**INDIAN INSTITUTE OF TECHNOLOGY BOMBAY**

Centre for Technology Alternatives for Rural Areas

# SYNOPSIS

of the Ph.D. thesis entitled

# Agricultural intensification and risk in water-constrained regions: a social-ecological systems analysis of horticulture cultivation in Maharashtra

Proposed to be submitted in

Partial fulfilment of the requirements for the Degree of

**DOCTOR OF PHILOSOPHY**

of the

INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

by

**Pooja Prasad**
Roll No. 134350003

**Supervisor: Prof. Milind Sohoni**

## Introduction

Developing countries frequently find the need for poverty alleviation initiatives to be at odds with promotion of sustainable practices. In India, half of the population depends upon agriculture for its livelihood yet the agricultural output is only about one-sixth of the national output. An important government strategy to raise farm productivity is the promotion of agricultural intensification through high-value horticulture cultivation (Chand 2017, GoI 2017). Land under horticulture has nearly doubled in the past two decades and the total horticulture production in the country has surpassed the production of food grains.

Agricultural intensification refers to activities that intend to increase the productivity or profitability of a given tract of agricultural land (Rasmussen et al. 2018). This includes activities such as reducing fallow time, increasing use of inputs or changing crop type to obtain greater return (Shaver et al. 2015, Rasmussen et al. 2018). Shift in cropping pattern towards horticulture crops to raise farm income requires intensification of inputs and often a reduction in fallow time. Fruits and vegetables (F&V) account for about 90% of India's horticulture production and is the focus of this work. Moreover, in India they are grown disproportionally more by marginal (< 1 ha) and smallholding (1-2 ha) farmers who account for 91% of fruit growing landholdings and 87% of all vegetable growing landholdings.

Horticulture production is input intensive with high cost of cultivation. It requires assured access to water, and has high dependence on input and output market particularly due to high perishability of produce. Most horticulture crops are water-intensive and the uncertainty in access to water poses great risk for the farmer. The high risk in farming, especially in case of cash crops has been linked to the rising agrarian distress and even farmer suicides (Reddy and Mishra 2010). Studies on the social-ecological impact of horticulture cultivation from India and other developing countries report that while horticulture cultivation raises farm incomes, it also raises social inequality and leads to degradation of natural resources (Birthal et al. 2008, Aragona and Orr 2011, Shaver et al. 2015). There is, thus, a need to critically examine the social-ecological drivers and consequences of intensification through horticulture cultivation.

## Objectives and methods

Existing literature on analysis of horticulture cultivation in India largely focuses on farmers or farmer groups that practice horticulture cultivation, with a predominant attention to economic outcomes (Joshi et al. 2006, Roy and Thorat 2008). There are no holistic studies of the impact of horticulture on village communities as a whole, especially with respect to common pool resources such as ground water in drought prone regions. The objective of this thesis is to conduct a critical analysis of the ongoing intensification from the social-ecological system's point of view (Berkes et al. 2003, Anderies et al. 2004, Rasmussen et al. 2018), and to analyse its impact on the farmer and the overall village community. We analyse the impact with respect to farm incomes, equity in access to ecological services and resilience (Holling 1973) of the social-ecological system to monsoon variability.

The focal social-ecological system (SES) of our study is the water-constrained shallow hard-rock aquifer (Shah 2012) region in the state of Maharashtra. Sinnar block of Nashik district is selected for intensive field work. An interdisciplinary approach is followed, borrowing methods from anthropology, engineering, economics and systems thinking. Detailed ethnographic interviews and biophysical surveys were conducted in four villages, first in the drought year of 2015-16 and then repeated in the good rainfall year of 2016-17. Narratives of 121 farmers were documented with respect to their farming decisions and intensification trajectory.

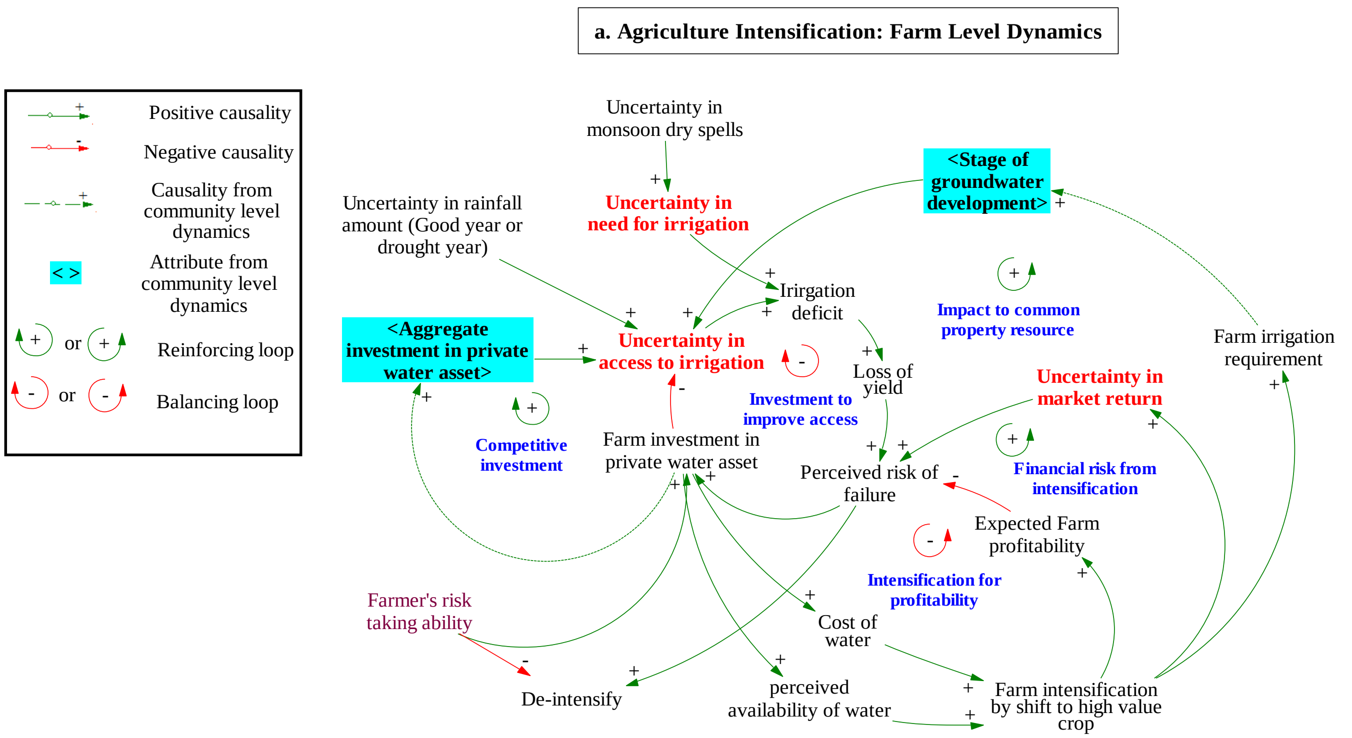
## Findings

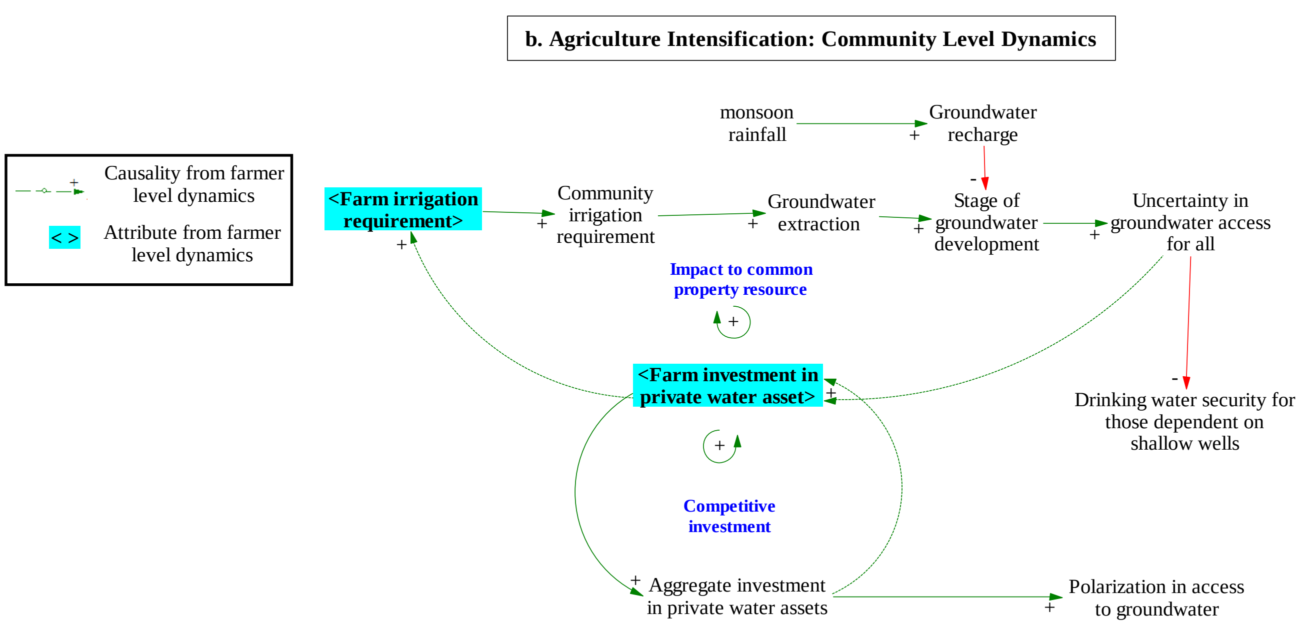
Study of seasonal cropping decisions of farmers shows that there is a crop intensification hierarchy in practice, from the traditional low-risk low-return subsistence food crops to the high-risk high-return market-oriented horticulture crops. Farmers operate at different levels of this hierarchy based on their access to resources and risk-taking ability. They intensify seasonally in good rainfall years and withdraw in bad years. Besides this seasonal intensification, farmers may occasionally make a strategic long-term decision to intensify by making an investment, typically in water, knowledge or other resources, and shifting to a higher value crop such as fruit orchards. As farmers intensify along this hierarchy, we find that there is an increase in their average crop returns, however, there is also an increase in the variability of returns. So, while some farmers get exceptionally high returns, a large number of farmers face losses.

We find that there is increasing uncertainty in assurance of irrigation water in our SES, which is the predominant reason for crop failures. This uncertainty is partly exogenous, caused by erratic monsoons with long dry spells, and partly endogenous, such as uncertainty in access to groundwater due to the high stage of development and the risk caused by large competitive demands for surface water sources. Faced by these uncertainties, and in absence of sound information about (a) seasonal water availability for a given rainfall year, and (b) overall community water demand for irrigation and other uses, farmers tend to under-estimate risk and sow optimistically, thereby running short of irrigation water and ending up with significantly compromised yields or crop failure. As a result, with increased risk of water and poor information, farmers are no longer able to rely on their traditional crops to meet their livelihood requirements. This increased vulnerability due to slipping assurance of water drives farmers to make private investments in water infrastructure and intensify cropping to recover this investment. This phenomenon of vulnerability-driven intensification stands in contrast to the narrative of aspiration-driven shift towards horticulture, often observed in water assured regions.

We use systems thinking (Sterman 2012) to model the SES and understand the dynamics and feedback mechanisms through which risk propagates (Figure 1). This manifests as a conflict between the interests of individual farmer and that of the community in the management of the common pool water resource (Ostrom 1990). As individual farmers invest in water infrastructure to diminish their personal risk without comprehension of the carrying capacity of the resource or coordination with other farmers, this in fact results in reinforcement of risk at the community level because the investments only serve to redistribute available water and total water is zero sum in the system. This begins the "treadmill" effect (Cochrane 1958) of incrementally greater investment and higher intensification which in turn leads to greater uncertainty and high crop failures, inducing more farmers to consider risky investments, often enabled by large loans (Turner and Ali 1996). With this vicious cycle at play, despite large investments farmers eventually end up with high uncertainty and many retreat from the "treadmill" after repeated failures. Additionally, a large number of farmers remain outside of this cycle primarily due to socio-economic constraints, and face the externalities of intensification by others.

**Figure 1: Causal-loop diagram showing farmers' decision making in response to uncertainties in socio-ecological factors (a) farm level dynamics** shows the decision-making at farmer level. Some of the factors that impact farmer decisions are attributes of the larger community dynamics (*stage of groundwater development* and *aggregate investment in private water assets*) (**b) community level dynamics** shows the effect of individual farmer's actions at the level of the community as a whole. Note that positive causality between two attributes (say x and y) implies that when all other factors are held constant, an increase in x causes increase in y (or decrease in x leads to decrease in y). Negative causality implies that increase in x causes a decrease in y, all other factors being equal.



## Conclusions

Through a stylized system dynamics model, we show that overall, villages are on an unsustainable trajectory of increasing intensification leading to the tragedy of the commons (Hardin 1968). The year-to-year variability in monsoon rains accelerates this. A drought year tips the system over its carrying capacity prompting a large number of investments in water which increases uncertainty even in an otherwise good rainfall year. The extraordinary high peaks in market prices of horticulture crops incentivize farmers to make greater investments even if they offer only temporary assurance. This is because the marginal gain from this investment is perceived to be so high that it outweighs the marginal cost of extraction.

Evaluation of leverage points (Meadows 1999) in the system shows current government programs are not only insufficient in stopping the vicious cycles at play, but in fact accelerate them further. Moreover, targeting of individual beneficiaries by the programs without consideration of broader impact weakens community action and feeds into the competitive behaviour, making everyone worse off.

Our model shows that there are thresholds in this trajectory of intensification, which must be identified in order to ensure sustainable intensification (Pretty and Bharucha 2014, Rockström et al. 2017). The model also illustrates that the impact of intensification on the parameters that monitor the health of the system (groundwater level in our case) may be gradual leading up to the threshold, but once the threshold is crossed, there may be a sudden catastrophic collapse, as is characteristic of social-ecological systems. From the perspective of water, this threshold corresponds to the amount of water made available for irrigation through rainfall (or the "water budget" after accounting for drinking and other essential water use).

We, therefore, conclude that promotion of horticulture must be done in a measured way. Reduction in orchards (because of its fixed all year water demand) and a strategy of well-regulated seasonal intensification (in step with the extent of rainfall for the year) within the limits of available water resource will not only result in more sustainable and equitable practice, but may actually result in increasing net profits due to reduction in uncertainty and wasteful infrastructure. It thus suggests a convergence of the three dimensions of sustainability: economics, environment and social equity. The ability to respond to poor rainfall years by collectively adjusting the seasonal cropping pattern, is key to increasing farm resilience.

Our findings point to the need for the scientific community to (a) equip the state with sound and practical tools for governance, for example in planning and regulation, and (b) improving the understanding of groundwater for users and developing a consensus, a substratum of commonly held knowledge, so that community regulation is enabled. This requires our scientists and state agencies to work closely with farming communities and develop sound tools and protocols based on local farm studies that will improve social comprehension of biophysical limits and the risk of operating close to these limits. It is only through such gains in commonly held knowledge that collective action will evolve and regulations will be obeyed. Only then will investments such as horticulture and watershed interventions contribute to greater security instead of competition.

An important contribution of this work is the development of such a community water-budget based risk-assessment framework which provides guidance to communities to assess the level of risk associated with different levels of intensification in reference to the resource threshold. This framework has been proposed to the Government of Maharashtra for its Project on Climate Resilient Agriculture (PoCRA) which has the mandate to enhance climate resilience and profitability of smallholding farmers in 15 drought prone districts of Maharashtra. Using a concrete example, we show how application of this framework based on knowledge of biophysical limits of water can help farming communities estimate the extent of horticulture that can be supported in a region.

**Selected References**


Anderies, J. M., M. A. Janssen, and E. Ostrom. 2004. A Framework to Analyze the Robustness of Social-ecological Systems from an Institutional Perspective. *Ecology and Society* 9(1).

Aragona, F. B., and B. Orr. 2011. Agricultural intensification, monocultures, and economic failure: The case of onion production in the Tipajara watershed on the eastern slope of the Bolivian Andes. *Journal of Sustainable Agriculture* 35(5):467–492.

Berkes, F., J. Colding, and C. Folke. 2003. *Navigating social-ecological systems: building resilience for complexity and change*. Cambridge university press.

Birthal, P. S., P. K. Joshi, S. Chauhan, and H. Singh. 2008. Can horticulture revitalise agricultural growth? *Indian Journal of Agricultural Economics* 63(3):310–321.

Chand, R. 2017. Doubling Farmers' Income - Rational, Strategy, Prospects and Action Plan. http://niti.gov.in/writereaddata/files/document_publication/DOUBLING FARMERS INCOME.pdf.

Cochrane, W. W. 1958. *Farm prices: myth and reality*. University of Minnesota Press.

GoI. 2017. Report of the Committee for Doubling Farmers ' Income: Vol VIII: Production Enhancement through Productivity Gains. http://farmer.gov.in/imagedefault/DFI/DFI Vol-8C.pdf.

Hardin, G. 1968. The Tragedy of the Commons. *Science* 162(3859):1243–1248.

Holling, C. S. 1973. Resilience and stability of ecological systems. *Annual review of ecology and systematics* 4(1):1–23.

Joshi, P. K., L. Joshi, and P. S. Birthal. 2006. Diversification and Its Impact on Smallholders : Evidence from a Study on Vegetable Production. *Agricultural Economics Research Review* 19(December):219–236.

Meadows, D. 1999. Leverage points: Places to Intervene in a System. https://www.bfi.org/sites/default/files/attachments/pages/PlacesInterveneSystem-Meadows.pdf.

Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press.

Pretty, J., and Z. P. Bharucha. 2014. Sustainable intensification in agricultural systems. *Annals of Botany* 114(8):1571–1596.

Rasmussen, L. V., B. Coolsaet, A. Martin, O. Mertz, U. Pascual, E. Corbera, N. Dawson, J. A. Fisher, P. Franks, and C. M. Ryan. 2018. Social-ecological outcomes of agricultural intensification. *Nature Sustainability* 1(7):376–376.

Reddy, D. N., and S. Mishra. 2010. *Agrarian crisis in India*. Oxford University Press.

Rockström, J., J. Williams, G. Daily, A. Noble, N. Matthews, L. Gordon, H. Wetterstrand, F. DeClerck, M. Shah, P. Steduto, C. de Fraiture, N. Hatibu, O. Unver, J. Bird, L. Sibanda, and J. Smith. 2017. Sustainable intensification of agriculture for human prosperity and global sustainability. *Ambio* 46(1):4–17.

Roy, D., and A. Thorat. 2008. Success in High Value Horticultural Export Markets for the Small Farmers: The Case of Mahagrapes in India. *World Development* 36(10):1874–1890.

Shah, T. 2012. Community response to aquifer development: Distinct patterns in india's alluvial and Hard rock aquifer areas. *Irrigation and Drainage* 61(SUPPL.1):14–25.

Shaver, I., A. Chain-Guadarrama, K. A. Cleary, A. Sanfiorenzo, R. J. Santiago-García, B. Finegan, L. Hormel, N. Sibelet, L. A. Vierling, N. A. Bosque-Pérez, F. DeClerck, M. E. Fagan, and L. P. Waits. 2015. Coupled social and ecological outcomes of agricultural intensification in Costa Rica and the future of biodiversity conservation in tropical agricultural regions. *Global Environmental Change* 32:74–86.

Sterman, J. D. 2012. Sustaining Sustainability: Creating a Systems Science in a Fragmented Academy and Polarized World. In: Sustainability Science: The Emerging Paradigm and the Urban Environment:21–58.

Turner, B. L., and A. M. S. Ali. 1996. Induced intensification: Agricultural change in Bangladesh with implications for Malthus and Boserup. *Proceedings of the National Academy of Sciences* 93(25):14984–14991.