Effects of climate variability and rice dominance on crop diversity in Viet Nam

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**Introduction**

*The benefits of high crop diversity.* At the farm level, rotation and intercropping – if implemented with the right combination of species - could increase yield, boost soil fertility, reduce pest load, and conserve water (Vernooy, 2022). These agronomical and ecological benefits in turn, can translate into less expenditure in purchased inputs and higher income. In the absence of alternative risk management options, crop diversity also provides an insurance against crop failure and product price fluctuation (Wala et al., 2017). Finally, crop diversity contributes to diet diversity and nutrition, which could be particularly important to subsistence farmers and countries that rely heavily on domestic production for food (Delphine & Tilman, 2019).

*Mechanism promoting crop diversity.* At a given locality, climate conditions, soil characteristics, and ground water availability determine what could be grown. Among what could be grown, farmers choose what to grow based on the purpose of their production (subsistence vs. commercial), affordability and access of inputs, labor, credit, and risk management options, access to markets, expected profits and utilities, and alternative employment opportunities. Within a country, the spatial distributional patterns of these factors – both ecological and social-economical- shapes how crop diversity varies among regions.

*Crop diversity in Viet Nam*. Historically, the agricultural policies of the Viet Nam government, from land-use policies to irrigation infrastructure building, had been focused on rice self-sufficiency, which lead to the “domination of rice” and relatively low crop diversity (World Bank, 2016). More recently, thanks to economic growth and structural transformation, income of urban population grows, so does a new demand for more diverse diets. However, rural income, particularly rice farmers’ income, does not increase as fast as their urban, non-farm counterparts. These two trends push rice farmers to diversify into higher value-added crops.

Previous studies (Van Luat, 2001) identified several barriers for Vietnamese rice farmers to diversify into high value-added crops. These included i) could not afford to purchase inputs, ii) the existing irrigation infrastructure designed for rice monoculture made it difficult to grow upland crops, iii) abiotic stresses, namely low temperature and drought in the north and flooding in the south making it difficult to identify the right (non-rice) crops, iv) lack of product market access and price fluctuations.

*Crop diversity and climate change*. Climate change will alter distribution of yield worldwide. For developing countries undergoing structural transformation, like Viet Nam, climate adaptation strategy needs to seek synergy with the foreseeable economic-social changes. As some of the current rice production areas in Viet Nam likely see yield decline under the changing climate, one possible adaptation strategy is to diversify into more climate-resilient *and* higher-valued crops.

In this analysis, I examined the effects of the following ecological and agronomical predictors on crop diversity at the district level (second level administrative unit) in Viet Nam. First, given the historical dominance of rice in Viet Nam, I hypothesized that higher yield of rice, presumably leading to higher income, discouraged farmers from diversification. Second, spatial climate variability within a district promoted crop diversity. Third, abiotic stresses, namely low temperature, flooding, and drought, hindered diversification. Last, input level and irrigation could influence crop diversity by boosting rice yield; however, as mentioned above, they might also influence crop diversity through mechanisms unrelated to rice yield.

**Methods**

*Data.* I calculated crop diversity (using Shannon’s index) at the district using mapSPAM data. Given that the factors that drive diversification likely differed commercial vs. subsistence farmers, I focused on non-subsistence farmers in this analysis. Using the same mapSPAM data, I also calculated rice yield, input level, and irrigation level at the district level. I calculated input level as the percentage of high-input and irrigated harvested area (assuming irrigated lands received high inputs), and the irrigation level as the percentage of irrigated, harvested area.

I obtained the following bio-climatic models from WorldClim: bio1 (annual mean temperature), bio12 (annual precipitation), bio6 (minimum temperature during the coldest month), bio13 (precipitation during the wettest month), bio14 (precipitation during the driest month). I calculated the ranges of bio1 and bio12 of each district as indicators for spatial climate variability. I used the district-level means of bio12, bio13, and bio14 as indicators for severity of coldness, flooding, and drought.

*Model.* Given that input and irrigation level can influence biodiversity through rice yield and alternative mechanisms, I regressed these two variables, separately, against rice yield and extracted the residuals. These residuals were later used as predictors to test if input and irrigation level affected crop diversity through mechanisms unrelated to rice yield.

I fitted a linear model of crop diversity as a function of rice yield, spatial climate variability (ranges of bio1 and bio12), abiotic stresses (bio6, bio13, bio14), and the residuals of input and irrigation level.

**Results and Discussion**

Crop diversity significantly decreased with rice yield and the residual of input level, increased with spatial climate variability, coldness, flooding, and irrigation level, and showed no significant effect by drought (Table 1). Together, these predictors explained 50% of the variation in crop diversity.

In line with my hypotheses, the legacy of rice dominance on crop diversity was still strong by 2014-2016, the period during which the mapSPAM data was collected. In districts where rice was lower, farmers were more likely to grow diverse crops. Furthermore, spatial environmental variability, which likely reflected landscape complexity (e.g., elevation), significantly shaped crop diversity.

In contrast to my hypothesis, abiotic stresses, namely coldness and flooding, promoted instead of hindered diversification. One possible explanation was that these stresses decreased rice yield, which in turn, promoted crop diversity. Further, given the prevalence of these stresses, farmers might grow diverse crops as an insurance against crop failure. Also, in contrast to my hypothesis, input level - after taking into account of its effect on rice yield – decreased crop diversity. One possible explanation was that higher input level was also associated with larger farmers with lower crop diversity – including both rice *and* other commercial crops. Finally, it was unclear why irrigation level -after taking the account of rice yield, had a positive effect on crop diversity.

Climate change is likely to influence the distribution of rice yield, climate variability, and abiotic stresses. The results of this analysis, through establishing the relationships between crop diversity and these variables, suggesting that climate change will likely alter the pattern of crop diversity in Viet Nam. In particular, the areas where rice yield is likely to see decline while climate variability and abiotic stresses are likely to increase could provide ripe opportunities for diversification.

**References**

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**Table 1. Model coefficient estimates and statistical significance.** Bold fond indicate P<0.01.

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| --- | --- | --- | --- |
|  | Estimate | t value | Pr(>|t|) |
| Yield\_rice | **-0.113** | -6.944 | 1.1E-11 |
| bio1\_ran | **0.046** | 3.229 | 1.3E-03 |
| bio12\_ran | 0.000 | 0.974 | 3.3E-01 |
| bio6\_mean | **-0.024** | -5.304 | 1.7E-07 |
| bio13\_mean | **0.002** | 5.223 | 2.5E-07 |
| bio14\_mean | -0.002 | -0.795 | 4.3E-01 |
| res\_perc\_input | **-4.423** | -9.926 | 2.2E-21 |
| res\_perc\_irri | **1.002** | 8.558 | 1.3E-16 |