**COVERING LETTER**

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TRADITIONAL ECOLOGICAL KNOWLEDGE AND FARM HOUSEHOLD RESILIENCE TO NATURAL HAZARDS

**Abstract**

Studies portray the roles of traditional ecological knowledge (TEK) in the mitigation of natural hazards. Based on that, we quantitatively analyse the role of TEK, especially those applied in the hilly areas, to support the household resilience to natural hazards. We surveyed 106 farm households in Banjararum and Sidoharjo Villages, Kalibawang and Samigaluh Subdistricts, Kulon Progo Regency, Yogyakarta Special Region. Descriptive statistic shows that farmers in both villages are highest in practicing alley cropping and integrated farming as TEK, while also applying mixed cropping, multiple cropping, and locally based planting schedule (*pranata mangsa*). From binary logistic regression, we found that TEK practices of multiple cropping, alley cropping, and *pranata mangsa* support farm household resilience to natural hazards, especially landslides. The TEK practices serve as sources of buffer and adaptation capacity in the development of farm household resilience. Interestingly, mixed cropping and membership in farmers group tend to weaken the resilience. With landslides happened annually in the study locations, mixed cropping often complicates the recovery efforts in the farmlands. Similarly with membership in farmers group, for it is not conditioned as a community organization that promptly act during hazards or disasters. While TEK has been proven to take roles in the mitigation and adaptation to natural hazards, there is a need to integrate scientific knowledge to improve its optimum benefits.

**Keywords:** climate change; mixed cropping; multiple cropping; resilience;Traditional Ecological Knowledge (TEK)

# INTRODUCTION

Climate change has made more frequent and severe natural disasters and hazards. Comparing between 1992-1999 and 2009-2017, Southeast Asia experienced an increase in natural disasters as much as 58%, second only after Pacific Island with 75% more natural disasters in the later period (FAO, 2018). The International Disasters Database (EM-DAT) noted that Indonesia underwent 267 climate-related natural disasters between 1990 and 2021. In Indonesia, Kulon Progo Regency of Yogyakarta Special Region is highly affected by natural hazards, such as fierce winds, floods, and landslides. In fact, it is a regency with the highest incidents of natural hazards in 2021 in Yogyakarta Special Region (Badan Penanggulangan Bencana Daerah Kabupaten Kulon Progo, 2021).

As agriculture is the second most important sector in Yogyakarta and Kulon Progo, its close linked to the environment requires mitigation and adaptation strategy to the increasing threat of natural hazards. Various strategies devises around the world comes from traditional ecological knowledge (TEK), an accumulation of knowledge about the environment that is handed down through generations. Studies showed the roles of TEK that are practiced by rural communities to mitigate and adapt to the environmental changes (Boillat & Berkes, 2013; Boissière et al., 2013; Olson, 2013), as well as to natural disasters and hazards (Bwambale et al., 2022; Hooli, 2016; Kurnio et al., 2021; Nakamura & Kanemasu, 2020).

Traditional ecological knowledge (TEK) is also called local or traditional knowledge. It is the accumulation of knowledge, practice, and belief system that is developed through interactions with the ecological and social environment and is passed down through generations (Berkes, 1993; Berkes et al., 2000). Knowledge gathering in TEK is inherently learning-by-doing based on trial-and-error processes. Therefore, TEK is hybrid and dynamic, capable of adjusting to modern and scientific knowledge (Berkes, 1993). These features emphasize TEK’s potential roles in the development of adaptive capacity and community resilience to the environmental and climatic changes.

Examples of TEK practices to develop adaptive capacity to natural hazards can be found around the world. Around the Indonesian archipelago, the constructional design of traditional houses in Sumatera, Java, Bali, Sulawesi, and Papua have been proven to be able to withstand earthquake, even from 8.0 Richter scale magnitude for those in West Sumatera (Kurnio et al., 2021). This kind of adaptation to natural hazards by using traditional design in residential construction is also found in Fiji, which is prone to cyclone storms (Nakamura & Kanemasu, 2020), and in the flood-prone area in Namibia (Hooli, 2016), among others. In the coastal region of Bangladesh, TEK helps in the flood management during rainy season, while the government intervention in the form of infrastructure development project in the river caused worsening flood problems, rather than relieving them (Chowdhooree, 2019).

Farming-related TEK also helps in the adaptation and mitigation of natural hazards. Some examples include mixed cropping, multiple cropping (known as ‘*tumpang sari*’ in Java, Indonesia), agroforestry, alley cropping, terracing, locally based planting calendar (known as ‘*pranata mangsa*’ in Java), alternating bed system (known as ‘*surjan’*), and use of manure and local seeds (Aminatun et al., 2015; Indradewa, 2021). TEK may also relatesto household livelihoods, such as diversifying foods (Utami, 2020; Utami et al., 2018), or diversifying market and jobs to guarantee various income sources. Moreover, the Fijian applies intercropping and windbreaker to mitigate the impact of cyclone storms, in addition to growing certain plants and fruit trees, such as bamboo, breadfruits, mango, or tamarind as a traditional early warning of the storms (Nakamura & Kanemasu, 2020). In the typhoon-prone Philippines, the custom of storing tuber crops, e.g., cassavas, sweet potato, and taros, and harvesting locally grown crops, e.g., bananas, pineapples, and squashes, supports the food security of the Mamanwa indigenous people following the devastation from typhoon Haiyan (Cuaton & Su, 2020).

As TEK are also intended to build social-ecological adaptive capacity, social capital is inherent in the TEK. Social capital includes trust, social network, and norms of reciprocity (Flora et al., 2018). Since the gradual acquisition of TEK involves the community, social capital is an important attribute of TEK. Social capital is also pivotal in the aftermath of natural hazards or disasters. Fijian people commonly practice rotating labour sharing to repair damages in the farms and houses, in addition to food sharing and collective prayers (Nakamura & Kanemasu, 2020). Meanwhile, community’s trust to an elder ‘hazard forecaster’ and information sharing among Mamanwa people in the Philippines, as well as in flood-prone area in Northern Namibia, play crucial roles in their disaster preparedness (Cuaton & Su, 2020; Hooli, 2016).

Furthermore, resilience is the ability of a system to absorb and withstand shocks, to take advantage from the past and ongoing changes (Ellis, 1998), and at the same time keeping its function (Berkes et al., 2003). Originated in the ecology (Holling, 1973), the resilience concept has gathered steam in psychology, social sciences, engineering, regional and macroeconomic, among others. Studies elaborated that resilience comprises the elements of buffer capacity, self-organization, and capacity for learning and adapting (Berkes et al., 2003; Nakamura & Kanemasu, 2020; Simmie & Martin, 2010). Additionally, IPCC asserts that resilient system recovers from shock in a timely manner (IPCC, 2012).

Social-ecological resilience, as the emphasis of this study, is closely linked to the adaptive capacity. Therefore, since TEK provides means for adaptive capacity (Berkes et al., 2000), TEK contributes to promote and bolster the community’s social-ecological resilience. Experiences, observations, and behaviours in dealing with the environmental and climatic changes, including natural disasters and hazards, are sources for buffer capacity that enables learning and adaptation. They also inform the community on how to best self-organize when dealing with the shocks beforehand, during, and after their occurrences. These are in line with Folke’s assertion on resilience thinking (Folke, 2016), which is about harmonious existence with recurring changes, while at the same time, going forward with innovation and development. Hence, the development of resilience is a dynamic process that requires perpetual learning, adaptation, and self-organization.

To the best of our knowledge, previous studies on TEK are mostly qualitative (Bwambale et al., 2022; Nakamura & Kanemasu, 2020), including those that relates TEK with community resilience (Hooli, 2016; Kurnio et al., 2021). Based on that, we quantitatively analyze the role of TEK in supporting farm household resilience to natural hazards in the hilly area of Kulon Progo. The area experienced erosion and landslides almost annually, despite the keen agoroforestry practice by its farmers. We measure resilience by using household’s recovery time from natural hazards, and we take mixed cropping, multiple cropping, integrated farming, alley cropping, and *pranata mangsa* as TEK commonly practiced in the area.

# MATERIAL AND METHODS

**Study Location**

This study was conducted in Banjararum and Sidoharjo Villages, Kalibawang and Samigaluh Subdistricts, Kulon Progo Regency, Yogyakarta Special Region (Figure 1), which is situated in the hilly areas in Kulon Progo. This regency was chosen because Kulon Progo experienced the highest number of disaster events compared to other districts in the province. Both Banjararum and Sidoharjo Villages encounter erosion annually; Sidoharjo is categorized as landslide-prone area, while some areas in Banjararum also undergoes repetitive landslides. Farmers in both areas also experienced pest outbreaks in the past year, as coincide with the La Nina year of 2022. In addition, traditional ecological knowledge (TEK) remains integral parts of farm households in both villages, which make them suitable locations to study the roles of TEK on farm household resilience to natural hazards.

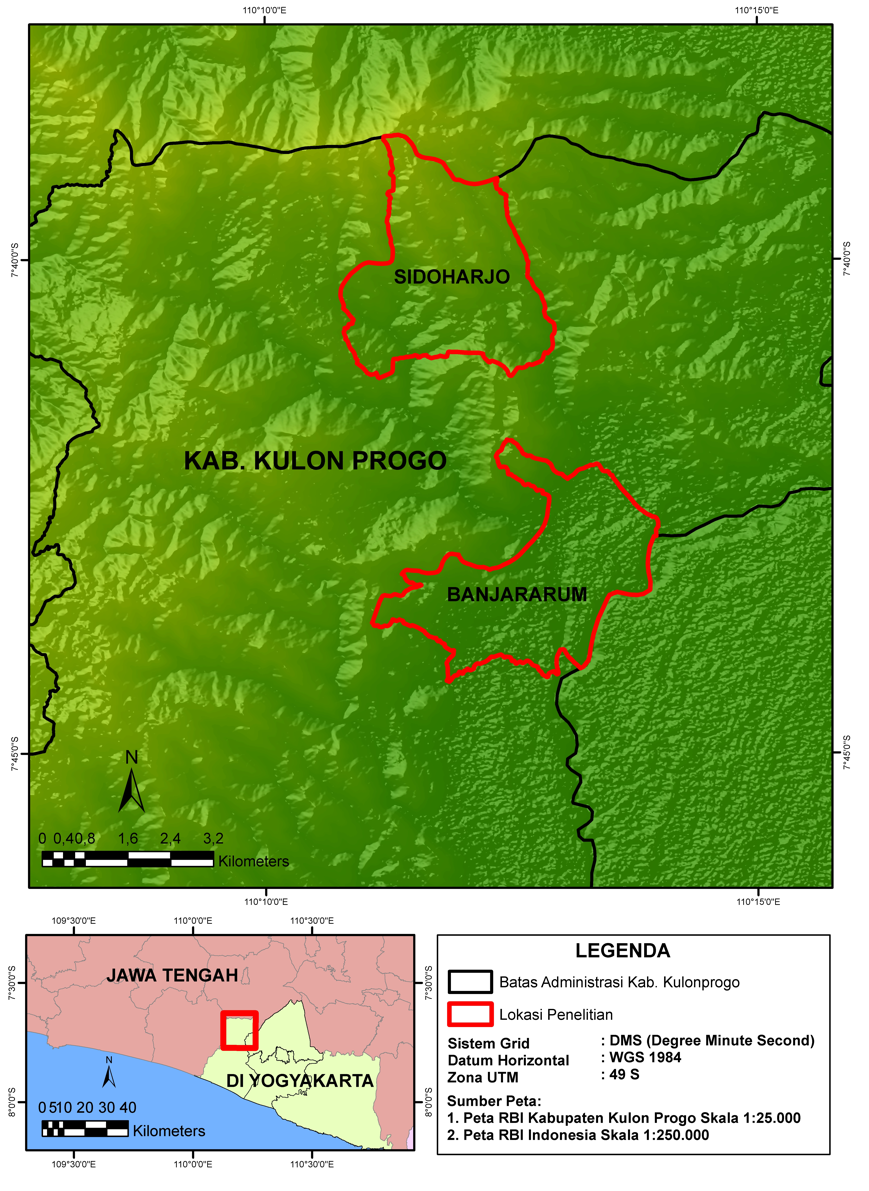


Figure 1. Map of Study Locations

## Data collection

We collected data through surveys on 106 farm households in two hamlets in Banjararum and Sidoharjo Villages, as well as interviews with eight key informants consisting of community leaders, residents, and government officials in Kalibawang and Samigaluh Subdistricts. We did census to all farm households in our study locations in Banjararum and Sidoharjo: 52 in one hamlet in Banjararum and 54 in one hamlet in Sidoharjo. Meanwhile, the key informants were chosen by using purposive and snowball sampling based on their knowledge and expertise on agriculture, natural hazards, and TEK. Both the farm household survey and key-informants interview took approximately 1-1.5 hours. The research team conducted interviews with informants, while research assistants interviewed farm households in the surveys.

## Data analysis

We computed the proportion of households practice on TEK by using a simple descriptive statistic. From this analysis, we can see which TEK practices are the most dominant in both study locations. The TEK in question include alley cropping, *pranata mangsa*, integrated farming, mixed cropping, and multiple cropping (or *tumpang sari*) practices.

To analyze the role of TEK to support the household resilience to natural hazards, we used a binary logistic regression. This model helps to determine the effects of several independent variables on a dichotomous dependent variable (Musafiri et al., 2022). The dependent variable is resilience, which is represented by the time the farm households took to fully recovered from climate-induced disaster, i.e., mostly landslide in the two study locations. The dependent variable takes values of 0 and 1, where 0 means recovery time more than 1 month, or lower resilience, while 1 means recovery time less than 1 month, or higher resilience. For the independent variables, we included a variety of TEK practices in the study location (i.e., mixed cropping, integrated farming, alley cropping, *pranata mangsa*, multiple cropping), besides also frequency of giving gifts to neighbors and farmers group membership that reflect social capital, as well as number of cattle owned by farmers that portray financial capital.

The binary logistic regression model is as follows:

*RC* = *β0* + *β1Mix* + *β2IF* + *β3AC* + *β4PM* + *β5Mul* + *β6GF* + *β7Member* + *β8Cattle* (1)

Where ‘RC’ is recovery time from shocks’, with 1 when the recovery time is less than 1 month (or higher resilience) and 0 for recovery time more than 1 month (or lower resilience); ‘Mix’, ‘IF’, ‘AC’, ‘PM’, and ‘Mul’ are mixed cropping, integrated farming, alley cropping, *pranata mangsa*, and multiple cropping, respectively. They are all dummy variables, with 1 is applying the TEK and 0 is not. For the social and financial capital, ‘GF’, ‘Member’, and ‘Cattle’ are giving frequency, farmers group membership (as a dummy variable, with 1 is a member and 0 is not), and number of cattle owned by the farm households, consecutively. We expect the regression coefficients of all TEK practices, as well as the social and financial capital, to be positive, which mean that TEK practices and higher social and financial capital are associated with higher resilience. To ensure model fit, we tested the regression model with the likelihood ratio (LR) test, and the model appropriateness with data with the Hosmer-Lemeshow test (Fagerland & Hosmer, 2012). Classification table also shows the model accuracy of predicting the outcome of higher and lower resilient household.

# RESULTS AND DISCUSSION

## Farmers characteristics

In the two hamlets of our study locations in Banjararum and Sidoharjo Villages, there are 106 farm households in total, with 52 and 54 farm households each in a hamlet in Banjararum and Sidoharjo, respectively. These farm households from the two villages show similar socio-demographic characteristics (Table 1). In Banjararum, the average household head age is 52 years old, while in Sidoharjo, it is four years older, as some household heads in Sidoharjo are older than those in Banjararum. In terms of education, household head in Banjararum has one-year higher education level than in Sidoharjo, namely second year in junior high school vs. first year in junior high school. In other words, the household head in Banjararum and Sidoharjo own a relatively low education level. Mariyono (Mariyono, 2019) showed that Indonesian farmers’ education level is commonly stopped at primary level, whether it elementary or junior high school, either graduated fully (6 years for elementary, with additional 3 years for junior high school) or dropped out.

The number of average family members in Banjararum and Sidoharjo are identical, which is two. These are smaller than the average family members in Indonesia, which is four (Minot et al., 2015; Murniati & Mutolib, 2020). The majority of respondents have small-size household since most of their children are grown up and left the parents’ houses to live in different areas/cities to work.

Regarding farmland, the average land ownership in the two villages is small, especially in Banjararum. Farmers in Banjararum own only about 2.3 hectares of land, including the cropland and home garden; thus, some farmers rent cropland, expecting to increase the crop production and on-farm income. On the other hand, Sidoharjo’s farmer own about a half hectare of land that is dominated with dryland, besides home garden. Herbs, timber, and fruit trees are commonly grown in these lands in Banjararum. In addition to cultivating crops, the farmers also rearing cattle. Farmers in Sidoharjo keep more livestock than its counterpart in Banjararum. There is one cattle owned by each farmer in the two villages, but Sidoharjo’s farmer has more goat (four goats) than in Banjararum that only has one.

**Table 1.** Farm household characteristics

| **Socio-demographic characteristics** | **Village** | |
| --- | --- | --- |
| **Banjararum**  **(mean; n=52)** | **Sidoharjo**  **(mean; n=54)** |
| Household head age (year) | 52 | 56 |
| Household head education (year) | 8 | 7 |
| Number of family members (person) | 2 | 2 |
| Land ownership (m2) | 2,372.89 | 5,056.48 |
| On-farm income (IDR per year) | 38,500,000 | 24,300,000 |
| Total household income (IDR per year) | 62,800,000 | 34,200,000 |
| Number of cattle | 1 | 1 |
| Number of goats | 1 | 4 |

Source: Primary data analysis (2023)

Nevertheless, having more livestock did not guarantee a higher on-farm income. Although Sidoharjo farmer has more livestock, they earn IDR 14.2 million per year lower in on-farm income than those in Banjararum. The main reason is the different principal crops in the two villages. Banjararum farmers obtain on-farm income dominantly from seasonal crops, such as rice, maize, ginger, galangal, chilli, and shallots, with additional income also comes from annual crops and inland fisheries. Therefore, Banjararum farmers receive on-farm income in shorter times more frequently compared to Sidoharjo farmers who grow more annual crops, especially timber and fruit trees like albisia, jack fruit, avocado, due to its hilly topography. Habitually, Sidoharjo farmers consider the timber trees a saving, so they do not cut it down and sell it without a certain household necessity that requires more cash. An instance is presented by Permadi’s et al. (Permadi et al., 2020) study, who reported that trees owned by farmers will be sold if they need to pay for their children school fees.

In terms of total household income, which comprises of on-farm, off-farm, non-farm incomes from all household members, on-farm income composes 61% of income among farm households in Banjararum, and 71% of income for Sidoharjo farmers. This shows that Banjararum farmers and their family members own more diverse income sources, while Sidoharjo farm households are dependent on farming as their primary income source.

## Implementation of TEK

In general, Sidoharjo farmers are keener in implementing TEK than Banjararum farmers, where there are more farmers that apply TEK of mixed cropping, integrated farming, alley cropping, terracing, *pranata mangsa,* and multiple cropping in Sidoharjo than in Banjararum (Table 2). One factor is the higher threat of landslide in Sidoharjo. According to surveys and interviews, the TEK practices in Sidoharjo are intended as coping mechanism and mitigation strategy to lessen the negative impact of landslides. This is consistent with Son’s et al. (2021) study in Vietnam.

Alley cropping, a type of agroforestry, is the most popular TEK in the study locations. Both in Sidoharjo and Banjararum, alley cropping plays crucial roles in diversifying on-farm income and lessening the threat of landslides. In the alley cropping, taller and wider-canopied timber and or fruit trees, e.g., albisia, jack fruit, and coffee, are usually grown aside seasonal crops, such as cassava, chilli, and maize.

**Table 2.** Traditional Ecological Knowledge (TEK) practices

| **TEK** | **Village** | | | | |
| --- | --- | --- | --- | --- | --- |
| **Banjararum (n=52)** | | | **Sidoharjo (n=54)** | |
| **Number of farmers applying** | **Percentage (%)** | **Number of farmers applying** | | **Percentage (%)** |
| Alley cropping | 32 | 69.23 | 54 | | 100.00 |
| Mixed cropping | 26 | 50.00 | 48 | | 88.89 |
| Multiple cropping | 14 | 26.92 | 47 | | 87.04 |
| Integrated farming | 27 | 51.92 | 50 | | 92.59 |
| Terracing | 28 | 53.85 | 40 | | 74.07 |
| *Pranata mangsa* | 10 | 19.23 | 41 | | 75.93 |

Source: Primary data analysis (2023)

Another type of agroforestry applied in the areas is mixed cropping. Compared to alley cropping that follows distinct spacing pattern between the perennial and seasonal crops, mixed cropping has no organized planting pattern. The timber and fruit trees are jumbled together with other shorter, smaller crops, from coffee, pineapple, and even closer to the ground medicinal plants, e.g., galangal, ginger, etc. The hilly areas of the two study locations, in addition to the vulnerable topography to landslides, make the local farmers received tree seedlings for land rehabilitation and reforestation from time to time. The farmers usually just plant them wherever there are available spaces in their home garden and lands. Many farmers stated that this variety of trees and crops are intended as saving, rather than as source of regular revenue.

Next, multiple cropping (or well-known in Indonesia as *tumpang sari*) is practiced by growing different type of seasonal crops together, with distinct planting rows for each crop. In both Sidoharjo and Banjararum, multiple cropping is aimed for higher on-farm income, as there would be revenue from various seasonal harvests. In Sidoharjo, however, the multiple cropping practice is under a constant threat of attack from monkeys, making seasonal crops provide less income to Sidoharjo farmers than to Banjararum.

Complementing to these practices is integrated farming between cattle rearing and crop cultivation. It is a culture in Sidoharjo and Banjararum to apply manure from the cattle to the soil, especially during the cultivation of seasonal crops, such as chilli, rice, maize. These are commercial crops that are considered main sources of on-farm income due to its shorter harvest, in comparison to annual crops and livestock. The manure improves soil health, which consequently help increasing crop production as well as on-farm income.

The hilly topography of the study locations requires farming on terraced lands. Terracing is a TEK practice that may well adapt to landslide prone areas (Suwarno et al., 2022), of which farmers in the two study locations also apply until now. The different plant height and layers in agroforestry, with the support of terraced lands, help reducing rainwater run-off. Hence, since extreme rainfall becomes more common nowadays, the agroforestry and terracing also support soil nutrition run-off due to soil erosions. Besides beneficial for the agricultural land, terracing is also important practice in the residential areas, since houses in the study locations, especially those in Sidoharjo, are built near extremely elevated areas.

Lastly, *pranata mangsa*, or seasonal planting calendar, is a legacy from the ancestors in the determination of planting and harvesting periods. While it is the lowest practiced TEK in Banjararum, it is the second lowest in Sidoharjo. The main reason is the availability of another more formal planting calendar issued by the local government of Kulon Progo. According to surveys and interviews, this formal planting calendar is implemented assidiously by farmers in the entire regency.

## The support of TEK on farm household resilience to natural hazards

Regarding recovery time from natural hazard events, most frequently erosion and landslide, Banjararum farmers take longer time to recover than Sidoharjo farmers (Table 3). While the majority of Banjararum farmers (78.85%) need a month or more, it is less than a month for the majority of Sidoharjo farmers (68.52%). Interestingly, one factor of this difference is the severity of the erosion or landslide. Although both study locations are hilly, Sidoharjo has more extreme topography, which make it more prone to bigger erosion or landslide that affect more people in the community (e.g., blocked road access or buried houses and croplands), either in the agricultural land or in residential areas. With the support of Kulon Progo’s Agency of Regional Disaster Management, besides the existing and solid mutual help culture in the rural communities, the landslides are usually overcome swiftly, sometimes even less than a week. In contrast, erosions in Banjararum are usually smaller in scale and affect the farmers individually. In addition to various off-farm and non-farm jobs owned by Banjararum farmers that require more complex time arrangement, many farmers tend to delay overcoming the erosion impact.

**Table 3.** Recovery time from natural hazard events.

|  |  |  |
| --- | --- | --- |
| **Villages** | **Recovery time** | |
| **1 month or more** | **Less than 1 month** |
| Banjararum (percentage of household; n=52) | 41 (78.85%) | 11 (21.15%) |
| Sidoharjo (percentage of household; n=54) | 17 (31.48%) | 37 (68.52%) |

Source: Primary data analysis (2023)

As for the binary logistic regression, the Likelihood Ratio (LR) test is statistically significant (p-value < alpha = 0.01), showing that the model is valid (Table 4). The Hosmer-Lemeshow test is statistically insignificant, meaning that the binary logistic model has appropriately model the data. In terms of the relationship between TEK, social and financial capital with farm household resilience to natural hazards, we found three practices of TEK that are associated statistically with the farm household resilience to natural hazards, i.e., alley cropping, multiple cropping, and *pranata mangsa*. As expected, the practices of alley cropping, multiple cropping, and *pranata mangsa* are linked to higher resilience to natural hazards, or lower recovery time. In the resilience theory, the TEK practices can be viewed as a source of buffer and adaptation capacity. They are a means for mitigation and adaptation strategies to natural disasters and hazards. From the social and financial capital perspective, there are membership in farmers group and number of cattle that are statistically associated with the farm household resilience significantly. In the meantime, we found no significant statistical association between the TEK practice of integrated farming and the social capital of frequencies of giving gifts to neighbours with the farm household resilience to natural hazards.

**Table 4.** Binary logistic regression results.

| **Dependent variable:**  **Recovery time** | **Coefficient** | | **Odds Ratio** | **Marginal effect** | **Std. Error** | **z** | **P>|z|** | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Constant | -1.632\* | | 0.195 |  | 0.868 | -1.88 | 0.060 | |
| Alley cropping | 1.376\* | | 3.959 | 0.291 | 0.822 | 1.67 | 0.094 | |
| Multiple cropping | 1.454\*\* | | 4.281 | 0.336 | 0.729 | 2.00 | 0.046 | |
| *Pranata mangsa* | 0.868\* | | 2.382 | 0.209 | 0.482 | 1.80 | 0.072 | |
| Mixed cropping | -1.837\*\* | | 0.159 | -0.429 | 0.776 | -2.37 | 0.018 | |
| Integrated farming | 0.259ns | | 1.295 | 0.063 | 0.650 | 0.40 | 0.690 | |
| Freq. of giving gifts to neighbors | 0.206ns | | 1.228 | 0.050 | 0.239 | 0.86 | 0.388 | |
| Farmers group membership | -0.941\* | | 0.390 | -0.230 | 0.511 | -1.84 | 0.065 | |
| Number of cattles | 0.515\*\* | | 1.673 | 0.126 | 0.249 | 2.06 | 0.039 | |
| **Overall model test:**  LR chi2 = 28.94\*\*\* |  | **Goodness of fit (Hosmer-Lemeshow Test):**  Pearson chi2 = 82.96ns | | | | | |
| Prob. chi2 = 0.0003 |  | Prob. chi2 = 0.1569 | | | |  |  | |

Source: Primary data analysis (2023)

Notes: \*), \*\*), \*\*\*) significant at 90%, 95%, and 99% respectively; ns = not significant

The likelihood of multiple cropping to improve farm household resilience is the highest compared to alley cropping and *pranata mangsa*, as shown by their odds ratios of 4.225 vs. 3.959 and 2.399, respectively. The marginal effect of multiple cropping is also the biggest, i.e., 33.6%, compared to alley cropping at 29.1% and *pranata mangsa* at 20.9%. The organized planting pattern in multiple cropping is clearly more advantageous compared to mixed cropping. The seasonal crops produced with multiple cropping also provide more frequent revenue stream for the farm household, in comparison to the unsteady flow of on-farm income from the mixed cropped lands. Additionally, from the view of soil conservation in particular and mitigation to natural hazards in general, multiple cropping pattern helps in reducing run-off during extreme rainfall, and thus, lowering the risk of soil erosion (Kumar et al., 2020).

Alley cropping, which is a type of agroforestry and the most applied TEK practice in both Sidoharjo and Banjararum (Table 2), is a crucial mitigation and adaptation strategies to natural hazards in the hilly areas of the study locations. The surveys and interviews found that agroforestry is habitual practice for generations, either with alley or mixed cropping method, especially due to the sloped topography of the area. Besides ecological benefits, agroforestry also provides economic advantages from the crop and income diversity that may serve as portfolio of risk and income. More importantly, we found that agroforestry practice with attention to spacing pattern and distribution between the perennial and seasonal crops is beneficial and advantageous to support the farm household resilience to natural hazards.

*Pranata mangsa*,a well-known Javanese local knowledge in the determination of planting calendar, is in fact can also serve as a useful monitor for the rainy season (Zaki et al., 2020). For example, *mangsa kanem* to *kadhasa* that occur on November 9th until April 19th indicate the steady rainy season when farmers should grow paddy with intermittent irrigation. The guidance about steady rainy season from the *pranata mangsa* provide another mitigation strategy, especially in informing on when to expect for natural hazards, such as landslides or floods. This is useful for areas with high exposure to landslides as in Sidoharjo (Badan Penanggulangan Bencana Daerah Kabupaten Kulon Progo, 2020b), and with moderate to high level exposure to floods as in Banjararum (Badan Penanggulangan Bencana Daerah Kabupaten Kulon Progo, 2020a).

Interestingly, mixed cropping tends to lower farm household resilience to natural hazards, as reflected by its negative regression coefficient and odds ratio that is less than 1. This deviates from the expectation that this practice is also beneficial for resilience. Field observation, survey, and interviews reveal that this disorganized planting pattern applied by farmers in their lands often complicated recovery efforts after landslides. Mixed cropping is favorable in increasing crop production (Gebru, 2015) amid the relatively small croplands owned by the farmers. However, the scattered and, sometimes, too densely populated trees and plants make it more arduous to clean up the debris after the landslides.

Membership in farmers group is another factor that may lower the farm household resilience to natural hazards, as its negative regression coefficient indicates. This is because farmers group, a community organization that gathers farmers in a hamlet, is not the main and only sources for mutual help during natural hazards situation. Additionally, farmers group is not conditioned to take part in the management of disasters and hazards. In Indonesia, this task is assumed by the Regional Disaster Management Agency (or, *Badan Penanggulangan Bencana Daerah*/BPBD). In Kulon Progo, the BPBD has even established a specific group of community members who will in charge in times of disasters and hazards, which called *Taruna Siaga Bencana*, or disaster-ready cadets.

Next, positive regression coefficient of number of cattle shows that cattle ownership is associated with higher resilience to natural hazards. An additional cattle reared by farm household links to lesser time to recover from natural hazards by 1.678 times. In times of natural hazards such as landslides as in Sidoharjo and Banjararum, cattles are rarely part of the casualties. Rather, when the seasonal and or perennial crops were failed from the hazards, the cattle may become a means of buffering the shocks. The farmers may sell the cattle for cash, as also found by Dartanto’s study (Dartanto, 2022). In this case, cattle rearing is an important income diversification (Nugroho et al., 2022), which is a coping strategy to lessen the risk of income loss.

Meanwhile, we do not find a significant statistical association between the TEK practice of integrated farming with farm household resilience to natural hazards. However, its regression coefficient is positive, meaning that integrated farming also potentially improves farm household resilience to natural hazards. Similarly, frequency of giving gifts with neighbours also shows positive regression coefficient, but statistically insignificant. We argue that this practice of reciprocity, which is an element in social capital is crucial in the development of farm household resilience to natural hazards. In the surveys and interviews, both stated by the community members, leaders, and government officials at the regency level, we often heard how this reciprocity practice complement the households and the community’s efforts in overcoming the impact of natural hazards. From the lense of resilience theory, the social capital goes hand in hand with TEK when the community is facing the natural disasters and hazards. While TEK provides a buffer and adaptation capacity to mitigate and adapt, social capital plays roles in the self organization around the shock events.

Lastly, to determine the level of accuracy of the regression model, we compute the classification table (Table 5). Overall, the model correctly classified the outcome for farm household whose recovery time to natural hazards is less than one month (i.e., those with higher resilience) at 71.70%, which is above the cut-off value of 50%. There are 68.75% of farm household with recovery time less than one month that are correctly classified (sensitivity), and 74.14% of those with recovery time one month or more, i.e., farm households with lower resilience, that are correctly classified (specificity) (Greene, 2012)

**Table 5.** Binary logistic regression classification table

|  |  |  |  |
| --- | --- | --- | --- |
|  | Prediction | |  |
| Classification | Recovery time=1  (less than one month) | Recovery time=0  (1 month or more) | Correct percentage |
| Recovery time=1  (less than one month) | 33 | 15 | 68.75% |
| Recovery time=0  (1 month or more) | 15 | 43 | 74.14% |
| Overall percentage |  |  | 71.70% |
| Sensitivity: Pr ( + | D ) |  |  | 68.75% |
| Specificity: Pr ( - | ~D ) |  |  | 74.14% |

Source: Primary data analysis (2023)

# CONCLUSION

All in all, there are three findings we conclude from this study. Our first finding leads to the support of TEK practices, such as multiple cropping (or *tumpang sari*), alley cropping, and *pranata mangsa*, as well as cattle ownership in quickening the recovery time from natural hazards, or in other words, improving the farm household resilience. The TEK practices are a source of buffer capacity in the development of resilience to natural disasters and hazards. Secondly however, we also found that TEK practice may also hinder the development of farm household resilience, such as the disorderly planting of mixed cropping that may complicate recovery efforts. This indicates that TEK application should take advantages from the scientific knowledge, for instance to add information about recommended planting pattern or spacing on extreme elevation. And third, as knowledge system related to the ecological environment, TEK goes hand in hand with community capital, including social and financial capital. Therefore, the process of gathering the TEK, and then applying and passing it down to the next generation are inseparable with the utilization of community capital.

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# REFERENCES

Aminatun, T., Widyastuti, S. H., & Djuwanto, D. (2015). Pola kearifan masyarakat lokal dalam sistem sawah surjan untuk konservasi ekosistem pertanian. *Jurnal Penelitian Humaniora*, *19*(1), 65–76. https://doi.org/10.21831/hum.v19i1.3521

Badan Penanggulangan Bencana Daerah Kabupaten Kulon Progo. (2020a). *Peta Rawan Bencana Banjir Kabupaten Kulon Progo*. https://bpbd.kulonprogokab.go.id/detil/370/peta-rawan-bencana-banjir-kabupaten-kulon-progo

Badan Penanggulangan Bencana Daerah Kabupaten Kulon Progo. (2020b). *Peta Rawan Bencana Longsor Kabupaten Kulon Progo*. https://bpbd.kulonprogokab.go.id/detil/361/peta-rawan-bencana-longsor-kabupaten-kulon-progo

Badan Penanggulangan Bencana Daerah Kabupaten Kulon Progo. (2021). *Kejadian Bencana 2021*. https://bpbd.kulonprogokab.go.id/detil/543/kejadian-bencana-2021

Berkes, F. (1993). Traditional Ecological Knowledge in Perspective. In J. T. Inglis (Ed.), *Traditional Ecological Knowledge: Concepts and Cases* (pp. 1–10). International Program on Traditional Ecological Knowledge.

Berkes, F., Colding, J., & Folke, C. (2000). Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications*, *10*(5), 1251–1262.

Berkes, F., Colding, J., & Folke, C. (2003). Introduction. In F. Berkes, J. Colding, & C. Folke (Eds.), *Navigating Social-Ecological Systems: Building Resilience for Complexity and Chang*. Cambridge University Press.

Boillat, S., & Berkes, F. (2013). Perception and interpretation of climate change among Quechua farmers of Bolivia: Indigenous knowledge as a resource for adaptive capacity. *Ecology and Society*, *18*(4), 1–13. https://doi.org/10.5751/ES-05894-180421

Boissière, M., Locatelli, B., Sheil, D., Padmanaba, M., & Sadjudin, E. (2013). Local perceptions of climate variability and change in tropical forests of Papua, Indonesia. *Ecology and Society*, *18*(4), 1–15. https://doi.org/10.5751/ES-05822-180413

Bwambale, B., Nyeko, M., Sekajugo, J., & Kervyn, M. (2022). The essential contribution of indigenous knowledge to understanding natural hazards and disaster risk: Historical evidence from the Rwenzori (Uganda). *Natural Hazards*, *110*(3), 1847–1867. https://doi.org/10.1007/s11069-021-05015-x

Chowdhooree, I. (2019). Indigenous knowledge for enhancing community resilience: An experience from the south-western coastal region of Bangladesh. *International Journal of Disaster Risk Reduction*, *40*, 1–11. https://doi.org/10.1016/j.ijdrr.2019.101259

Cuaton, G. P., & Su, Y. (2020). Local-indigenous knowledge on disaster risk reduction: Insights from the Mamanwa indigenous peoples in Basey, Samar after Typhoon Haiyan in the Philippines. *International Journal of Disaster Risk Reduction*, *48*, 1–12. https://doi.org/10.1016/j.ijdrr.2020.101596

Dartanto, T. (2022). Natural disasters, mitigation and household welfare in Indonesia: Evidence from a large-scale longitudinal survey. *Cogent Economics and Finance*, *10*(1), 1–31. https://doi.org/10.1080/23322039.2022.2037250

Ellis, F. (1998). Household strategies and rural livelihood diversification. *The Journal of Development Studies*, *35*(1), 1–38. https://doi.org/https://doi.org/10.1080/00220389808422553

Fagerland, M. W., & Hosmer, D. W. (2012). A generalized Hosmer-Lemeshow goodness-of-fit test for multinomial logistic regression models. *Stata Journal*, *12*(3), 447–453. https://doi.org/10.1177/1536867x1201200307

FAO. (2018). *Asia and the Pacific Regional Overview of Food Security and Nutrition 2018 - Accelerating Progress towards the SDGs*.

Flora, C. B., Flora, J. L., & Gasteyer, S. P. (2018). *Rural Communities: Legacy and Change* (5th Editio). Routledge. https://doi.org/https://doi.org/10.4324/9780429494697

Folke, C. (2016). Resilience (republished). *Ecology and Society*, *21*(4), 1–44. https://doi.org/https://doi.org/10.5751/ES-09088-210444

Gebru, H. (2015). A review on the comparative advantage of intercropping systems. *Journal of Biology, Agriculture and Healthcare*, *5*(9), 28–38.

Greene, W. H. (2012). *Econometric Analysis Seventh Edition* (7th ed.). Pearson.

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, *4*, 1–23.

Hooli, L. J. (2016). Resilience of the poorest: Coping strategies and indigenous knowledge of living with the floods in Northern Namibia. *Regional Environmental Change*, *16*(3), 695–707. https://doi.org/10.1007/s10113-015-0782-5

Indradewa, D. (2021). *Etnoagronomi Indonesia*. Penerbit Andi.

IPCC. (2012). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*.

Kumar, K. S., Kumar, A., Khanduri, V. P., & Singh, S. K. (2020). Indigenous Knowledge for Disaster Solutions in the Hilly State of Mizoram, Northeast India. In *Techniques for Disaster Risk Management and Mitigation* (pp. 23–32). John Wiley & Sons. https://doi.org/10.1002/9781119359203.ch2

Kurnio, H., Fekete, A., Naz, F., Norf, C., & Jüpner, R. (2021). Resilience learning and indigenous knowledge of earthquake risk in Indonesia. *International Journal of Disaster Risk Reduction*, *62*, 1–11. https://doi.org/10.1016/j.ijdrr.2021.102423

Mariyono, J. (2019). *Farmer training to simultaneously increase productivity of soybean and rice in Indonesia*. https://doi.org/10.1108/IJPPM-10-2018-0367

Minot, N., Stringer, R., Umberger, W. J., & Maghraby, W. (2015). Urban shopping patterns in Indonesia and their implications for small farmers. *Bulletin of Indonesian Economic Studies*, *51*(3), 375–388. https://doi.org/10.1080/00074918.2015.1104410

Murniati, K., & Mutolib, A. (2020). The impact of climate change on the household food security of upland rice farmers in Sidomulyo, Lampung Province, Indonesia. *Biodiversitas*, *21*(8), 3487–3493. https://doi.org/10.13057/biodiv/d210809

Musafiri, C. M., Kiboi, M., Macharia, J., Ng’etich, O. K., Kosgei, D. K., Mulianga, B., Okoti, M., & Ngetich, F. K. (2022). Smallholders’ adaptation to climate change in Western Kenya: Considering socioeconomic, institutional and biophysical determinants. *Environmental Challenges*, *7*, 1–11. https://doi.org/10.1016/j.envc.2022.100489

Nakamura, N., & Kanemasu, Y. (2020). Traditional knowledge, social capital, and community response to a disaster: Resilience of remote communities in Fiji after a severe climatic event. *Regional Environmental Change*, *20*(23), 1–14. https://doi.org/10.1007/s10113-020-01613-w

Nugroho, E., Ihle, R., Heijman, W., & Oosting, S. J. (2022). The contribution of forest extraction to income diversification and poverty alleviation for Indonesian smallholder cattle breeders. *Small-Scale Forestry*, *21*(3), 417–435. https://doi.org/10.1007/s11842-022-09504-0

Olson, E. A. (2013). Anthropology and traditional ecological knowledge: A summary of quantitative approaches to traditional knowledge, market participation, and conservation. *Culture, Agriculture, Food and Environment*, *35*(2), 140–151. https://doi.org/10.1111/cuag.12017

Permadi, D. B., Muin, N., Bisjoe, A. R., Purwanti, R., Hayati, N., Hapsari, E., Silvia, D., Darisman, A., Oktalina, S. N., & Hardiyanto, E. B. (2020). Adoption of Tree Farming by Smallholders in Pati and Bulukumba, Indonesia. In *ACIAR Project FST/2015/040–Enhancing community-based commercial forestry in Indonesia. Canberra: Australian Centre for International Agricultural Research Contact for Primary Author Dwiko Budi Permadi, Dbpermadi@ ugm. ac. id Contact for Project Leader Dig* (Issue July).

Simmie, J., & Martin, R. (2010). The economic resilience of regions: Towards an evolutionary approach. *Cambridge Journal of Regions, Economy and Society*, *3*(1), 27–43. https://doi.org/10.1093/cjres/rsp029

Son, H. N., Kingsbury, A., & Hoa, H. T. (2021). Indigenous knowledge and the enhancement of community resilience to climate change in the Northern Mountainous Region of Vietnam. *Agroecology and Sustainable Food Systems*, *45*(4), 499–522. https://doi.org/10.1080/21683565.2020.1829777

Suwarno, Nirwansyah, A. W., Sutomo, Demirdag, I., Sarjanti, E., & Bramasta, D. (2022). The existence of indigenous knowledge and local landslide mitigation: A case study of Banyumas People in Gununglurah Village, Central Java, Indonesia. *Sustainability*, *14*(19), 1–15. https://doi.org/10.3390/su141912765

Utami, A. W. (2020). Diversifikasi Makanan Pokok Lokal dan Resiliensi terhadap Bencana. In T. Yuwono (Ed.), *Pembangunan Pertanian: Membangun Kemandirian Pangan dalam Masa Bencana dan Pandemi*. Lily Publisher.

Utami, A. W., Cramer, L. A., & Rosenberger, N. (2018). Staple food diversification versus raskin: Developing climate change resilience in rural Indonesia. *Human Organization*, *77*(4), 359–370. https://doi.org/https://doi.org/10.17730/0018-7259.77.4.359

Zaki, M. K., Noda, K., Ito, K., Komariah, K., Sumani, S., & Senge, M. (2020). Adaptation to extreme hydrological events by Javanese society through local knowledge. *Sustainability*, *12*(24), 1–11. https://doi.org/10.3390/su122410373