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The structural analysis of the farming systems resilience after the Covid-19 pandemic in West Timor, Indonesia

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Highlights

- Comparison of the resilience of wetland and dryland farming systems after the Covid-19 pandemic.
- SEM was employed to evaluate the resilience of wetland and dryland farming systems.
- Dryland farming system is more resilient than wetland farming system.
- Economic performance is a significant factor that will create better farming system resilience.
- The economic recovery and farming inputs supply have increased the resilience of dryland farming systems.

Abstract: Although Indonesia has recorded good performance in its national economic development, especially in the agriculture sector during the Covid-19 pandemic, the impact of the pandemic on farming and food systems has not been evaluated yet. This study has evaluated the resilience of the two dominant existing farming systems in West Timor, i.e. (i) wetland farming system and (ii) dryland farming system. This research aims to understand the resilience of farming after the Covid-19 pandemic and to develop strategic policies that could be adopted to increase the resilience of the farming system in West Timor. A quantitative analysis using the Structural Equation Modelling (SEM) was employed to evaluate the relationship and impact of the following seven generic aspects: labour movement, sustainability, economy, socio-culture, output markets, input markets, farming system resilience, and 27 reflective indicators. The analysis shows that dryland farming systems are more resilient than wetland farming systems. It might be understood from the size of the regression coefficient, as the impact of exogenous construct variables of the environment, socioculture, input, and output on the resilience of dryland farming systems is more significant than on wetlands. Economic performance rather than labour movement factors will create better resilience of farming systems for wetland or dryland after the Covid-19 pandemic. Finally, the economic recovery process and the ongoing input supply mechanism after the Covid-19 pandemic have increased the resilience of the dryland food system more than the resilience of the wetland farming system.

Keywords: dryland, resilience, structural equation model, West Timor, wetland

INTRODUCTION

The coronavirus (Covid-19) pandemic has created numerous problems for humankind, including health, economic, social, cultural, and political issues. According to some experts, the pandemic has coincided with widespread sustainable development challenges, which have intensified over time (Rockström *et al.*, 2020; Dixon *et al.*, 2021; Otsuka and Fan (eds.), 2021). The agriculture sector of Indonesia also suffered difficulties when the pandemic reduced its productivity because of the lockdown taken at different levels of government (Dixon *et al.*, 2021). Dixon *et al.* (2021), in their study about the resilience of Asian agrifood systems during Covid-19, found that the pandemic has generated major social and economic crises in many countries in Asia, exposing institutional, social, and economic vulnerabilities and aggravating existing food insecurity and poverty. Covid-19 revealed the vulnerabilities of modern agricultural and food economies.

The agriculture sector in Indonesia is one of sectors that the pandemic severely impaired. Although the number of Covid-19 cases has decreased drastically since 2021, compared to the previous two years due to targeted policies taken by the Indonesian government, the impact has been detrimental to the economic performance of Indonesia, especially the performance of the agriculture sector's production and productivity. However, in October 2021, the Chief Representative of the Food and Agriculture Organization of the United Nations (FAO) for Indonesia and Timor Leste, Rajendra Aryal, acknowledged the achievements of the Indonesian agriculture development. The excellent performance of the Indonesian agriculture sector during the pandemic is determined mainly by a significant commitment of the Indonesian government to the national economic recovery program.

Although Indonesia has recorded good performance in its national economic development, especially in the agriculture sector, because of a strong commitment by the Indonesian government, the impact of Covid-19 on farming systems has to be evaluated regarding the resilience of this sector, especially in West Timor (Arifah and Kim, 2022). West Timor has been chosen as the object of the research, since West Timor has two farming systems, i.e. dryland and wetland, which can be compared regarding their resilience, especially after the Covid-19 pandemic. At the same time, West Timor performed well in resilience during the pandemic because farming systems on this island are not deeply engaged in modern market mechanisms, especially regarding input and output supply. This study has evaluated the resilience of the two dominant farming systems in West Timor.

Farming systems. According to the scheme elaborated by Dixon *et al.* (2021), there are at least four farming systems employed in Asia that could be evaluated concerning the effect of the Covid-19 pandemic and the resilience of the sector. These include: (i) dryland mixed farming system; (ii) up-hill mixed farming system; (iii) irrigated wheat-based farming system; and (iv) lowland rice-based farming system.

Dixon *et al.* (2021) describe the four farming and food system (FFSs) that cover most of rural Asia, including: (i) dryland mixed FFSs, (ii) hill mixed FFSs, (iii) irrigated wheat-based (FFSs), and (iv) irrigated rice-based (FFSs). The conceptual model characterises the pathways and drivers influencing the effects on each FFS, food and nutrition security, and system resilience. In the model, local food and labour markets were linked to food and nutrition system (FNS) outcomes for rural farm- and non-farm-households (in contrast to urban residents who depend on food supply chains from farms). Furthermore, productivity, natural resource, economic, human, and social aspects of resilience were considered for each FFS. Direct effects of Covid-19 could include reduced availability of labour for farm operations and policies to limit the spread of the virus, protection of vulnerable populations, and the stimulation of agriculture. Indirect effects of Covid-19 on FFSs were expected from labour migration following job losses, disrupted markets due to movement restrictions, improved disposable income of farm households from welfare programmes, and policy and planned support for farm production and marketing. Labour and gender themes were considered to be closely related, and market and policy effects were expected to be strongly interdependent. These four elements could influence FFS performance, sustainability, and resilience.

West Timor has two dominant farming systems that need to be evaluated. They are the lowland rice-based farming system (LRB), represented by the wetland farming system, and the up-hill mixed farming system (HM), represented by the dryland farming system. Dixon *et al.* (2021) also emphasise that some issues that should be evaluated concerning the resilience of the farming and food systems are: (i) gender dynamics, (ii) food chain; (iii) labour movement; (iv) sustainability; (v) output markets; (vii) input markets; and (vii) food and nutrition security. However, this study captures the last five issues that are used to determine the resilience of the farming systems in West Timor.

According to Dixon *et al.* (2021), pre-pandemic policies reduced the vulnerability of the irrigated, more intensive farming and food systems, i.e. the irrigated wheat-based farming system and the lowland rice-based farming system (Indonesia), compared with the lower-input hill mixed farming system and dryland farming system, particularly for machinery services, fertiliser subsidies, and minimum support prices.

Basuki *et al.* (2022), in their research on "The existence of farming types in dryland agriculture in Timor, Indonesia", found that the dominant type of a farming system in West Timor, is mixed farming. This farming covers several commodities in the exact location, including the livestock sector. This type of farming is part of an adaptation and copping strategy applied by local farmers due to the agroecological conditions of semi-arid land.

According to Benu (2003), farmers in West Timor run a traditional agriculture production system of shifting cultivation that has been practiced and passed from generation to generation. This production system level is primarily focused on providing food for the family. Furthermore, the productivity of this production system in West Timor is very low and fluctuates depending on annual precipitation and fertility resilience.

There are many definitions of resilience concerning the capacity of the farming system to re-establish its essential function of production and productivity. According to Zampieri *et al.* (2020), the original meaning of resilience – first introduced in ecology – refers to the most significant pressure a system can cope with before changing its internal structure and losing its functioning capacity (Holling, 1973). However, the concept of resilience has been modified in other fields of science, especially engineering and social sciences (Folke, 2006; Brand and Jax, 2007; D'Angelo *et al.*, 2013; Angeler and Allen, 2016; Quinlan *et al.*, 2016).

Furthermore, according to the Centre de Developpement de l'Agroecologie (CDA) (Oliveira *et al.*, 2019), the resilience of a system should cover three main instruments including: (i) robustness: the system can tolerate disturbances without deviating from its routine regime; (ii) adaptability: the system is capable of implementing technical, organisational or commercial adaptations to cope with hazards and quickly return to a routine regime; and (iii) transformability: the system is capable of profound transformation to endure.

Meuwissen *et al.* (2019) also define the resilience of a farming system as "its ability to ensure the provision of the system functions in the face of increasingly complex and accumulating economic, social, environmental and institutional shocks and stresses, through capacities of robustness, adaptability, and transformability."

This research is more dealing with the first two instruments, i.e. the ability of the farming system to tolerate the disturbance of Covid-19 without deviating from its primary function and the capability of the farming system to cope with the Covid-19 pandemic and quickly return to its preparatory process of producing food for villagers. However, this research also ensures the third instrument of transformability, whether the system has been transformed from its routine function to endure since the Covid-19 pandemic. The two mechanisms of robustness and adaptability proxies are analysed through the numeric measure of the labour movement, sustainability, output markets, input markets, and food and nutrition security.

Sustainable economic development. A strategy for involving the community in the agricultural sector development is to be accorded access to all the development processes, including decision-making, planning and implementation, monitoring and problem-solving while instilling full awareness that the process benefits all parties. This strategy allows the local community to express local knowledge and their view on the agricultural sector, how it can be sustainable, and how they could be involved in its development. According to Lynam and Herdt (1989), sustainability is "the capacity of a system to maintain output at a level approximately equal to or greater than its historical average, with the approximation determined by the historical level of variability" (Lynam and Herdt, 1989). Pearce and Turner (1989, p. 24) put their definition of sustainability from the perspective of economic development as "Maximizing the net benefit of economic development, subject to maintaining the services and quality of natural resources over time."

For a definition of sustainability from the perspective of natural resources and the environment, Fresco and Kroonenberg (1992) state that the sustainability of the natural ecosystem can be defined as the dynamic equilibrium between natural inputs and outputs modified by external events, such as climatic change and natural disasters. Benu *et al.* (2018) elaborate on the concept of sustainability in the context of sustainable economic development that should be in tandem with sustainable livelihoods, meaning that humans have the freedom to economic development, which is not merely freedom of economic activity (freedom to enter into market exchanges) or political activity (freedom to vote and be an active citizen). However, humans also have the right to access social services, such as health care, sanitation, nutrition, and education, through sustainable livelihood.

The agricultural sector should be developed using a model based on a bottom-up approach to enable sustainable growth for economic development and good benefits for the livelihoods of local communities. Local communities should be involved in designing the agricultural/farming sector development. However, in many developing countries, the government has developed the agricultural sector with a top-down approach model without consultation with or involvement of local communities (Tosun, 2001; Suchet and Raspaud, 2010; Nost, 2013). In many sectors, top-down processes developed in Indonesia have obstructed or destroyed local businesses and undermined existing livelihoods (Lasso and Dahles, 2018). Accordingly, sustainable agriculture and farming require human resolve and planning effort. There is an absolute need to indicate how the many disparate groups of actors in the agricultural industry can find linkages and the means to support cooperative efforts in league with the destination communities.

Bahaire and Elliott-White (2010) describe some themes and their indicator that should be covered in the study of sustainability, including such indicator descriptors as: (i) environment with a village participating in land conservation programmes, waste treatment and rural employment; (ii) economic activity with businesses located outside the village, newly registered businesses and per capita income generated by the industry; (iii) society and culture with villagers included in awareness programs, employees who have been on training courses.

MATERIALS AND METHODS

STRUCTURAL EQUATION MODELLING

The structural model in this research covers the linear relationship between constructed latent variables. The general model of the structural equation might be formulated in the form of a matrix (Hair *et al.*, 2009) as Equation (1):

$$\eta(m) = B(m \cdot m)\eta(m) + \Gamma(m \cdot n)\xi(n) + \varsigma(m) \qquad (1)$$

where: η = variance of the latent endogenous variable of size m, B = regression coefficient of latent endogen variable, Γ = regression coefficient of latent exogenous variable, ξ = exogenous latent variable of size n, ς = error of the model, m = several latent endogenous variables, n = number of latent exogenous variables; η, ξ, ς are a random vector of latent endogenous variables.

Furthermore, the model might be reduced into the following formula in Equation (2) (Timm, 2002):

$$\eta = (1 - B)^{-1}\Gamma\xi + (1 - B)^{-1}\varsigma = \Pi\xi + e \qquad (2)$$

With covariance matrix is as follows:

$$\sum = \begin{bmatrix} \sum_{\eta\eta} & \sum_{\eta\xi} \\ \sum_{\xi\eta} & \sum_{\xi\xi} \end{bmatrix} = \begin{bmatrix} \mathrm{E}(\eta\eta') & \mathrm{E}(\eta\xi') \\ \mathrm{E}(\xi\eta') & \mathrm{E}(\xi\xi') \end{bmatrix} = \\ = \begin{bmatrix} (1 - B)^{-1}(\Gamma\Phi\Gamma' + \Psi)(1 - B)^{-1'} & (1 - B^{-1}\Gamma\Phi) \\ \Gamma'(1 - B)^{-1'}\Phi & \Phi \end{bmatrix} \qquad (3)$$

It should be understood that latent variables are commonly utilised in some studies, such as intra- and inter-organisational relationships (James and Jones, 1980; Stone-Romero, 1995; Scandura and Williams, 2000). Generally, these fields of study utilised latent variables as reflective (effect) indicators rather than formative indicators [e.g. James and Jones (1980), Hogan and Martell (1987), Lam, Chen and Schaubroeck (2002), Morrison (2002), Subramani and Venkatraman (2003), Ramamoorthy and

Flood (2004), Tihanyi, Griffith and Russell (2005), Sarros, Cooper and Santora (2008)].

However, Diamantopoulos and Siguaw (2006, p. 263) emphasise that "in many cases, indicators could be viewed as causing rather than being caused by the latent variable measured by the indicators." Indicators that could be viewed as the cause of the latent variable are called formative (or causal), and in the case of the latent variable measured by the indicators, we refer to it a reflective one.

The model of SEM might be formulated for a reflective or formative indicator based on the theoretical concept that has been developed. In reflective models, the variables manifested as indicators are affected by the latent variable, whereas in formative models, the indicators determine the latent variable (Hanafiah, 2020).

All the reflective indicators might be interchanged, since the different indicators reflect the concept. At the same time, all the indicators in the formative model are not interchangeable since each indicator will contribute a particular impact to the latent variable. Based on the theoretical concept, this research deals with a reflective model where all the indicators contribute a particular impact to the latent variable. Practically, all scales in the model use a reflective approach to measurement.

The critical question is what has been the effect on the resilience of the farming system in Timor after the heavy disturbance caused by the pandemic? There are two essential questions addressed in this research.

1. How has the Covid-19 pandemic affected the resilience of the farming system in West Timor after the heavy disturbance caused by the Covid-19 virus?
2. What policies should be implemented to increase the resilience of the farming system?

The objectives of this research are to understand the resilience of the farming systems of West Timor after the Covid-19 pandemic, and to develop strategic policies that could be adopted to increase the resilience of the farming systems in West Timor.

RESEARCH APPROACH

This research used a mixed method approach to analyse farmers' socio-economic conditions, the impact of external hazards (Covid-19) on the farming systems, and the resilience of the farming system after the Covid-19 pandemic in West Timor. A descriptive, qualitative analysis was conducted to evaluate the socio-economic conditions based on information gathered during the Focus Group Discussion (FGD) and in-depth interviews with key informants. The FGD has been involved sample groups from two villages, and each FGD process takes roughly two hours to gather information regarding all aspects of farming system resilience.

The participants in each FGD include many stakeholders representing the formal leader at the village level, traditional leader, religious leader, extension workers, farmers, local traders, etc., with total participants of roughly 20 people. Information gathered from each FGD, including descriptive data on farming system practices, production, input, marketing, consumption pattern, etc., has been used to support the quantitative analysis of the farming system resilience. Quantitative and qualitative data gathered during the interview from March to April 2022 were used to analyse the resilience of the farming systems after the Covid-19 pandemic, including: (i) labour movement, (ii) environmental sustainability, (iii) economy, (iv) social culture, (v) output markets, (vi) input markets, and (vii) the resilience of farming systems in West Timor.

Based on the sustainable theoretical framework developed by Harrison and Husbands (1996) as quoted by Bahaire and Elliott-White (2010, pp. 159–174), combined with the concept of the farming system developed by Dixon *et al.* (2021), we developed some themes and indicators as shown in Table S1.

TOOLS OF ANALYSIS

The triangulation design for this mixed method occupied the convergence triangulation model, starting from quantitative and qualitative data collection simultaneously and finishing with interpreting results of both data analyses. At the same time, a quantitative analysis using the Structural Equation Modelling (SEM) with AMOS software was employed to evaluate the relationship and the impact of the six generic aspects as construct variables (labour movement, sustainability, economy, socio-culture, output markets, and input markets – together with their reflective indicators) on the resilience of the existing farming system. Based on the concept of sustainable development Harrison and Husbands (1996), as quoted by Bahaire and Elliott-White (2010, p. 251), combined with the resilience of farming systems (Dixon *et al.* 2021), the themes of farming systems and their objectives and reflective indicators are shown in Table S1. The questionnaire focused on probable medium-term effects and implications for their recovery. The questions scored the vulnerability assessment and the relative severity of Covid-19 effects using the Likert scale of 0–5.

The remaining questionnaire content comprised closed and open-ended questions on pathways to and implications of the Covid-19 effects, supplemented by listings of local reports, studies, media accounts, and databases (Dixon *et al.*, 2021). The quantitative analysis of the SEM has been conducted using AMOS Software, since all the manifest variables of the model have been treated as reflective indicators.

Two districts were selected representing the wetland farming system and dryland farming system in West Timor. The districts chosen included Kupang (representing wetland farming systems) and TTS (representing dryland farming systems). These two districts in West Timor were selected for data collecting relevance to the study themes. There are 235 samples of farmers from the two villages, who were selected randomly to be interviewed regarding all the reflective variables of the resilience of the farming system after the Covid-19 pandemic. The interview was conducted face to face, based on the questionnaire prepared to represent the 27 reflective indicators with no incentive. The average time for each interview was 30 min, with a more than 90% response rate. Coding and tabulation processes were conducted by two researchers soon after data collection from the field using the SPSS software.

STRUCTURAL MODEL

Based on the sustainable theoretical framework developed by Harrison and Husbands (1996), as quoted by cited in Bahaire and Elliott-White (2010, p. 251), combined with the concept of the farming system developed by Dixon *et al.* (2021), the general model applied in this research is presented in Figure 1.

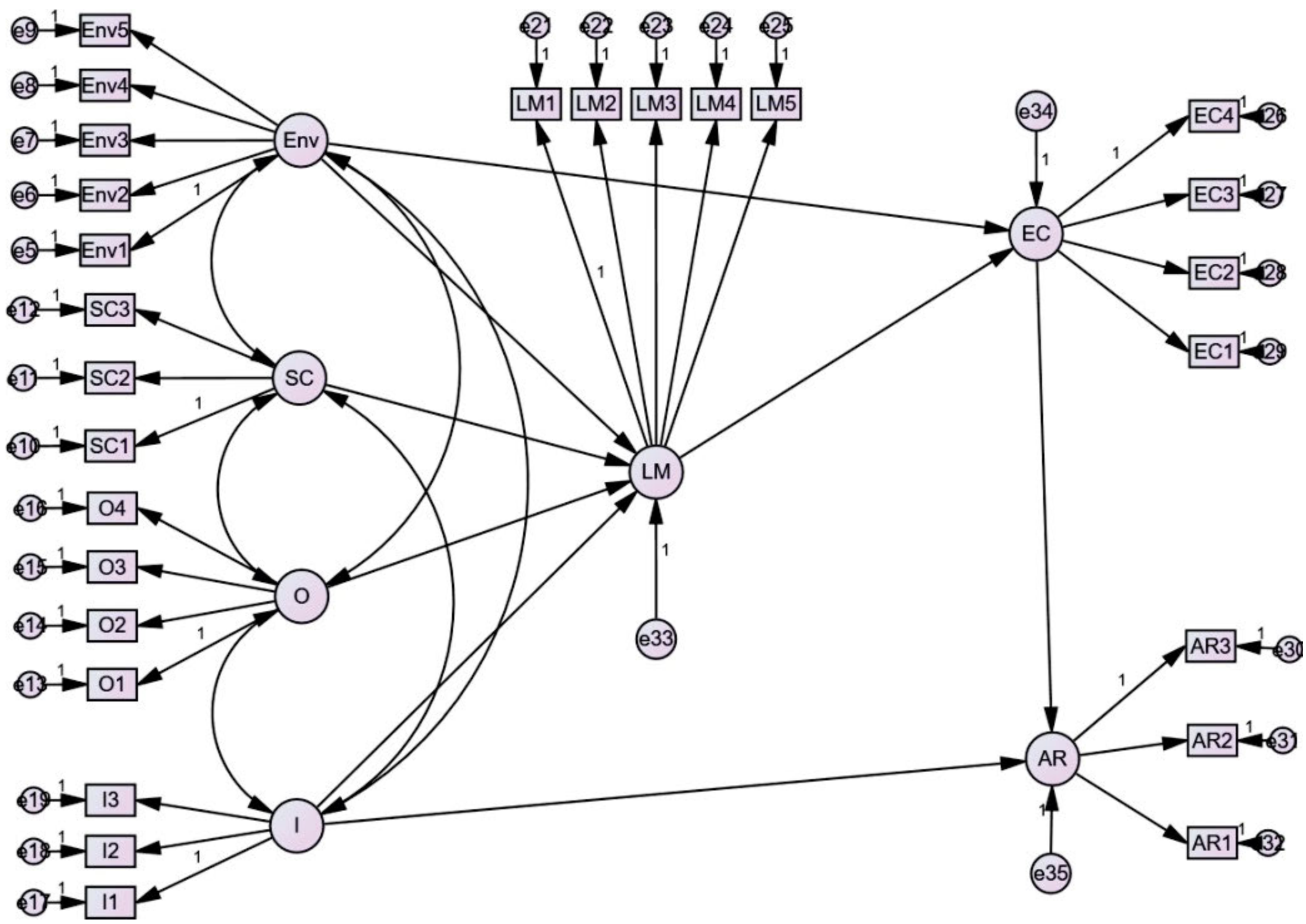

Fig. 1. The initial model of SEM for dryland and wetland farming systems; source: own elaboration

Where:

Env = exogenous construct variable of environment
- Env1 = environmental security from pandemic's destruction impact
- Env2 = need for an environmental conservations program
- Env3 = need for water resources protection program
- Env4 = need for a waste recycling program
- Env5 = need for water saving program

SC = exogenous construct variable of social culture
- SC1 = traditional wisdom in anticipating disaster
- SC2 = sociocultural kinship relationship in handling the pandemic impact
- SC3 = local cultivation activities in handling the pandemic impact

O = exogenous construct variable of output
- O1 = price and the profitability of production output
- O2 = cost of the output distribution
- O3 = distance of output marketing
- O4 = marketing channel of output marketing

I = exogenous construct variable of input
- I1 = price of production input
- I2 = production input availability
- I3 = cost of distribution of production input

LM = endogenous construct variable of labour movement
- LM1 = farmer's participation in land occupation
- LM2 = authority of the farmer to decide the commodity that has to be cultivated
- LM3 = government commitment to empowering agriculture extension workers
- LM4 = availability of female labour in agriculture
- LM5 = availability of male labour in agriculture

EC = endogenous construct variable of economic
- EC1 = agriculture sector recovery from pandemic
- EC2 = production input access
- EC3 = production output marketing
- EC4 = labour movement into the non-agriculture sector

AR = endogenous construct variable of farming systems resilience
- AR1 = farmer's consumption pattern and balanced nutrition
- AR2 = food price affordability by farmers
- AR3 = food access by farmers

e1; e2; e3; …; e32 = vector for the measurement error

e33; e34; e35 = vector for the latent variable

RESULTS AND DISCUSSIONS

WEST TIMOR FARMING SYSTEM

Basuki *et al.* (2022), in their research "The existence of farming types in dryland agriculture in Timor, Indonesia", found that dryland mixed farming is the dominant type of farming system in East Nusa Tenggara Province, especially in West Timor. This farming covers several commodities in the same location (Basuki *et al.*, 2022). This type of farming is part of an adaptation and coping strategy used by local farmers for the agroecological conditions of semi-arid land. However, over time, information gathered from the FGD during the survey shows that the dryland farming orientation in West Timor has shifted from subsistence to marginally orientated toward commercial enterprise. There are at least five types of agroecosystems practised by local farmers in West Timor. They are lea, house garden, irrigated rice, upland rice, livestock, and agroforestry.

The result of the FGD also indicates that there are at least seven constraints to technology adoption to improve cultivation practices and agricultural production in Timor, including: (i) soil fertility and erratic rainfall often exposing the area to drought conditions; (ii) the main food crops, especially maize, are grown in less developed or remote areas; (iii) farmers have little formal education and a lack cash capital; (iv) no price incentives; (v) no access to agricultural inputs; (vi) poor management systems; and (vii) improved technologies receive little promotion. Furthermore, regarding maize cultivation, the leading staple food in West Timor, Benu *et al.* (2011) said that based on the agronomic, climatic, and edaphic conditions, the determinant factors affecting maize production in West Timor are seed quality, weeds, rainfall, plant population, pre-and post-harvest pest destruction, and soil conditions.

According to CIDA (1980), as cited in Benu (2003, p. 73), farmers in West Timor run a traditional agriculture production system of shifting cultivation practiced and passed from generation to generation. The level of this production system is subsistence, where the primary orientation is to provide food for the family. Furthermore, the productivity of this production system in West Timor is very low and fluctuates depending on the annual precipitation and land fertility level.

Information gathered from the FGD also shows that farming in these semi-arid areas has a high risk of failure, mainly due to water shortages. Therefore, planting many edible crops ensures that at least one or two crops will endure being harvested, thus minimising vulnerability. Therefore, farmers rely on nature rather than other external inputs, such as the market system, financial institutions (banks, cooperatives, etc.), government policy, NGOs, and research agencies, among other externalities.

Recently, farmers in West Timor, a part of East Nusa Tenggara (Ind. Indonesian: Nusa Tenggara Timur – NTT), have joined a unique programme of food production titled "Planting Corn Harvest Cattle (Ind. "Tanam Jagung Panen Sapi" – TJPS)" run by the NTT Provincial Government. The programme commenced in 2018. This particular programme was designed to encourage farmers, through an increase in corn production, to sell the corn surplus and buy cattle in a relatively short time. According to Matitaputty, Hau and Nulik (2021, p. 2): "In TJPS management, a farmer with 1 ha of land is expected to produce at least 5 tonnes of corn grain/ha, of which 1 ton will be stored for daily meals and the remaining 4 tonnes will be sold to generate capital to buy cattle and savings. Assuming that the value of 1 kg of corn is IDR3,200, farmers may obtain IDR12.8 millions. This amount can buy at least 2 pieces of feeder cattle. This innovation in short of corn life (Quick win) of 3 months may change the farmer ownership status."

Under the special food production programme of the TJPS, food crop production in West Timor, especially maize, has increased yearly. The average growth of the gross domestic regional product of West Timor increased by 2.57% in 2021, after a deep slide into negative growth in 2020 (–0.87%) because of the impact of the Covid-19 pandemic. At the same time, rice production in West Timor increased by 24.10% in 2021 (147,224 Mg) after a contraction of –26.03% in 2020 (118,631 Mg) because of the social restriction policy adopted by the central, provincial, and district governments. However, the recovery of rice production in 2021 was determined by the strong commitment of the central and provincial governments to support the agriculture sector during the pandemic period.

On the one hand, most of the farmers in West Timor have been utilising a mixed cropping system, especially in uphill land areas characterised by a dry land farming system. On the other hand, some of the farmers living in low land areas apply a rice-based farming system which requires more modern input supplies, such as fertiliser, pesticide, and herbicide, and the support from a good irrigation system. Generally, the latter is a modern mono-culture rice farming system which depends on modern input and output supplies. The primary orientation of rice production is cash income after farmers allocate sufficient products for daily household consumption during a year. Some farmers produce two crops yearly, especially in areas with a good irrigation system. Approximately 56,000 ha of lowland in West Timor is utilised for rice production.

CONFIRMATORY FACTOR ANALYSIS

Two formulas that can be used to analyse the reliability of the indicators are (i) composite reliability and (ii) variance extracted. A reasonable threshold of composite reliability is ≥0.60. At the same time, the rule of thumb value of variance extracted is >0.50. Table 2 displays the output of the standardised loading factor (standardised regression weights) produced by Amos Software, Version-22.

The validity of the indicators has to be proved by two formulas, i.e. (i) composite reliability (*CR*) ("construct reliability" sometimes is used) and (ii) variance extracted (*AVE*). A reasonable threshold of composite reliability is ≥0.60. In comparison, the rule of thumb value of variance extracted is >0.50. Composite reliability indicates the shared variance among observed variables to indicate a latent construct (Fornell and Larcker, 1981). The formula of composite reliability (*CR*) is shown in Equation (4):

$$CR = \frac{\left(\sum_{i=1}^{n} SLF_i\right)^2}{\left(\sum_{i=1}^{n} SLF_i\right)^2 + \sum_{i=1}^{n} \varepsilon_j} \tag{4}$$

where: *SLF* = standardised loading factor. Standardised loading might be identified from the standardised loading for each indicator; εj = measurement error; εj = 1 – (standardised loading)^2.

The result of the analysis of *CR* for Wetland Farming System (WAFS) shows that: CR_{Env} = 0.81, $CR_{\mathrm{socioculture}}$ = 0.89, CR_{output} = 0.75, CR_{input} = 0.86, CR_{LM} = 0.86, CR_{EC} = 0.74, CR_{AR} = 0.86.

At the same time, variance extracted demonstrates the total variance of indicators extracted from construct variables. A high value of variance extracted shows that the indicators are a good representation of the construct. Variance extracted (*AVE*) might be calculated with the formula of Equation (5):

$$AVE = \frac{\sum_{i=1}^{n} SLF_i^2}{\sum_{i=1}^{n} SLF_i^2 + \sum_{i=1}^{n} \varepsilon_j} \tag{5}$$

The result of the analysis of *CR* for WAFS shows that $AVE_{\text{Env}} = 0.59$, $AVE_{\text{socio-cult}} = 0.80$, $AVE_{\text{output}} = 0.52$, $AVE_{\text{input}} = 0.52$, $AVE_{\text{labour move}} = 0.60$, $AVE_{\text{EC}} = 0.50$, $AVE_{\text{wetland resilience}} = 0.67$. Furthermore, the result of the analysis of *CR* for dryland farming system (DAFS) shows that: $CR_{\text{Env}} = 0.88$, $CR_{\text{socio-cult}} = 0.86$, $CR_{\text{output}} = 0.86$, $CR_{\text{input}} = 0.82$, $CR_{\text{LM}} = 0.93$, $CR_{\text{EC}} = 0.85$, $CR_{\text{AR}} = 0.92$. The result of the analysis of *AVE* for DAFS shows that: $AVE_{\text{Env}} = 0.602$, $AVE_{\text{socio-cult}} = 0.669$, $AVE_{\text{output}} = 0.620$, $AVE_{\text{input}} = 0.615$, $AVE_{\text{labour move}} = 0.632$, $AVE_{\text{EC}} = 0.600$, $AVE_{\text{dryland resilience}} = 0.784$.

Based on the reliability test of the model, either $CR \geq 0.60$ and $AVE \geq 0.50$, we can say that all manifest variables have the reliability to predict all construct variables.

THE GOODNESS OF FIT TEST FOR THE MODEL

At least six pillars should be empowered to support the resilience of the farming system after the Covid-19 pandemic. These include sustainability of the environment, socio-economic factors, output market, input market, labour movement, and economics. These six pillars have been elaborated into 21 indicators for wetland farming systems and 27 indicators for dryland farming systems to construct the resilience of the structural model of farming systems.

The farming systems themselves cover two types of already existing farming systems, including (i) wetland farming system (WAFS) and (ii) dryland farming system (DAFS). The effect of all indicators on the resilience of the farming systems is then calculated by entering the score into the structural equation model (SEM) analysis. Structural equation modelling of the resilience of the farming systems was performed using the Amos Software Version-22 by checking various model indicators, including model identification, and estimating model parameters.

Based on the criteria of Chi-square analysis, a model might be categorised as an excellent fit model if the probability level of Chi-square ≤ 0.10. Supposedly, the value of X^2 is higher than the degree of freedom. In that case, we can say that the covariance matrix or correlation between the observation and prediction values is significant and will produce a probability level less than a significant level. The analysis results show that the probability level of Chi-square for the resilience of agriculture and food systems in WAFS or DAFS is 0.00. Therefore, we say that the covariance matrix of the model is not different from the covariance matrix of the sample, and therefore the model is a good fit. Furthermore, the reliability test of the models, namely composite reliability either for wetland or dryland farming systems, is more than 0.60, and the variance extracted for both models is more than 0.50. We can then say that all manifest variables have the reliability to predict the construct variables.

Furthermore, the analysis results also show that the goodness of fit index (*GFI*) indicators of the two models are 0.925 and 0.952. Usually, the value of the *GFI* is between zero and one ($0 \leq GFI \leq 1$), and a model is categorised as an excellent fit if the value of the *GFI* is close to 1. Because the value of the *GFI* of the model is almost 1, we can say that the model of farming system resilience is a good fit model. Another indicator of absolute fit measures (AFM) is a root mean square residual (*RMR*). The *RMR* is an indicator of the difference between covariance matrixes of model estimation and the covariance matrix of the sample. If the $RMR \leq 0.05$, then the model fits well. The analysis results show that the value of the *RMR* of the model is 0.049 for WAFS and 0.041 for DAFS. Then we can say that the model is a good fit model. Another tool for good fit of the model is the incremental fit measure (*IFM*) with three indicators, including normed fit index (*NFI*), incremental fit index (*IFI*), and comparative fit index (*CFI*), together with their rules of thumb values. The rule of thumb value of the *NFI* should be greater than or equal to 0.90 before the model can be categorised as a good fit model. The analysis results show that the value of the *NFI* for the farming system models of WAFS and DAFS are 0.944 and 0.999, respectively. At the same time, the rule of thumb value of the *IFI* should also be greater than or equal to 0.90. The analysis results also show that the values of the *IFI* for the model of WAFS and DAFS are 0.919 and 0.999, respectively. The last indicator *CFI* also has the same rule of thumb values ($CFI \geq 0.95$), and the analysis results show that the values of the *CFI* for the model of WAFS and DAFS are 0.966 and 0.952, respectively. These three indicators emphasise that the model of the resilience of the wetland and dryland farming systems is quite suitable for further prediction.

Based on the goodness of fit test of the model, it can be concluded that the model of the wetland and dryland farming systems is quite a good fit to be evaluated further regarding the impact of the four exogenous construct variables (environment, sociocultural, input market, and output market) and the two endogenous construct variables (labour movement and economics) on the constructed variable of farming systems resilience (see: Tab. S2, Figs. 2, 3).

PERFORMANCE COMPARISON

The size and the sign of the regression coefficient, as the direct impact of exogenous construct variables of the economic factor and input of production after the Covid-19 pandemic on the dryland farming system resilience is positive and more considerable than the impact on the wetland farming system. The direct impact of the economic factor on the resilience of the dryland farming system is 0.92, and the direct impact of input on the resilience of the dryland farming is 0.87. At the same time, the direct impact of the economic factor on the resilience of the wetland farming system and the direct impact of input are 0.44 and 0.38, respectively. The results mean that after the pandemic the economic and input supply conditions have increased the dryland farming system resilience more than for the wetland.

The structural analysis results show that the dryland farming system in West Timor is more resilient than the wetland farming system. As we know, resilience is the ability of a system to respond to external pressures. According to the WEF (2019), resilience is "the ability of people, communities, governments, and systems to withstand the impacts of negative events and to continue to grow despite them." Economic factors, rather than the labour movement factor, will create better resilience of farming systems, both for wetlands and dryland (WEF, 2019). However, the impact of better economic performance after the pandemic on the resilience of dryland farming systems is more significant than in the case of the wetland farming systems. The analysis results are supported by previous research (Dixon *et al.*, 2021) which showed that the dryland represented by the Hill-Mixed Farming and Food System (HM FFS) was the most

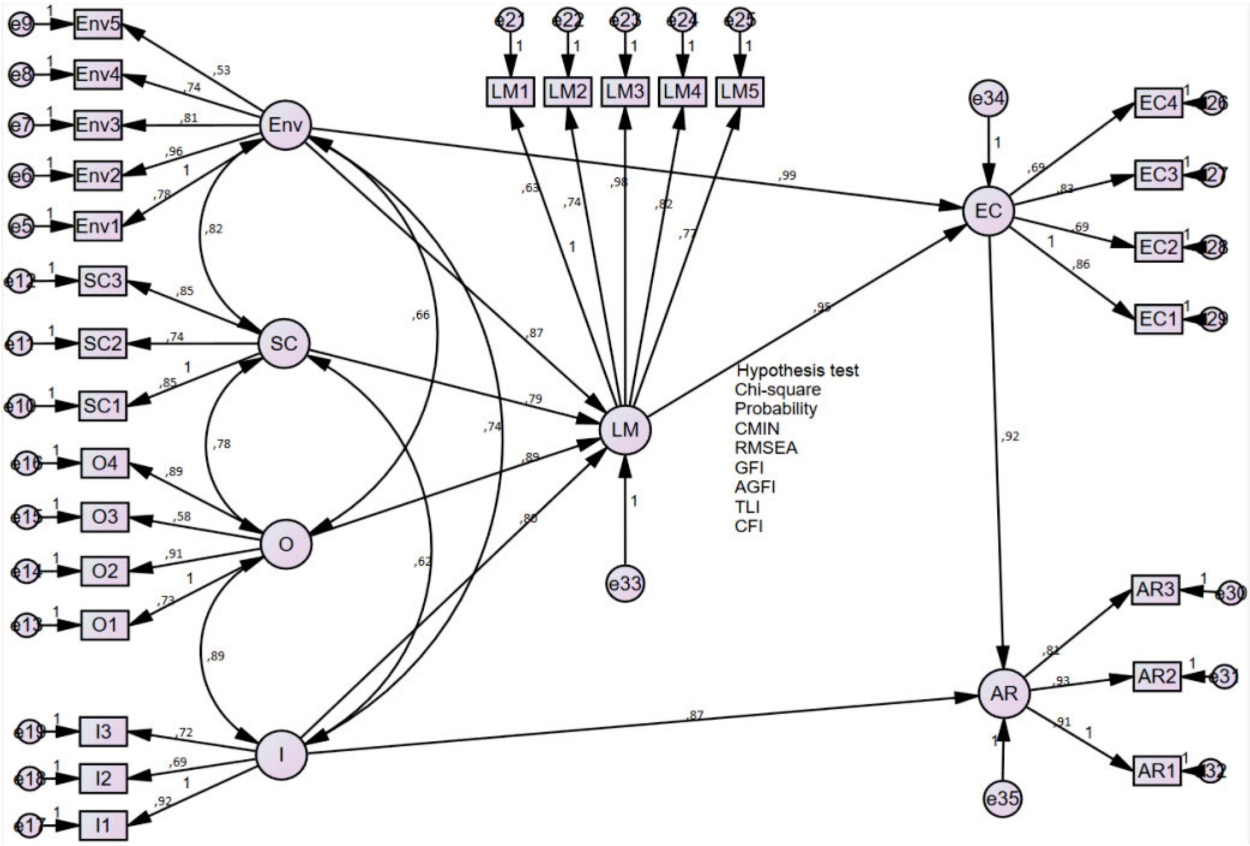

Fig. 2. Measurement and structural model of the resilience of dryland farming system in West Timor; explanations as in Fig. 1; source: own study, primary data analysis produced by Amos Software

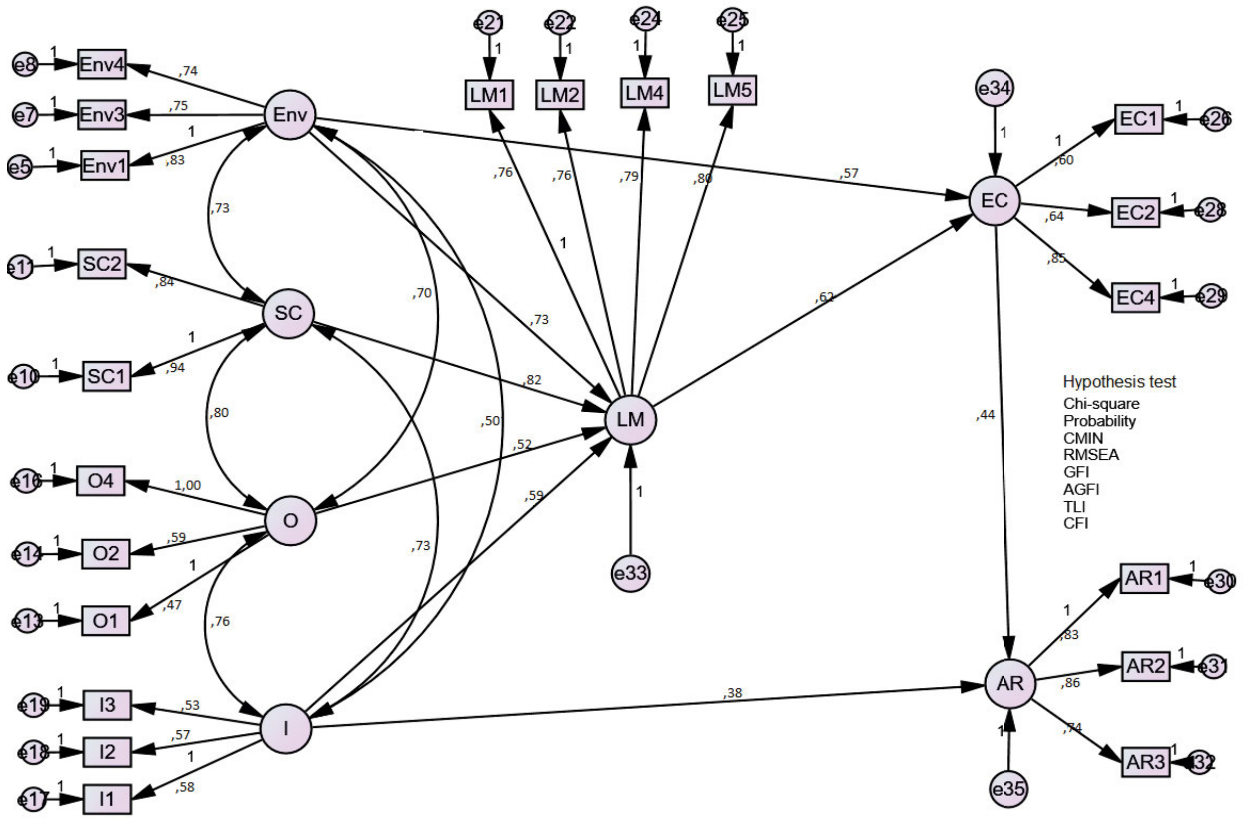

Fig. 3. Measurement and structural model of the resilience of wetland farming system in West Timor; explanations as in Fig. 1; source: own study, primary data analysis produced by Amos Software

resilient system. The wetland represented by the Irrigated Wheat Based Farming and Food System (IWB FFS) was the most severely affected. Information gathered from the FGD process also shows that dryland farmers are not affected by the Covid-19 pandemic, especially regarding their access to food and affordability compared to wetland farmers.

The structural analysis results show that soon after the economic recovery, the resilience of the dryland farming system is stronger than the resilience of the wetland one. However, it can also be interpreted that if economic performance is under pressure because of the pandemic, then the resilience of the dryland farming system is stronger than that of the wetland system. Again, this condition is determined by wetland farming systems being more deeply engaged with current economic conditions than dryland farming.

Based on the discussion with all stakeholders in the FGD, it might be concluded that the dryland farming system has not been firmly coupled with the modern market regarding input supply and marketing of the product. Indeed, the mixed farming system is a semi-subsistence farming system whose primary orientation is to provide food for villagers (Photo 1b). The existing dryland mixed cropping system farming in Timor consists of diverse food crops, such as maize, cassava, legumes, pumpkin, etc. (Photo 1a). Local farmers are practising a mixed cropping system by putting all commodities together in one hole as a coping mechanism to anticipate any external hazard, such as extreme weather conditions, diseases, etc.

A study of resilient farming systems that can better meet farmers' complex needs and confront future challenges was conducted by the CGIAR (2020). It found that the increase in the farm's agricultural biodiversity can help to improve its resilience to shocks, as well as promote its soil health and nutritional output. These phenomena prove that the dryland farming system in Timor has not transformed into another mechanism for providing essential foods to villagers because of the existing practice of mixed cropping.

Furthermore, the research by Dixon *et al.* (2021) also claims that the wetland represented by Low Rice Based Farming and Food System (LRB FFS) was moderately negatively affected by movement restrictions and urban-rural migration. It benefited from market support and social protection programmes, as well as production, marketing, and food security of this farming system, as it benefited in particular from input subsidies, irrigation, and mechanisation. As mentioned in the previous section, the dryland farming system employed by the local farmers in West Timor is the most common strategy to protect against vulnerabilities and crop failure. The idea is to plant several food crops in the same holes and furrows (Dixon *et al.*, 2021). This is also reported by McCord *et al.* (2015), who stated that the diversification of crops is a strategy adopted by small land holding farmers to reduce their vulnerability. Benu *et al.* (2011) mentioned that local farmers commonly utilise seeds they secure from previous harvests. Very rarely do they use high-quality seed (certified seed), which means that a dryland mixed farming system is not coupled with modern market systems as much as the wetland farming system (Benu *et al.*, 2011).

We know that the modern market system has been deeply affected by the Covid-19 pandemic since 2020. Hence, the impact of the Covid-19 pandemic on the modern market system determines vulnerabilities in the wetland farming system used by farmers in West Timor. According to the UN-OCHA (2016), experience suggests that resilience can be achieved through a combination of technologies and institutional and policy reforms, including improved extension strategies and safety nets for farmers, particularly in marginal areas most threatened by crop and livestock failures. Furthermore, Dhar (2021), in their publication "Building resilience in dryland global guidelines for restoration of forest landscapes and degraded lands", mentioned that drylands provide many unique species that have adapted to extreme ecological conditions. They provide essential ecosystem goods and services for people's livelihood and well-being.

From the above description, we might conclude that the traditional dryland mixed farming system cannot be transformed into a modern mono-cropping system fully coupled with the modern market without considering the coping mechanism that local farmers have been using for many years. A specific policy, institution, and process must be designed appropriately with the

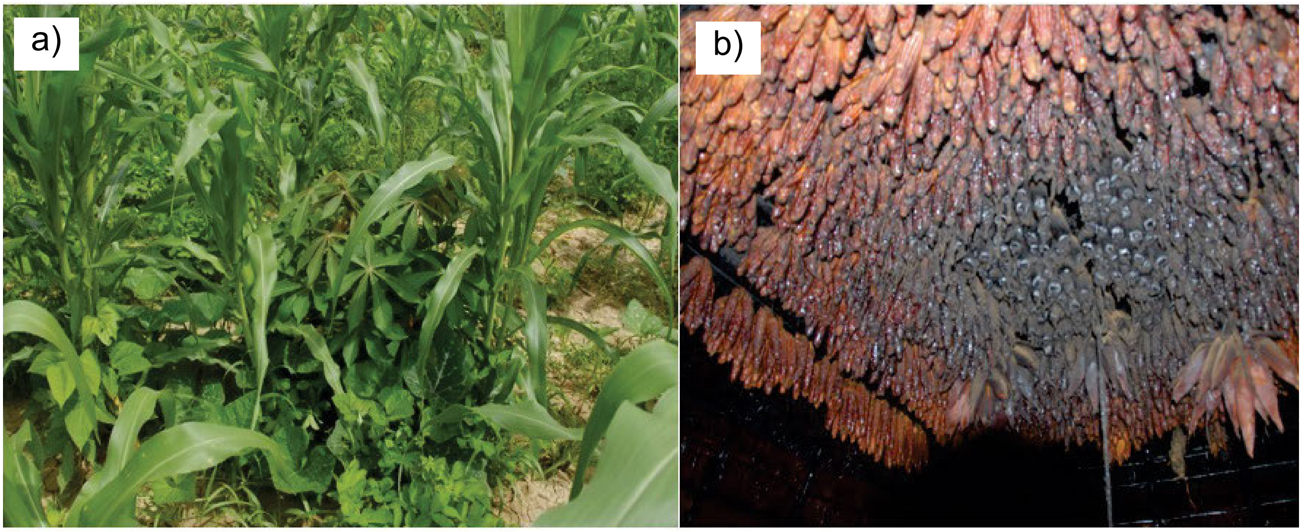

Photo 1. Two stages of food production: a) mixed cropping systems as a cropping mechanism to anticipate crop failure, b) food produced from the existing farming system hung on the kitchen's roof for the smoking process to prevent decay because of pests (phot.: *Mudita*)

involvement of all stakeholders before the transformation is implemented in West Timor.

The result of the analysis shows that the model of the SEM that has been developed to evaluate the resilience of farming systems might be referred to as the good scientific model because it proved that the resilience of farming systems, when hampered by external modern factors, such as diseases, mobilisation, and the market mechanism, depends on how deep the systems is coupled with modern activities, such as transportation and market mechanism of input and output supply.

CONCLUSIONS

Timorese farmers face problems of limited precipitation, lack of fertile land for cultivation, limited access to input, limited access to capital, limited access to assurance, and limited access to the output market. Rural livelihood and food security were affected by the Covid-19 pandemic primarily because of disruptions to local labour markets (especially for off-farm work), farm produce markets (notably for perishable foods), and input supply chains (seeds and fertilisers). Overall, the impact on the system was worse in the wetland farming system and least harmful in the mixed hill dryland farming system. Associated with the latter case are greater resilience and diversification and less dependence on external inputs and extended supply chains. Dryland farming systems are more resilient than wetland farming and food systems. Economic performance rather than the labour movement is the most salient factor that creates better resilience for the wetland and dryland farming systems after the Covid-19 pandemic. The dryland farming system has not been fully hampered by the Covid-19 pandemic because it has not been too strongly coupled with the modern market regarding input supply and marketing of the product. Indeed, the mixed farming system is a semi-subsistence farming system whose primary orientation is to provide food for villagers. The existing dryland farming system in West Timor consists of diverse food crops, as a coping mechanism that helps to anticipate any external shock. However, the dryland farming orientation in West Timor has shifted from being subsistence to being marginally orientated toward commercial enterprise. The economic recovery process and the ongoing input supply mechanism after the Covid-19 pandemic have increased the resilience of the dryland farming system more than the resilience of the wetland farming and food system.

CONFLICT OF INTERESTS

All authors declare that they have no conflict of interests.

SUPPLEMENTARY MATERIAL

Supplementary material to Table S1 and Table S2 can be found online at: https://docs.google.com/document/u/0/d/12v2YuX-4czVPdmVGcpakPlSNj2uDDMwr/mobilebasic and https://docs.google.com/document/u/0/d/1-hByGWNYpQofR0OY9qXvBTzqXwCD7tPZ/mobilebasic.

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