



## Traditional Ecological Knowledge and Farm Household Resilience to Natural Hazards

Arini Wahyu Utami<sup>1\*</sup>, Nadila Puspa Arum Widjanarko<sup>1</sup>, Didik Indradewa<sup>2</sup>, Aura Dhamira<sup>3</sup>, Mutiarra Ridyo Arum<sup>1</sup>, Fathi Alfinur Rizqi<sup>4</sup>, Nurul Amri Komarudin<sup>5</sup> and Din Prabaningtyas<sup>1</sup>

<sup>1</sup>Department of Agricultural Socioeconomics, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia; <sup>2</sup>Department of Agronomy, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia; <sup>3</sup>Department of Agribusiness, Faculty of Agriculture, Universitas Pembangunan Nasional Veteran, Yogyakarta, Indonesia; <sup>4</sup>Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia; <sup>5</sup>Study Program of Environmental Engineering, Faculty of Environment and Mineral Technology, Sumbawa University of Technology, Sumbawa, Indonesia

\*Corresponding author: [ariniwu@ugm.ac.id](mailto:ariniwu@ugm.ac.id)

### Abstract

This study portrays the roles of Traditional Ecological Knowledge (TEK) in the mitigation of natural hazards. Menoreh Hill in Kulon Progo experienced more than 200 landslides in 2022 and its communities implemented TEK to mitigate them. Hence, this research quantitatively analyzes the role of agriculture-related TEK, especially those applied in hilly areas, to support household resilience to natural hazards. Authors surveyed 106 farm households and interviewed eight key informants in Banjararum and Sidoharjo Villages, Kalibawang and Samigaluh Sub-districts, Kulon Progo Regency, D.I. Yogyakarta. The data were then analyzed using descriptive statistics and binary logistic regression. The descriptive statistics showed that farmers in both villages are highest in practicing alley cropping and integrated farming, while also applying mixed cropping, multiple cropping and locally based planting schedule (*pranata mangsa*). From binary logistic regression, authors 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 farmer groups tend to weaken resilience, as mixed cropping often complicates the recovery efforts in the farmlands, and farmers' groups are not conditioned to act promptly 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)

**Cite this as:** Utami, A. W., Widjanarko, N. P. A., Indradewa, D., Dhamira, A., Arum, M. R., Rizqi, F. A., Komarudin, N. A., & Prabaningtyas, D. (2024). Traditional Ecological Knowledge and Farm Household Resilience to Natural Hazards. *Caraka Tani: Journal of Sustainable Agriculture*, 39(1), 154-166. doi: <http://dx.doi.org/10.20961/carakatani.v39i1.79774>

### INTRODUCTION

Climate change has made more frequent and severe natural disasters and hazards (WMO, 2021). Comparing 1992-1999 and 2009-2017, Southeast Asia experienced an increase in natural disasters of 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 D.I. Yogyakarta (*Daerah Istimewa Yogyakarta/DIY*) is highly

\* Received for publication October 21, 2023

Accepted after corrections February 21, 2024

affected by natural hazards, such as fierce winds, floods and landslides. This regency has the highest incidents of natural hazards in 2021 in Yogyakarta (Regional Disaster Management Agency of Kulon Progo Regency, 2021).

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

The existence of natural hazards can hinder several goals of sustainable agriculture, namely, to increase the production of human food and increase profitable farm income, where if this happens, farmers' production will be disrupted, making it difficult for farmers' income to increase. On the other hand, the existence of TEK turns out to influence sustainable agriculture. Based on research conducted by Jiao et al. (2024), it was concluded that local farmers utilizing various kinds of traditional knowledge succeeded in improving the soil and water conservation capacity of the Shexian Dryland Stone Terraced System (SDSTS) and could meet the needs of local communities. Other research conducted in India by Nautiyal and Goswami (2022) provides initial insight into the socio-ecological significance of the TEK component, namely Field Margin Vegetation (FMV) in agroecosystems. These findings will then help in devising strategies to achieve sustainable development goals through health and nutrition, sustainable agriculture, environmental conservation and economic prosperity. This suggests that TEK is also closely related to sustainable agriculture.

TEK is called local or traditional knowledge. It is the accumulation of knowledge, practice, and belief systems developed through interactions with the ecological and social environment and 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 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 earthquakes, even from 8.0 Richter scale magnitude for those in West Sumatera (Kurnio et al., 2021). Adaptation to natural hazards by using traditional design in residential construction is also found in Fiji, which is prone to cyclone storms (Nakamura and Kanemasu, 2020), and in the flood-prone area in Namibia (Hooli, 2016), among others. In the coastal region of Bangladesh, TEK helps in flood management during the rainy season, while the government intervention in the form of infrastructure development project in the river caused worsening flood problems, rather than relieving them (Chowdhoree, 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 relate to household livelihoods, such as diversifying foods (Utami et al., 2018; Utami, 2020) or diversifying markets and jobs to guarantee various income sources. Moreover, the Fijian applies intercropping and windbreakers 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 and 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 and Su, 2020).

As TEK is also intended to build social-ecological adaptive capacity, social capital is inherent in the TEK. Social capital includes trust,

social networks 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 labor-sharing to repair damages in the farms and houses, in addition to food sharing and collective prayers (Nakamura and Kanemasu, 2020). Meanwhile, the community's trust in an elder 'hazard forecaster' and information sharing among Mamanwa people in the Philippines, as well as in flood-prone areas in Northern Namibia, play crucial roles in their disaster preparedness (Hooli, 2016; Cuaton and Su, 2020).

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 keep its function (Berkes et al., 2003). Originating in ecology (Holling, 1973), the resilience concept has gathered steam in psychology, which among others are social sciences, engineering, as well as regional and macroeconomics. Studies elaborated that resilience comprises the elements of buffer capacity, self-organization, and capacity for learning and adapting (Berkes et al., 2003; Simmie and Martin, 2010; Nakamura and Kanemasu, 2020). Additionally, the Intergovernmental Panel on Climate Change (IPCC) asserts that a resilient system recovers from shock promptly (IPCC, 2012).

Social-ecological resilience, as the emphasis of this study, is closely linked to adaptive capacity. Therefore, since TEK provides a means for adaptive capacity (Berkes et al., 2000), TEK contributes to promoting and bolstering the community's social-ecological resilience. Experiences, observations and behaviors in dealing with environmental and climatic changes, including natural disasters and hazards, are sources of buffer capacity that enable 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 (Nakamura and Kanemasu, 2020; Bwambale et al., 2022), including those that relate TEK with community resilience (Hooli, 2016; Kurnio et al., 2021). Therefore, this research quantitatively analyzes 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 agroforestry practice by its farmers. Authors measure resilience by using the household's recovery time from natural hazards, and take mixed cropping, multiple cropping, integrated farming, alley cropping, and *pranata mangsa* as TEK commonly practiced in the area.

## MATERIALS AND METHOD

### Study location

This study was conducted in Banjararum and Sidoharjo Villages, Kalibawang and Samigaluh Sub-districts, Kulon Progo Regency, Yogyakarta (Figure 1), 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 undergo repetitive landslides. Farmers in both areas also experienced pest outbreaks in the past year, as coincide with the La Nina in 2022. According to Surmaini et al. (2023), the damaged area caused by brown planthopper was strongly influenced by temperature and rainfall associated with La Nina events. In addition, 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.

### Data collection

Data were collected 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 Sub-districts. Census was done to all farm households 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

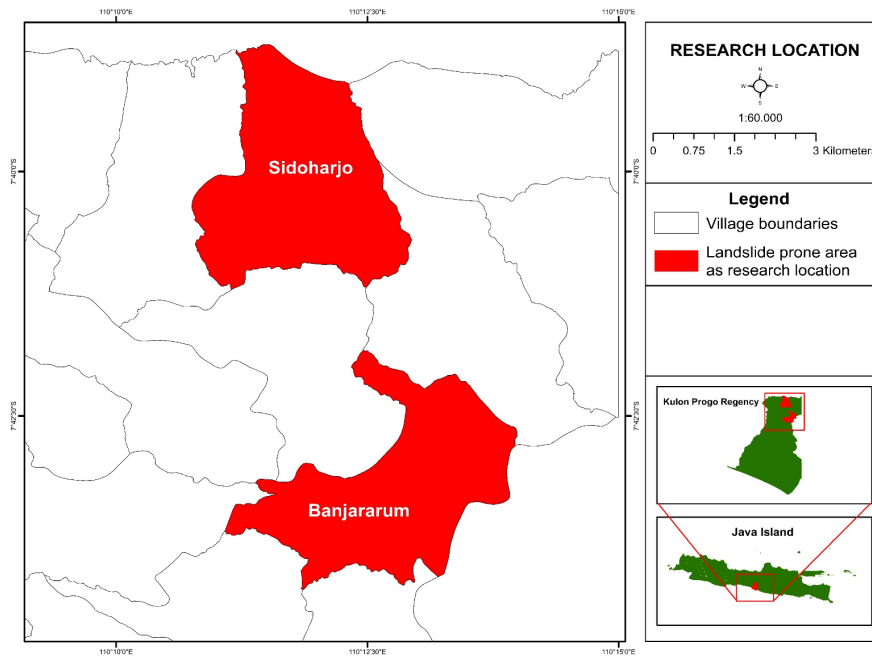


Figure 1. Map of study locations

and TEK. Both the farm household survey and key-informants interview took approximately 1 to 1.5 hours. The research team conducted interviews with informants, while research assistants interviewed farm households in the surveys held on January 2023.

#### Data analysis

The proportion of households practice on TEK was computed by using a simple descriptive statistic. From this analysis, authors can see which TEK practices are the most dominant in both study locations. The TEK in question includes 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, binary logistic regression was used. 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 recover from climate-induced disaster, i.e., mostly landslides in the two study locations. The dependent variable takes values of 0 and 1, where 0 means recovery time of more than 1 month or lower resilience, while 1 means recovery time of less than 1 month or higher resilience. For the independent variables, a variety of TEK practices were included 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 the number of cattle owned by farmers that portray financial capital.

The binary logistic regression model was expressed by Equation 1.

$$RC = \beta_0 + \beta_1 \text{Mix} + \beta_2 \text{IF} + \beta_3 \text{AC} + \beta_4 \text{PM} + \beta_5 \text{Mul} + \beta_6 \text{GF} + \beta_7 \text{Member} + \beta_8 \text{Cattle} \quad (1)$$

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 not. For the social and financial capital, 'GF,' 'Member,' and 'Cattle' are given frequency, farmer group membership (as a dummy variable, with 1 being a member and 0 not), and the number of cattle owned by the farm households, consecutively. Authors expect the regression coefficients of all TEK practices, as well as the social and financial capital, to be positive, which means that TEK practices and higher social and financial

capital are associated with higher resilience. To ensure model fit, the regression model was tested with the likelihood ratio (LR) test, and the model appropriateness with data with the Hosmer-Lemeshow test (Fagerland and Hosmer, 2012). The classification table also shows the accuracy of the model in predicting the outcome of higher and lower resilient households.

## RESULTS AND DISCUSSION

### Farmers characteristics

There are 106 farm households in total, with 52 and 54 farm households 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 vs. first year in junior high school. In other words, the household heads in Banjararum and Sidoharjo own relatively low education levels. Mariyono (2019) showed that Indonesian farmers' education level is commonly at the primary level, whether it is elementary or junior high school, either graduated (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 number of family members in Indonesia, which is four (Minot et al., 2015; Murniati and Mutolib, 2020). The majority of respondents have small households since most of their children are grown up and left their 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 crop production and on-farm income. On the other hand, farmers in Sidoharjo own about a half hectare of land dominated by dryland, besides a home garden. Herbs, timber and fruit trees are commonly grown in these lands in Banjararum. In addition to cultivating crops, the farmers rear cattle. Farmers in Sidoharjo keep more livestock in Banjararum. There is one cattle owned by each farmer in the two villages, but farmers in Sidoharjo have more goats (four) than in Banjararum (one).

Nevertheless, having more livestock did not guarantee a higher on-farm income. Although Sidoharjo farmers have more livestock, they earn 14.2 million IDR per year, which is 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, chili and shallots, with additional income coming 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 albizia, jack fruit, and avocado, due to its hilly topography. Habitually, Sidoharjo farmers consider the timber trees savings, so they do not cut them down and sell them without a certain household necessity that requires more cash. An instance is presented in the study by Permadi et al. (2020) that trees owned by farmers will be sold if they need to pay for their children's school fees.

In terms of total household income, which comprises on-farm, off-farm and non-farm incomes from all household members, on-farm income composes 61% of income among farm households in Banjararum and 71% of income for

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 (m <sup>2</sup> )	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

Sidoarjo farmers. This shows that Banjararum farmers and their family members own more diverse income sources, while Sidoarjo farm households are dependent on farming as their primary income source.

### Implementation of TEK

In general, Sidoarjo farmers are more perceptive 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 Sidoarjo than in Banjararum (Table 2). One factor is the higher threat of landslide in Sidoarjo. According to surveys and interviews, the TEK practices in Sidoarjo are intended as coping mechanism and mitigation strategy to lessen the negative impact of landslides. This is consistent with the study by Son et al. (2021) in Vietnam.

Alley cropping, a type of agroforestry, is the most popular TEK in the study locations. Both in Sidoarjo 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., albizia, jack fruit and coffee, are usually grown aside from seasonal crops, such as cassava, chili and maize.

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, such as galangal and ginger. 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 savings, rather than as sources of regular revenue.

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

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

Table 2. TEK practices

TEK	Village			
	Banjararum (n = 52)		Sidoarjo (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
<i>Pranata mangsa</i>	10	19.23	41	75.93

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 assiduously 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 makes it more prone to bigger erosions or landslides 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 Regional Disaster Management Agency of Kulon Progo, besides the existing and solid mutual help culture in the rural communities, the landslides are usually overcome swiftly, sometimes even in 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 arrangements, many farmers tend to delay overcoming the erosion impact.

As for the binary logistic regression, the LR test is statistically significant ( $p$ -value < 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, it is identified that three practices of TEK 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, this study did not find significant statistical association between the TEK practice of integrated farming and the social capital of frequencies of giving gifts to neighbors with the farm household resilience to natural hazards.

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 of natural hazards in general, multiple cropping pattern helps in reducing run-off during extreme rainfall, 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 strategy to natural hazards in the hilly areas of the study locations. The surveys and interviews found that

Table 3. Recovery time from natural hazard events

Villages	Recovery time	
	≥ 1 month	< 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%)

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
<i>Pranata mangsa</i>	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	0.259 <sup>ns</sup>	1.295	0.063	0.650	0.40	0.690
Freq. of giving gifts to neighbors	0.206 <sup>ns</sup>	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:	Goodness of fit (Hosmer-Lemeshow test):					
LR $\chi^2 = 28.94$ ***	Pearson $\chi^2 = 82.96$ <sup>ns</sup>					
Prob. $\chi^2 = 0.0003$	Prob. $\chi^2 = 0.1569$					

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

agroforestry has been a habitual practice for generations, either with alley or mixed cropping methods, especially due to the sloped topography of the area. Besides ecological benefits, agroforestry provides economic advantages from the crop and income diversity that may serve as a portfolio of risk and income. More importantly, authors found that agroforestry practice with attention to spacing patterns and distribution between the perennial and seasonal crops is beneficial and advantageous to support the farm household's resilience to natural hazards.

*Pranata mangsa*, a well-known Javanese local knowledge in the determination of planting calendar, 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 9<sup>th</sup> until April 19<sup>th</sup> indicate the steady rainy season when farmers should grow paddy with intermittent irrigation. The guidance about steady rainy season from the *pranata mangsa* provides 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 (Regional Disaster Management Agency of Kulon Progo Regency, 2020b), and with moderate to high level exposure to floods as in Banjararum (Regional Disaster Management Agency of Kulon Progo Regency, 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 (Geburu, 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 farmer group is another factor that may lower the farm household resilience to natural hazards, as its negative regression coefficient indicates. This is because farmer 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, farmer 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. In Kulon Progo, the Regional Disaster Management Agency has even established a specific group of community members who will in charge in times of disasters and hazards, which is 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. 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, cattle are rarely part of the casualties. Rather, when the seasonal and/or perennial crops fail from the hazards, the cattle may become a means of buffering the shocks. The farmers may



Table 5. Binary logistic regression classification table

Classification	Prediction		Correct percentage (%)
	Recovery time = 1 (< 1 month)	Recovery time = 0 ( $\geq$ 1 month)	
Recovery time = 1 (< 1 month)	33	15	68.75
Recovery time = 0 ( $\geq$ 1 month)	15	43	74.14
Overall percentage			71.70
Sensitivity: Pr ( +   D )			68.75
Specificity: Pr ( -   ~D )			74.14

sell the cattle for cash, as also found by Dartanto (2022) and Rozaki et al. (2023). 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, authors 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, the frequency of presenting gifts to neighbors shows a positive regression coefficient but is statistically insignificant. Authors 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, as stated by the community members, leaders, and government officials at the regency level, this reciprocity practice complements the households and the community's efforts in overcoming the impact of natural hazards. From the lens of resilience theory, social capital goes hand in hand with TEK when the community is facing natural disasters and hazards. While TEK provides a buffer and adaptation capacity to mitigate and adapt, social capital plays a role in the self-organization around the shock events.

Lastly, to determine the level of accuracy of the regression model, authors compute the classification table (Table 5). Overall, the model correctly classified the outcome for farm households 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 households with recovery time of less than one month that is correctly classified (sensitivity), and 74.14% of those with a recovery time of one month or more, i.e., farm households with

lower resilience, are correctly classified (specificity) (Greene, 2012).

## CONCLUSIONS

The finding of this research 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. However, TEK practice may 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 of the scientific knowledge, for instance to add information about recommended planting pattern or spacing on extreme elevation. As knowledge system is related to the ecological environment, TEK goes hand in hand with community capital, including social and financial capital. Therefore, the process of TEK gathering, and then applying and passing it down to the next generation are inseparable with the utilization of community capital.

## ACKNOWLEDGEMENT

Authors are grateful for the research funding from *Badan Pengelolaan Dana Lingkungan Hidup* (BPDLH), Ministry of Finance, Indonesia. Authors would like to also express their gratitude to community leaders and members of Banjararum and Sidoharjo Villages, as well as government officials at the Agricultural Extension Offices, Office of Agriculture, Regional Development Planning Agency, and Regional Disaster Management Agency of Kulon Progo Regency.

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