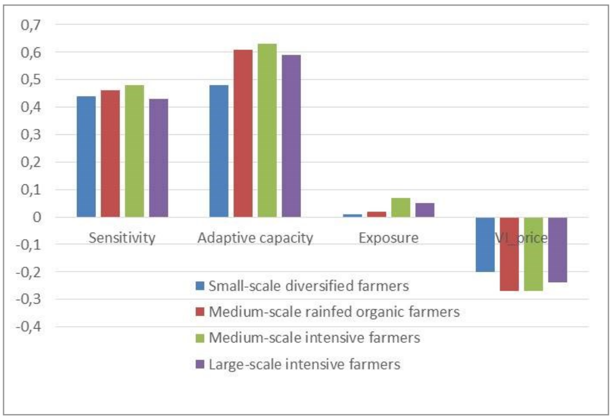

Figure 3. Vulnerability to crop prices volatility stressors. It illustrates the three dimensions of vulnerability when farmers are exposed to the volatility of crop prices. This VI_prices is on a scale from -0.48 (least vulnerable) to 0.062 (most vulnerable). These values were the minimum and maximum results of VI when related to the price volatility stressor.

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2- Index values should be interpreted as relative values to be considered within the study sample only

The group of *Small-scale diversified farmer* is the most vulnerable group to both climatic factors and crops' price volatility. *Organic farmers group* is the second most vulnerable group to climate variability, but is not particularly vulnerable to prices volatility. *Large-scale intensive farmers* are the second most vulnerable group of farmers (after small-scale diversified farmers) because they manage the largest areas of cash crops and are thus highly exposed to commodity price volatility and climate variability. An interesting finding is that the most vulnerable groups are the least sensitive but their low adaptive capacity makes them vulnerable.

To identify and understand the causes of the vulnerability we disaggregated the Vulnerability Index. Figure 4 identifies the contribution of each dimension of vulnerability (detailed in Figure 1) to the Vulnerability Index, when considering climate related stressors. A similar figure is obtained when assessing vulnerability to crop prices volatility.

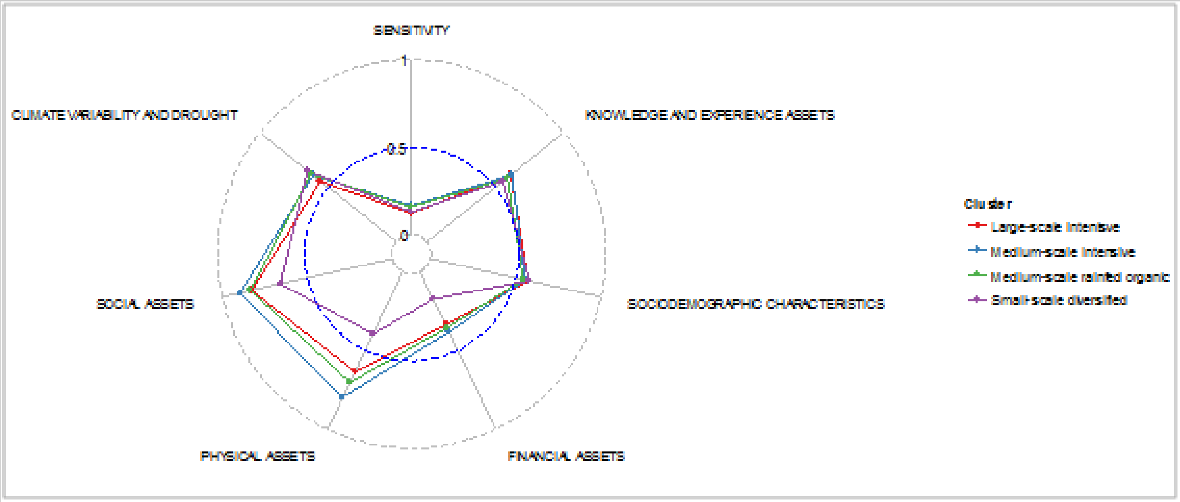

Figure 4. Vulnerability radar diagram for the four types of farmer groups when exposed to climate variability

This diagram allows us understanding that the reasons of such low adaptive capacity of small-scale diversified farmers is their lack of access to technology, social networks and financial assets such as subsidies, insurances and credit.

Conclusions

This vulnerability analysis suggests overall that small-scale diversified farmers are the most vulnerable group in the case study of Itoiz-Canal de Navarra. They are the most vulnerable group to both market prices volatility and climate variability and drought, since they have not adopted modern irrigation and thus, most have lost their traditional irrigation rights (revealed through participatory observations). Contrary to what has been shown in other research, small-landholders of this case study region have been disinterested in adopting modern irrigation as a means to enter markets and diversify into increased-value, higher-yielding crops.

Additionally, small-scale diversified farmers were also the most vulnerable to crops' prices volatility, even if they do not tend to commercialise their crops. This can be explained by the fact that their low sensitivity and exposure (represented as two single sub-components to explain households' sensitivity and exposure) do not have much importance when compared to their available adaptation options. Further, the Vulnerability Index results do not distinguish across relative levels of crops' commercialisation, since a variable to reflect so was not included in the index. The lack of adaptive capacity of these farmers is grounded primarily on their constrained access to financial assets, technology and social networks, which are key factors when addressing socio-economic and environmental change. The VI calculations for both climate-related and price factors reflect the inability of small-scale diversified farmers to access modern irrigation (physical asset) and the latter's related subsidies (financial assets) and water management cooperatives (social assets). In turn, the inability to access to these key assets negatively affects their capability to participate in emerging agrarian institutions linked to large-scale production. Small-scale diversified farmers, thus, base their livelihoods on the self -consumption of their crops and a diversified household economy.

Organic farmers' vulnerability is due to their high sensitivity (i.e. a high level of family-based dependency). Although these farmers have the financial options to adapt, their social networks with mainstream organisations are nearly non-existent. Moreover, the literature also suggests that their coping capacity is lower due to the high investment they make to plant their crops (often vineyards), including the necessary time to reach fruition. This exposes these farmers to significant financial risks during initial stages of vineyard establishment. The indexes utilised within this analysis do not accurately account for this issue, and thus do not reflect that intensive agriculture can have cross-scalar negative impacts over organically managed fields, rendering their land management procedures impractical. This insight was obtained through interviews and participatory observation. Additionally, the management practices of this farming group are misaligned with those promoted by existing institutions implementing modern irrigation. Despite being young, educated and with access to financial subsidies, these farmers remain a minority, are not well-connected with the existing local cooperatives, and furthermore, seem to lack influential power over regional rural strategies and policies.

Finally, we found that the most intensive farmers were the least vulnerable farmers to climate variability, drought and prices volatility. Their high adaptive capacity is associated with a particular collection of key resources, including access to large tracks of land (owned or rented), education, relevant cash flows and social connections. Their adoption of the modern irrigation system involves higher financial benefits through subsidies (e.g. CAP, modernisation and irrigation subsidies). Interviews revealed that those adopting modern irrigation not only accessed most of the available subsidies but also received higher amounts of such subsidies, precisely as a result of adopting irrigation.

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