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http://online.agris.cz

ISSN 1804-1930
XV, 2023, 2

International scientific journal
Prague

# Agris on-line Papers in Economics and Informatics

The international reviewed scientific journal issued by the Faculty of Economics and Management of the Czech University of Life Sciences Prague.

The journal publishes original scientific contributions from the area of economics and informatics with focus on agriculture and rural development.


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## Publisher

Faculty of Economics and Management
Czech University of Life Sciences Prague
Kamýcká 129, 165 00 Praha-Suchdol
Czech Republic
Reg. number: 60460709

ISSN 1804-1930

XV, 2023,
30th of June 2023
Prague

# Agris on-line
# Papers in Economics and Informatics

**ISSN 1804-1930**

**XV, 2023, 2**

Agris on-line Papers in Economics and Informatics

Volume XV Number 2, 2023

Content:

Agris on-line Papers in Economics and Informatics

Volume XV Number 2, 2023

# Global Competitiveness of Trade in the West Coast of Sumatra from the Perspective of the Agglomeration of Economic Approach

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## Abstract

The main aim of this study is to analysed the pattern of agglomeration of trade flows in the city of Padang and Teluk Bayur Port with the regencies and cities along the west coast of Sumatra, as well as the factors that influence them. How competitive is trade flow with the West coast region compared to the East coast of Sumatra. The analytical approach used is spatial econometrics, especially the spatial lag model and spatial error model. The data used is the volume of loading and unloading of inter-island and foreign ships at Teluk Bayur Port and other districts and cities in 133 areas on the West Coast and 155 districts and cities in the economic corridors of Sumatra. The results showed that the West Coast trade flow variable had no significant effect on the existence of Padang City as the centre of economic agglomeration in the economic corridor area of Sumatra. Our findings are that trade flows in the city of Padang have not been able to encourage economic agglomeration in regencies and cities on the West Coast of Sumatra, on the contrary there are connections with regencies and cities in the economic corridors of the East Coast of Sumatra. Therefore, to accelerate the process of economic agglomeration through trade flows, joint policies are needed with the agricultural sector in the Sumatran economic corridor in facing global market competition, as well as strengthening inter-regional internal markets in the Sumatra corridor, agricultural commodity transactions between regencies and cities in the Sumatran economic corridor which must be strengthened, so as to be able to compete in a competitive global market.

JEL Classification: F14, P25, C21

## Keywords

Trade flow, economic agglomeration, spatial models.

Ansonfino, A. and Zusmelia, Z. (2023) "Global Competitiveness of Trade in the West Coast of Sumatra from the Perspective of the Agglomeration of Economic Approach", *AGRIS on-line Papers in Economics and Informatics*, Vol. 15, No. 2, pp. 3-17. ISSN 1804-1930. DOI 10.7160/aol.2023.150201.

## Introduction

The gravity model of inter-regional trade flows was first put forward by Tinbergen (1962) and Lineman (1966) by determining the interaction of trade in goods and people or in the form of exports or imports between one region and another (Dresdner and Zerom, 2021). The trade gravity model has become increasingly popular since Krugman (1991) argued that the problem of geographical vulnerability influences the flow of trade in goods and people within an area. Research on gravitational graph models has become increasingly popular in regional scientific circles since (Asselin and Griffith, 1988), with analysis of spatial effects and spatial dependencies (Krugman et al., 1999). This is also in line with research from trade theory itself, which since Leontief (1963) has developed multiregional independence research that emphasizes the four concepts of trade structure analysis namely dependence, interdependence and hierarchy, as well as the spatial hierarchy of trade flows and the spatial flow of trade (Fujita and Hamaguchi, 2001), the strong impetus of agglomeration of trade flows in driving regional trade competitiveness (Bolduc et al., 1992; Parr et al., 2002; Guillain and le Gallo, 2010; Bergeijk and Brakman, 2010).

The interrelationship between location theory and trade has long been analysed by using economic interactions at a level of geographic space such as: regional, multiregional, national and international (Polenske and Hewing, 2004). This view has been dominated by a spatial analysis often referred to as the “first law of geography”(Tobler, 1987;

Vaz, 2020), which states that a region is always related to another region, and areas that are closed together tend to have closer proximity intense than the others. A measure of the proximity and interaction of a region with other regions uses a weighting matrix that measures the degree of interaction between neighbouring areas. The weighting matrix can be specified in various ways, the most popular is the contiguity matrix, with the most frequently used measurement methods being the Moran Index and the local index spatial autocorrelation (LISA) (Porojan, 2001). This study aims to analysed trade flows between regencies and cities in Sumatra's economic corridor through the approach of spatial effects and spatial dependence on agglomeration patterns of trade flows formed in global trade competition. Using the Moran and LISA indices to measure the proximity of districts and cities to Sumatra's economic corridors, as well as analysed the factors that affect their global competitiveness.

Trade routes in the West Coast of Sumatra, especially the Coastal Area of the province of West Sumatra today, have become international trade routes since the sixteenth century ago, with trading commodities in the form of gold, pepper, rice, dried fish, silk cloth, resin, camphor, brown sugar, raw tobacco and so on. (Kathirithamby, 1969; Kato, 1978; Kato, 1980; Kuzmina, 2008; Xinru Liu, 2010; Dobbin, 2016). Pariaman City and Tiku Harbour are the most active trading ports in connecting land trade routes (silk route) which supply the main commodities of gold and spices from the Minangkabau hinterland areas such as Sicincin, Padangpanjang, Pagaruyung, Salimpaung, Rao-Rao, Saruaso with international trade routes by sea with traders from Aceh, Gujarat (India) and the Portuguese in the Straits of Melaka (Dobbin, 2016). Meanwhile, Teluk Bayur, Indropuro, and Salido ports in the south are trading ports that have intense trade with Air Bangis, Sibolga in North Sumatra province, Singkil and Barus in Aceh province. This is the international trade route that has been going on around the XVII century with Portuguese, Indian and Arab traders, better known as the Silk Road. The involvement and hegemony of the West Coast Harbour area of West Sumatra; starting from the South, Port of Indrapuro, Salido, Teluk Bayur, Pariaman, Tiku, to the northernmost coastal area, namely Air Bangis in playing an important role in international trade routes in the West Coast Region of Sumatra, with Aceh, Gujarat, the Malacca Strait, and even up to Sunda Kelapa Harbour in Banten.

However, at this time, its role as a trade centre for the West Coast region has begun to diminish with the lack of integration of trade in the interior of West Sumatra with other regencies and cities, and the lack of integration of trade in West Sumatra with other cities and towns the economic corridor of Sumatra and ASEAN, so that the trade competitiveness of the main commodities of the province of West Sumatra is low and its economic value added is captured by external regions and neighbouring countries (Ansofino et al., 2019; Ansonfino et al., 2021). The factor causing the uncompetitive trade of the main commodities of the province of West Sumatra in the economic corridor area is due to the low added value of the commodities produced, so that this added value is captured by external trading partners in the trading system. Therefore, to increase regional and global economic competitiveness, it is necessary to encourage the development of economic agglomeration (Ansofino, 2021). Economic agglomeration is an economic activity carried out by several industrial companies or several regions located in the same location, so that they provide mutual benefits to each other due to decreased transportation and production costs, and costs for trade and export activities between regions (Bikker, 1987; Frenken et al., 2007; Porojan, 2001).

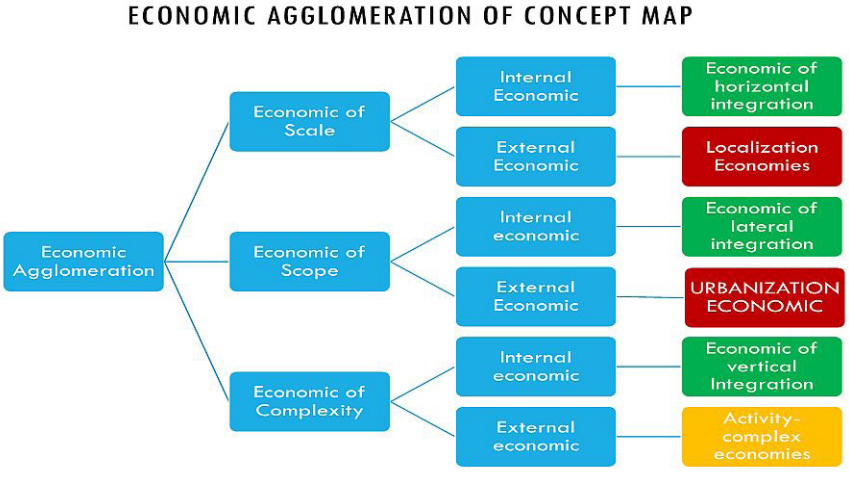
The integration of trade between the hinterland and the West coast of Sumatra as a gateway to the outside world, especially with other districts and cities along the West Coast of Sumatra, had been going on long before the arrival of the Dutch colonials (Dobbin, 1974; Kato, 1980). However, at this time, trade interactions with neighbouring areas in the West Coast Region of Sumatra, where there are 25 districts and cities among 155 districts and cities on the island of Sumatra, are still low.

This study wants to reveal how the patterns of trade integration and agglomeration between regencies and cities in the West Coast of Sumatra have been so far? What are the factors that determine the spatial agglomeration activities of leading commodity trade between regencies and cities in the West Coast Region of Sumatra? What are the leading commodities that are the mainstay in regional trade between regencies and cities in the West Coast Region of Sumatra? How is clustering formed based on the trade of the leading commodities of each district and city in the West Coast of Sumatra? How is the strength of clustering competitiveness based on the superior commodities

in the West coast of Sumatra, able to compete in international trade? how this competitiveness and cooperation can improve the economic competitiveness of the West Coast region of Sumatra. It is hoped that by analysing all the problems raised, using spatial analysis and using the economic agglomeration approach through analysis of spatial concentration and spatial distribution of trade integration activities in the West Coast of Sumatra, policy proposals can be formulated in increasing the competitiveness of the West Coast region's economy in the trade constellation. regional and global.

Economic activity at a certain location tends to lead to stability in an area where the spatial configuration of economic activity can be traced through the two forces that make it up, namely the agglomeration force (centripetal), and the dispersion force (centrifugal) (Fujita and Thisse, 1996; Guillain, 2010). These two forces are believed to accelerate the renewal of regional economic development, and the structural transformation of the regional economy (Parr et al., 2002). In relation to regional trade, the root for the occurrence of economic agglomeration is that it begins with trade integration, either horizontally, laterally or vertically (Porojan, 2001; Parr et al., 2002; Bergeijk and Brakman, 2010; Peng et al., 2006). Vertical integration refers to the dimensions of the operational size of a company or economic business, which reflects the internal economy of scale or increasing returns, or more generally the unit cost of output is decreasing function of scale. Lateral integration refers to the multi-product of a company or economic enterprise and its expansion depends on the internal economic scope. This refers to the fact that the production of two or more products, is produced at a lower total cost among individual firms, then that product diversity results from the sharing of inputs among firms. While Vertical integration is the involvement of a company in relation to other companies in various processes and stages of production, in this case internal economic of complexity is a force that directs a company to produce stages of production of a product or goods that are produced or traded, meaning that several stages of production are carried out by a separate company (specialized firm) (Parr et al., 2002).

The study of patterns of trade integration patterns both horizontally, laterally and vertically is based more on the economic approach of the business scale of one company or several companies. At the time of increasing economic scale of business (increasing return) and increasing multi-output by several companies (economic of scope) at one location or several locations, it has become a geographical economic study, because it is related to the spatial proximity of activities. particular economy, which is an important feature in the concept of economic agglomeration. An internal economic (economic of scale) and external economic (economic of scope), is only seen as an economic agglomeration if there are co-location and concentration of production constraints are met (Parr, 2002). In the Figure 1, the study of regional trade in the West Coast of Sumatra is traced from the window or economic agglomeration approach by referring to the theory of economic localization, economic urbanization, and economic




Source: inferred from J. Parr et al. (2002)

Figure 1: The Concept of Economic Agglomeration in the Case of Regional Trade in the West Coast of Sumatra.

complexity in the regional context of the Sumatran economic corridor area. Regional trade referred to in this study is trade in the main commodities traded between regencies and cities that have carried out regional trade with agricultural commodities such as rice, horticulture, capture fishery products, including processed fish products such as dried fish and so on, as well as forestry products such as rubber, palm oil, Gambhir and so on. The selection of this trading commodity begins with analysing trade commodities which are currently the mainstay of regional trade and have long roots since the pre-colonial and colonial times and until now.

## Materials and methods

In relation to mutual trade relations between different regions, it can be analysed through a gravity model approach. The amount of trade flow between districts and cities will be inversely proportional to the distance, the farther the distance, the lower the intensity of trade between regions, and vice versa, so that adjacent areas will group together in one trading activity.

The gravity model of the flow of trade between regions was first proposed by Tinbergen (1962) and Linnemann (1966) by determining the interaction of trade in goods and people or in the form of exports or imports between one region and another (Bikker, 1987; Porojan, 2001; Behar and Nelson, 2014). The gravity trade model has become increasingly popular since Krugman (1991) suggested that the problem of geographical proximity affects the flow of trade in goods and people within a region. Research on the gravity trade model has become increasingly popular among regional sciences since Anselin and Griffith (1988) included it as a very important location role model which has so far made standard econometric analysis techniques fail to overcome the autocorrelation problem, resulting in biased estimates, has been successfully overcome with the spatial auto regressive model and the spatial lag model (Anselin and Griffith, 1988; Cainelli et al., 2014; Griffith, Chun and Li, 2019b; Johansson and Quigley, 2003).

The initial contribution of the gravity model to the trade flow of two regions as suggested by Tinbergen (1962), Linnemann (1966), Bergeijk and Brakman (2010), the model itself can be applied to various phenomena, but the earliest application is to bilateral trade flows which take the form of the equation is as follows:

$$T_{ij} = \frac{GDP_i^{\alpha} GDP_j^{\beta}}{D_{ij}^{\theta}} \quad (1)$$

Where $T_{ij}$ shows bilateral trade between region $i$ and area $j$. The economic size index in region $i$, measured by $GDP_i$, $D_{ij}$ is a measure for the bilateral distance between the two regions $i$, and $j$, while the parameters, and I are estimated through linear logs through model estimation. So that equation (1) above is able to explain bilateral trade using economic measures and distance. Where the larger the size of the economy between trades, the greater the trade flow. On the other hand, the farther the distance between the two regions, the lower the bilateral trade.

The gravity trade model describes the flow of goods or people from region $i$ to region $j$, symbolized by ($F_{ij}$) as a function of the characteristics of the origin region (region $i$) by the symbol ($O_i$), the characteristics of the destination region symbolized by ($D_j$) and several measurements separation, in the symbol with ($S_{ij}$) (Porojan, 2001). The formula is as follows:

$$F_{ij} = g[O_i, D_j, S_{ij}] \quad (2)$$

This model was later developed by Zhang and Kristensen (1995), using the law of universal gravity, emphasizing that trade increases with increasing volume and the proximity of partner territories, so that the bilateral trade model takes the following form:

$$F_{ij} = X_{\beta} + \varepsilon, \qquad \varepsilon \sim N(0, \sigma^2) \quad (3)$$

$$F_{ij} = \rho W F_{ij} + X_{\beta} + \varepsilon \quad (4)$$

Where $X$ is a vector of explanatory variables which can be in the form of an estimate of the size of two regional economic conditions in the form of GDP, GDP per capita, Exports, Imports and the distance between the two regions; can be in the form of transportation costs, and other forms of trade disruption. This study uses a trade flow model between regencies and cities in the Sumatran economic corridor, especially exports and imports of marine products between 155 regencies and cities in the Sumatran economic corridor.

Furthermore, this study also looks at the influence of two types of spatial effects: spatial dependence and heterogeneity (Porojan, 2001; Anselin, 1988; Anselin and Rey, 2012; Anselin and Arribas, 2013). This exploration is problematic for regression models using the ordinary least square (OLS) method, which is related to heteroscedasticity

and spatial autocorrelation problems which can generally cause misspecifications in the model, due to the presence of spatial autocorrelation and heterogeneity in the residuals from OLS estimates. Therefore, facing spatial autocorrelation and spatial dependence, (Griffith et al, 2019a; Kelejian and Piras, 2017), the spatial econometric model can overcome this by adding a weight contiguity matrix to the error term multilateral trade flow equation in equation (4) above, so that it becomes as follows:

$$\varepsilon = \lambda W_{\varepsilon} + \mu, \qquad \mu \sim (0, \sigma_{\mu}^{2} I) \tag{5}$$

$$ln\left(T_{ij}/Y_i E_j\right) = (1 - \sigma)t_{ij} + \alpha_1^i D^i + \alpha_2^j D^j + \\ + 1\text{-}\lambda W)^{-1}\alpha_3 \varepsilon_{ij} \tag{6}$$

where the null hypothesis is = 0, if the parameter is statistically different from zero, it will have the implication that the size of the trade flow of a region will affect the size of the trade flow of its neighbouring region, only if the trade flow of the neighbouring region is above the normal average. So it is clear that, is the coefficient of autoregressive error term, when $W$, represents a weighting matrix, which measures the degree of potential interaction between neighbouring regions (Pons and Marsal, 1999; Anselin et al., 1996). Matrix $W$, can be estimated in various ways (see Anselin, 1988; Bolduc, et al., 1992). This study uses a more popular formulation, namely the Moran index, which is a matrix that measures spatial dependence between regions that are geographically close. Moran's index value is positive and significant, positive spatial autocorrelation which indicates that the area interacts spatially.

$$I_n = \frac{\sum_{i=1}^{m}\sum_{j=1}^{m} w_{ij}(x_i - \bar{\mu}_x)(x_j - \bar{\mu}_x)}{\sum_{i=1}^{m}(x_i - \bar{\mu}_x)^2}$$

$W_{ij}^{*} = \left(W_{ij}/\sum_j W_{ij}\right)$ where $W_{ij} = 1$ for countiguous countries,0,otherwise (7)

The data used by this study for the contiguous matrix ($W_{ij}$) is data on trade in marine products in the economic corridor of Sumatra. Therefore, this study uses several measurements of spatial autocorrelation by comparing two types of information, namely: the similarity between the attributes, and the similarity between the locations. This spatial effect occurs, if a number of neighbouring units from the trading area in the Sumatra economic corridor affect each other directly, or the trade flow value of a region is determined by several other variables which are spatially correlated (Granovetter, 1973).

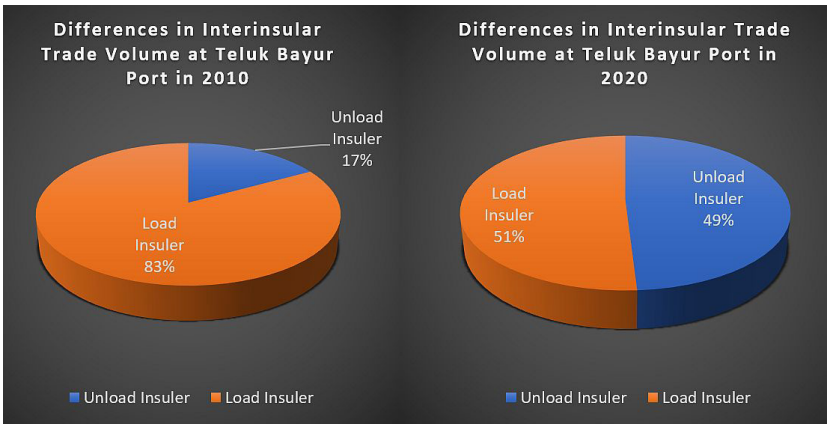
Furthermore, to measure the accuracy of the spatial model, both SLM and SEM, four indicators are used that can be considered when the ML approach is used, the four indicators are: (1). Pseudo $R^2$, (2) maximum likelihood (LIK), (3) Akaike information criterion (AIC) and Schwartz Criterion (SC). A good model (goodness of fit) is fulfilled if the Pseudo $R^2$ value, the LIK value is higher, while for AIC and SC, which have small values for a better model (Anselin, 2019; Putra, et al., 2020).

## Result and discussion

### Overview of Inter-Regional Trade in the West Coast of the Island Sumatra

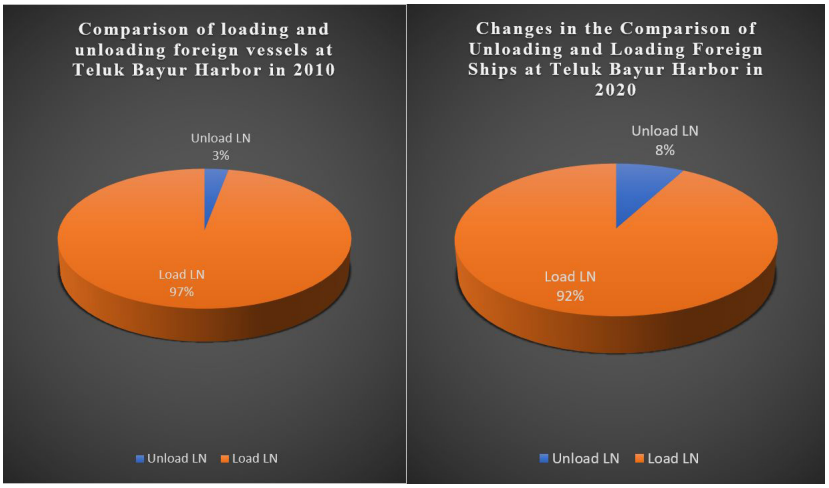
Trade between regions on the West Coast of Sumatra has long been going on, especially Teluk Bayur Port with ports along the West Coast of Sumatra, areas along the East Coast of Sumatra, even to the North Coast of Java. The main commodities that are the mainstay for this trade are rice, spices, rattan, dried fish and vegetables. Activities of Teluk Bayur Port as an important port on the West Coast of Sumatra, in the last ten years, loading and unloading activities at this port have shown an increasing trend, the activity of Teluk Bayur Port is more dominated by activities of loading goods on ships to be carried and traded at a number of ports. important on the East Coast of Sumatra and Java.

In 2010 until now, the busyness of Teluk Bayur Port has been dominated by loading and unloading activities for inter-insular vessels with a loading volume much larger than the loading and unloading activities. This means that the volume of goods transported outside the region (exports) is much greater than the volume of goods unloaded (imports), as shown in Figure 2 below, so that trade between regions has so far been a surplus. This indicates that the flow of trade between regions on the West Coast of Sumatra with other regions, namely the East Coast of Sumatra and the North Coast of Java is quite large and the trend is increasing from time to time. However, the trend of the volume of goods loaded (exported) during the last ten years has decreased. This means that the volume of trade in goods for the province of West Sumatra for inter-regional export activities tends to decrease and become increasingly in deficit after the COVID-19 pandemic, due to restrictions




Source: own calculation based on data the West Sumatra statistical centre bureau, 2022

Figure 2: Comparison of the volume of loading and unloading of inter-insular trade at Teluk Bayur Port during 2010 and 2020.




Source: own calculation based on data the West Sumatra statistical centre bureau, 2022

Figure 3: Comparison of the volume of loading and unloading of foreign vessels at Teluk Bayur Port during 2010 and 2020.

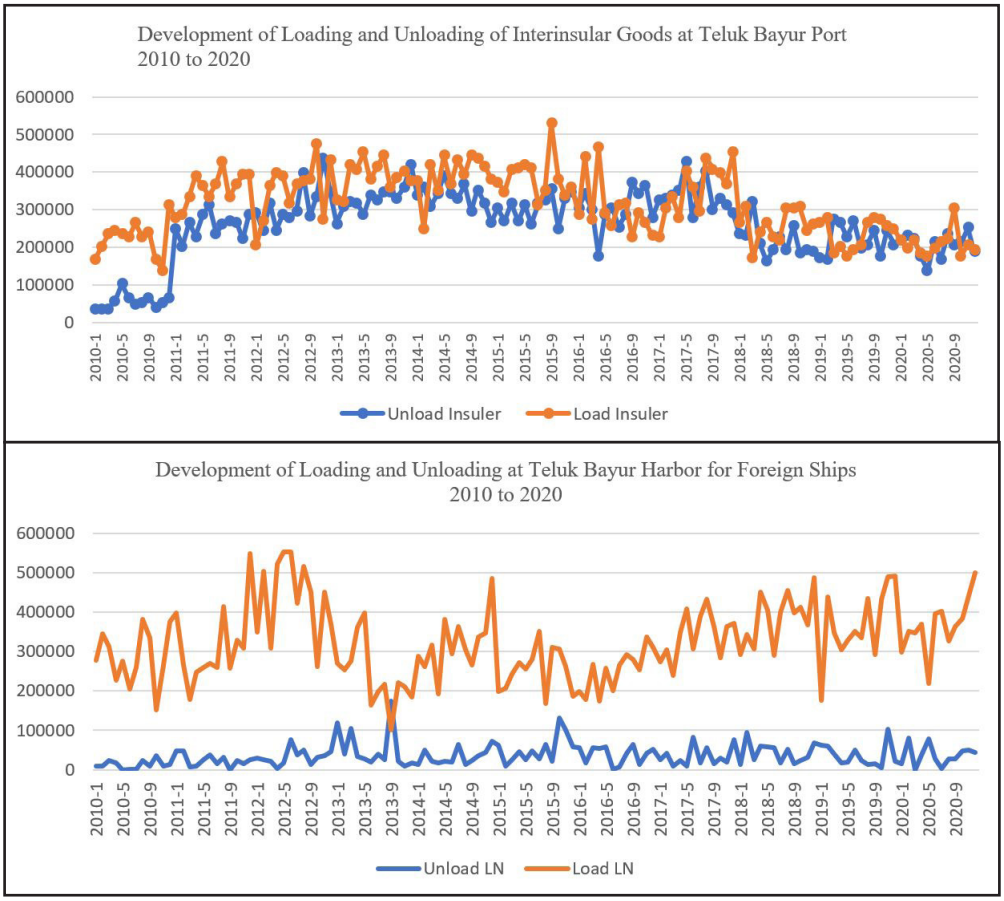
on large-scale community activities.

On the other hand, if we look at the developments over the last ten years, it turns out that the volume of cargo loading on inter insular vessels has changed drastically, as seen from the 2010 volume of goods loading on inter insular vessels, which decreased by 83% to 51% in 2020. This is presumably due to because of the lack of integration of inter-regional trade between the West Sumatra region and its neighbouring regions. Plus the impact of the implementation of large-scale social restrictions during the current COVID-19 pandemic.

In Figure 3 above it can also be seen that the loading and unloading activities of foreign ships at Teluk Bayur Port, actually looks less shaky, because the decrease in the percentage of shiploads on ships to overseas is not so significant the difference in the decrease, namely from 97% in 2010 it fell to 92% in 2020. Likewise for unloading activities, in 2010 by 3%, it will increase to 8% in 2020.

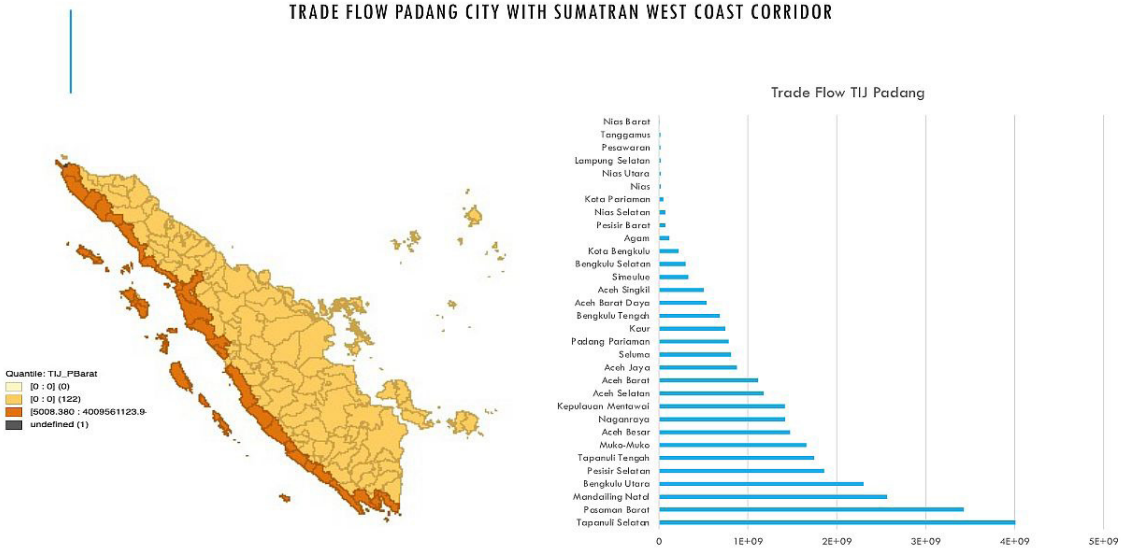
In Figure 4 below, it can be seen that there is a downward trend of loading and unloading of goods on inter-insular vessels at Teluk Bayur Harbour for the last ten years. On the other hand, unloading activities from inter insular vessels have shown an increasing trend over the last ten years. This means that the import or entry of goods from various ports in the archipelago has an increasing trend over the last ten years.

The flow of trade between the city of Padang and the area along the west coast of Sumatra with 33 regencies and cities along the west coast is dominated by the districts of South Tapanuli, West Pasaman, Mandailing Natal, to Aceh Besar and Nagan Raya (Figure 5). The city of Padang has Teluk Bayur Harbour, which has been built since




Source: own calculation based on data the West Sumatra statistical centre bureau, 2022

Figure 4: Trend of trading activities at Teluk Bayur Port for the last ten years.




Source: own calculations based on data from the Central Bureau of Statistics for each province on the island of Sumatra, 2022

Figure 5: Padang City trade flow hierarchy with regencies and cities along the West Coast of Sumatra.

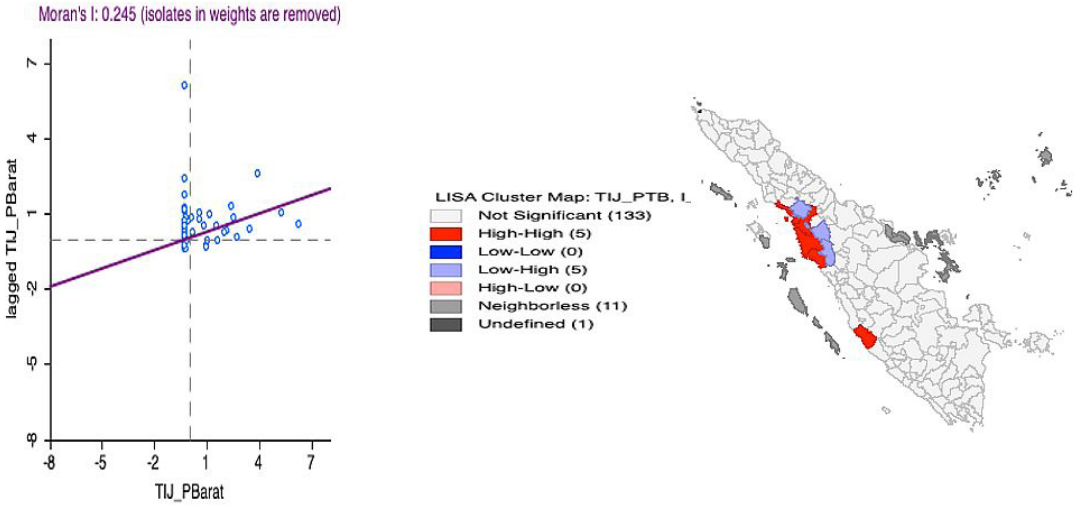
the Dutch colonial era, namely in 1893 under the name Emma haven. The main commodities transported at this port for loading and unloading activities are coal, cement, clinker, palm oil, cinnamon, tea, moulding, furniture and rubber, all of which are leading export commodities to the Americas, Europe, Asia, Australia and Africa.

Teluk Bayur Port is included in the working area of PT Pelindo II along with twelve other sea ports on the North Coast of Java Island and West Kalimantan. The interaction of this port with ports along the West Coast and East Coast of Sumatra is mainly with Sibolga Port, in Sibolga City, Panjang Port in Lampung, and Tanjung Periok Port in Jakarta. The West Coast of northern Sumatra is under PT Pelindo 1, which consists of sixteen main ports, especially the Malahayati Port, in Aceh Besar, Lhokseumawe Port, Lhokseumawe City, Gunung Sitoli Port, and Sibolga Port.

The flow of trade from Padang City, especially the flow of goods to the West Coast Region, turned out to be a spatial variable, as indicated by the statistical Moran Index value of 0.245, which is much larger than the standard size of 0.02, which indicates that an increase in the flow of trade in Padang City will have an impact in the surrounding area. The trade flow of the city of Padang has an effect on the surrounding area, especially the agglomeration effect. This reinforces the view of Parr and Hewing (2002) that economic agglomeration occurs because of the integration and externalities of economic activities in an area, so that districts and cities that form agglomerations with the Port of Padang City are areas that have a relationship with the flow of trade in agricultural products and processed agricultural goods. such as Mandailing Natal, South Tapanuli, Central Tapanuli and Muko-muko Regencies, as shown in Figure 6.

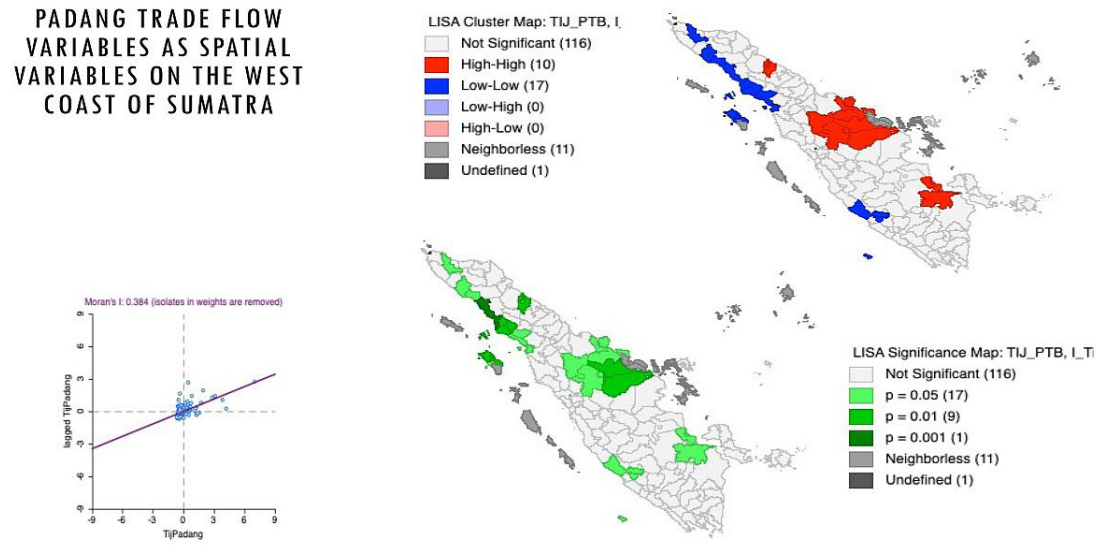
The local indicator spatial association map (LISA) in Figure 7 shows that there are 5 regencies and cities that have agglomeration links with Padang City in the HH category, namely West Pasaman, Mandailing Natal, South Tapanuli, Central Tapanuli, and regional Muko-Muko. There are 3 regencies that have environmental linkages, namely: Pasaman, Padang Lawas, and North Tapanuli. Apart from that, there are 11 areas on the West Coast of Sumatra which have absolutely nothing to do with Padang (less neighbours). This is in line with the study by (Guillain and le Gallo, 2010) which identified agglomeration patterns of economic activity around the City of Paris, areas that have a Lisa index in the HH and HL categories are clusters of economic activity.

Based on this LISA analysis, it can be stated that the Trade flow City of Padang is less related to the districts and cities on the West Coast, which amount to 33 districts and cities, the LISA indicator shows that the spatial dependencies between the districts of this city in regional trade are less related to each other. However, the results of the LISA trade flow analysis of Padang City with the Sumatra Economic Corridor area, there are 10 categories of HH, and 17 categories of LL. That is, the flow of trade in the city of Padang in the Sumatran economic corridor, not only




Source: own calculation based on data Trade Flow of Padang city

Figure 6: Matrix I Moran and Lisa Cluster Map West Coast of Sumatra.




Source: own calculation based on data from Padang trade flow variabel as spatial variable

Figure 7: Matrix I Moran and LISA Cluster trade flow of Padang City with Sumatra economic corridor Area.

with the West Coast area of the Sumatran economic corridor, but more dominantly with the Sumatran Economic Corridor, on the East Coast of Sumatra.

The spatial relationship of the Padang City trade flow is much greater with the East Coast Region of the Sumatran economic corridor area compared to the West Coast of Sumatra, this is indicated by the much higher Moran Index value of 0.384 which has a very significant spatial impact and the development of economic agglomeration between the regions. The city of Padang which has the Teluk Bayur Inter insular Port has a spatial concentration and spatial distribution with the surrounding area, the spatial concentration with the districts and cities along the West Coast is less concentrated and less related to the districts along the districts and cities on the West Coast of Sumatra, compared to the districts and cities along the East Coast of Sumatra.

Figure 7 above shows that the concentration and spatial linkages of the City of Padang as a trading centre in the Sumatra region on the West Coast are much higher with the regencies and cities in the economic corridors of Sumatra on the east coast compared to the spatial relationships with regencies and cities along the west coast of Sumatra. Therefore, to increase economic agglomeration in the West Coast region, the flow of trade between regencies and cities in the West Coast region must be intensified by developing its economic agglomeration, through strengthening and tightening trade in regional superior commodities between regencies and cities in the West Coast region of Sumatra. This is in line with the findings and recommendations of (Cainelli et al., 2014) who studied spatial agglomeration in Italy, where spatial agglomeration can be carried out through strengthening the specialization of local production systems while maintaining their respective comparative advantages.

### Factors affecting Teluk Bayur Port trade flow with West Coast Region

The improvement of inter-economic linkages and integration between districts and cities in the West Coast of Sumatra trade area that needs to be done will of course be caused by a number of factors that condition it, as indicated in Tinbergen (1966), Zang and Kirstensen (1985) and Porojan (2001) namely GRDP, the distance between regions, the volume of trade, and other economic characteristics of the region.

The trade flow model for the West Coast Region can be analysed using the spatial regression method, because this model has a Moran Index value of 0.1594 which is much greater than 0.02, so this model can be estimated using the spatial regression method. The variables used in the estimation have a spatial value. So that applies Tobler's law (1977), adjacent areas will have a greater advantage, when compared to areas that are far apart. Supposedly, districts and cities located on the West coast of Sumatra, interact more and integrate with each other, but the City of Padang actually integrates and has greater connectivity with districts and cities located on the East coast of Sumatra. It is

certainly interesting to explore the factors causing it. Moreover, since the colonial period, the trade relations and interaction of this region in producing trading commodities, especially spices and marine products, have become the prima donna in regional trade.

The results of the analysis using regression using the OLS method indicate that the factors that affect the trade flow of Padang City with the surrounding area are the economic growth of the districts and cities in the West Coast Region of Sumatra with a coefficient value of 6.3985, significant at the 10% level. This model has a Moran Index value of 0.1594, the probability is significant. The LM Lag and LM error values also have a significant probability, so this model is better analysed using the spatial regression method using the spatial lag and spatial error methods.

Spatial regression analysis provides the advantage of being able to analyse the occurrence of autocorrelation and heteroscedasticity in the OLS model, as indicated by Anselin et al. (1988), by using spatial data, so that the occurrence of spatial autocorrelation provides our understanding, that there is an interaction between the sample data or the area that becomes the unit of analysis that has been carried out. So with data on trade flows between districts and cities in the West Coast Region of Sumatra, it can be determined patterns of concentration and distribution of trade flows between Padang City; which has Teluk Bayur Port, as a port that carries out loading and unloading of goods to the archipelago, called inter insular ships and ships that carry and carry goods abroad.

The flow of trade between the City of Padang with the regencies and cities along the West Coast of Sumatra is the first model to be modelled with a weighting matrix for the volume of goods transported through Teluk Bayur Port, Padang City to sea ports along the West coast such as Sibolga Port, Lhokseumawe, and Gunung Sitoli Harbour, Panjang Harbour. While in model 2, the spatial interaction between the trade flow of Padang City and its Teluk Bayur Harbour with regencies and cities in the Sumatran economic corridor area. The results can be seen in Table 2 below.

In the Table 2, in both models, the weighting matrix variable for the Padang City trade flow with the districts and cities in the West Coast

| Trade flow model of Padang City with West Coast Region | | | | |
|---|---|---|---|---|
| Variable | Coefficient | Standar Erorr | T Statistic | Probability |
| Constant | 44.93 | 18.982 | 2.3667 | 0.0193 |
| Trade | -3.3714 | 1.65167 | -0.2041 | 0.8386 |
| Induso | -5.8485 | 2.70964 | -0.02158 | 0.9828 |
| Agris | 6.7055 | 4.0571 | 1.6527 | 0.10059 |
| PDRB_HB | 4.3724 | 1.7648 | 0.2477 | 0.8046 |
| Aksess | 0.1080 | 0.1375 | 0.7855 | 0.4335 |
| Expen_Tot | 1.2137 | 1.01907 | 0.1191 | 0.9054 |
| Export | -1.1046 | 1.8765 | -0.5886 | 0.5570 |
| ECGrowth | 6.3985 | 3.3909 | 1.8869 | 0.0612 |
| Tij_PBarat | 3.3298 | 6.1033 | 0.5455 | 0.58621 |
| | | | | |
| Moran I | 0.1594 (0.00285) | | | |
| LM Lag | (0.01800) | | | |
| Robust LM | (0.89021) | | | |
| LM Error | (0.00753) | | | |
| Robust LM Error | (0.21092) | | | |
| LM (Sarma) | (0.02785) | | | |
| Breusch-Pagan Test | 7.2910 (0.60685) | | | |
| $R^2$ | 0.06696 | | | |

Source: own calculation, 2022

Table 1: Regression results with OLS model.

| The trade flow model of Padang City with the West Coast Region | | | | | Trade flow model of Padang City with Sumatra Economic Corridor | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Coefficient | Std Error | Z Value | Probability | Coefficient | Std Error | Z Value | Probability |
| W_TijPdg | 0.1956 | 0.0896 | 2.1823 | 0.02908 | 0.1945 | 0.0897 | 2.1671 | 0.0302 |
| Constant | 42.005 | 18.6737 | 2.2494 | 0.02448 | 43.2239 | 18.6115 | 2.3224 | 0.0202 |
| Trade | 8.4992 | 1.5694 | 0.5416 | 0.58812 | 8.5208 | 1.5711 | 0.5423 | 0.5875 |
| Induso | -1.8164 | 2.5714 | -0.7063 | 0.4799 | -1.8373 | 2.5741 | -0.7137 | 0.4754 |
| Agris | 7.5304 | 3.8450 | 1.9585 | 0.05017 | 7.4603 | 3.8483 | 1.9386 | 0.0525 |
| PDRB_HB | 1.1378 | 1.6707 | 0.6811 | 0.4958 | 1.1473 | 1.6727 | 0.6858 | 0.4927 |
| Aksess | 0.0776 | 0.1303 | 0.5954 | 0.5515 | 0.0696 | 0.1298 | 0.5362 | 0.5918 |
| Expen_Tot | -4.8521 | 9.6467 | -0.0502 | 0.9599 | -1.2185 | 9.5841 | -0.1271 | 0.8988 |
| Export | -5.9751 | 1.8026 | -0.3314 | 0.7403 | -6.1352 | 1.8051 | -0.3398 | 0.7339 |
| ECGrowth | 4.1149 | 3.2237 | 1.2765 | 0.2018 | 4.1963 | 3.2249 | 1.3012 | 0.1932 |
| Tij_PBarat | 3.5735 | 5.7769 | 0.6186 | 0.5362 | - | | | |
| Spatial Lag Dependence | 4.9956 (0.0254) | | | | | | | |
| Breusch-Pagan Test | 7.4918 (0.5861) | | | | | | | |
| $R^2$ | 0.1052 | | | | 0.1029 | | | |

Note: Dependent variable trade flow of Padang
Source: own calculation, 2022

Table 2: Spatial regression results factors affecting the trade flow of Padang City with neighbouring areas.

Region has a coefficient value of 0.1956, with a Z value of 2.1823, this is significant because the probability value is small from the error generated tolerable 5%. Likewise in model 2, the coefficient value is 0.145 with a Z value of 2.1671 which is also significant. This means that the variable that is weighted for this spatial regression model has an impact that is spatial dependence.

In the model using the OLS method in the Table 1, the factors that influence changes in the trade flow variable of Padang City to the districts and cities along the West Coast are economic growth with a coefficient value of 6.3985 and a t-count value of 1.8869 and a probability of 0.0612, significant at 10%. If the economic growth of regencies and cities along the west coast of Sumatra increases by 1%, it will have an impact on increasing the trade flow of Padang City with this regency and city area of 6.3985 tons.

The West Coast trade flow variable does not significantly affect the existence of Padang City as the centre of economic agglomeration in the Sumatran economic corridor area. This means that the flow of trade in Padang City has not been able to encourage the occurrence of economic agglomeration in the districts and cities in the West coast of Sumatra, on the contrary, connectivity occurs with districts and cities in the East Coast Region of Sumatra's economic corridor.

Therefore, to accelerate the process of economic agglomeration through trade flows, joint policies are needed with the agricultural sector in the economic corridor of Sumatra in facing global market competition, as well as strengthening the internal market among regions in the corridor of Sumatra, such as agricultural integration in European countries in facing current global trends (Svatoš, 2008; Svatoš et al., 2018). This is also in line with the trade transactions of agricultural commodities between districts and cities in the Sumatran economic corridor that must be strengthened (Ansofino, 2021), so that they are able to compete in the competitive global market, including transactions between existing economic sectors, such as agricultural products used to support culinary tourism.

The processing industry and wholesale trade have not been able to create connectivity and the formation of economic agglomeration between regencies and cities in the West coast of Sumatra, this is apparently due to the fact that industrial products, especially from the agricultural sector, are still limited to plantation agricultural products, while processed products are sub-sectors fisheries and food crops have not been able to penetrate the markets of neighbouring areas along the west coast, because goods transported

through Teluk Bayur Port as a trading node for goods are dominated by cement, clinker and palm oil products. Meanwhile, the volume of processed food crops and processed marine products is still small.

However, agriculture broadly is able to encourage connectivity and agglomeration between districts and cities along the West coast of Sumatra, especially perennial plantation products such as oil palm and rubber, as well as horticultural agricultural products such as mangosteen, durian and others. Trade products originating from food crops such as rice, rice flour, corn, which have always been the mainstay of the commodity from the West Sumatra region, are no longer able to trigger trade interactions with areas along the West Coast.

## Conclusion

Based on the problems and discussions that have been carried out previously, some conclusions can be drawn as follows:

1. Patterns of trade integration and agglomeration between regencies and cities in the West Coast of Sumatra in inter-regional trade activities have decreased drastically over the last ten years. This can be seen from the decrease in the volume of loading and unloading of goods at Teluk Bayur Port from inter-insular vessels, from 83% in 2010 to 51% in 2020. This is due to the lack of integration of inter-regional trade between the West Sumatra region and its neighbouring regions. Plus the impact of the implementation of large-scale social restrictions during the current COVID-19 pandemic.
2. The economic agglomeration formed between regencies and cities along the West coast is weaker than the regencies and cities on the East coast, because trade flows come from commodities from old plantation crops such as oil palm and rubber, where the processing industry is centred in the area. the east coast of Sumatra such as the ports of North Sumatra, Riau and Riau Islands, as well as ports in South Sumatra and Jambi. Meanwhile, trade commodities with regencies and cities along the West Coast are more dominant in processed products from the agricultural sector in a broad sense.
3. The activity of exporting goods (ships loading) between regions has decreased during the last ten years, while import activities (ships unloading) over the past ten years have shown an increasing trend. So that the trade balance of the West Sumatra region becomes a deficit.
4. The flow of trade between the city of Padang and the area along the west coast of Sumatra with 33 regencies and cities along the west coast is dominated by the districts of South Tapanuli, West Pasaman, Mandailing Natal, to Aceh Besar and Nagan Raya. especially Malahayati Port, in Aceh Besar, Lhokseumawe Port, in Lhokseumawe City, Gunung Sitoli Port, and Sibolga Port.
5. The flow of trade from the city of Padang to the West Coast Region is a spatial variable, as indicated by its statistically significant Moran Index value of 0.245, but this is smaller than the same Moran index value in the East coast of Sumatra. So that the spatial relationship between the trade flow of the city of Padang and the East Coast is greater than that of the districts and cities on the West coast. This is reinforced by the LISA analysis which shows that the relationship between the flow of trade in Padang City and the districts and cities on the West Coast in the HH category is 5, and HL is 5. 17 and all are significant at the 5% level.
6. Factors that influence changes in the trade flow variable of Padang City to the districts and cities along the West Coast are economic growth with a coefficient value of 6.3985 and a t-count value of 1.8869 and a probability of 0.0612, significant at 10% .
7. The competitiveness of the processing industry and wholesale trade has not been able to create connectivity and the formation of economic agglomeration between regencies and cities in the West coast of Sumatra, this is apparently due to the fact that processing industry products, especially agricultural sector products, are still limited to plantation agricultural products, while processed products of the fishery and food crops sub-sector have not been able to penetrate the neighbouring markets along the west coast, because the goods transported through Teluk Bayur Port as the goods trading node are dominated by cement, clinker and palm oil products.

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Agris on-line Papers in Economics and Informatics

Volume XV Number 2, 2023

# An Analysis of the Gross Domestic Product of Municipalities: a Spatial Glance into the State of Paraná-Brazil

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## Abstract

The vast relevance of applications of spatial regression models has recently captured the interest of Economics and Agriculture, in the sense of better understanding the spatial behavior of the region under study, in the different forms of approaches. It is interesting to understand why some regions show greater variability than others, and why some forms of regional development are better explained. It is up to the researcher to understand, explore, and organize a series of observations, so that it is possible to make predictions, diagnoses, and recommendations to public policy managers and regional development agents. The municipalities' Gross Domestic Product (Gdp) has driven studies involving spatial information. The objective of this study was to analyze the Gdp of the municipalities in Paraná-Brazil, in 2018, regarding soybean yield, corn yield, pig production, and the tax on the circulation of goods, through different approaches of spatial regression models. SAR and CAR models are global models, while the GWR model is considered a local one. Three spatial analysis models were used to perform this study: Spatial Autoregressive (SAR), Conditional Autoregressive (CAR), and Geographically Weighted Regression (GWR). The results were compared using the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Cross-Validation Criterion (CVC), and the descriptive graphic of residual diagnoses-Worm Plot. The best result obtained was for the GWR model, which best explained the GDP of the state of Paraná-Brazil in terms of its covariates.

## Keywords

Agribusiness, economic scenario, production chains, development, spatial regression models.

Cima, E. G., da Rocha-Junior, W. F., Uribe-Opazo, M. A. and Dalposso, G. H. (2023) "An Analysis of the Gross Domestic Product of Municipalities: A Spatial Glance into the State of Paraná-Brazil", *AGRIS on-line Papers in Economics and Informatics*, Vol. 15, No. 2, pp. 19-29. ISSN 1804-1930. DOI 10.7160/aol.2023.150202.

This work's innovative and relevant approach is in using original georeferenced spatial data, considering economy and agriculture. The present work is justified by analyzing whether the impacts of soybean yield, corn yield, pig production, and the tax on the circulation of goods influence the Gross Domestic Product (GDP) of the municipalities. Previous works have proven such an influence and responded differently to this question. Therefore, the study intended to present and demonstrate the impact of economic growth interpreted as soybean yield, corn yield, pig production, and the tax on the circulation of goods in the GDP. The motivation for this approach is given by the fact that the agro-industrial growth in Paraná-Brazil is not just another means of generating wealth, but rather a vigorous activity that promotes values, citizenship, and economic sustainability, generating and promoting benefits in the different economic, social, and environmental areas, in society as a whole. The sector is present in all areas, whether innovative to improve its activity, or in the positive impact of innovation on the return of productive and economic gains, on constant improvement of this activity so necessary for the growth and development of the municipalities that make up the state of Paraná-Brazil.

Banacu et al. (2019) analyzed business economic management with emphasis on urban waste control management and its relationship with the GDP, through a linear regression model, in the European Union (EU). The authors concluded that public

policies need to be focused on increasing the use of public and private investment in environmental control programs.

Fan and Hao (2020) analyzed, using regression models, economic growth, the environmental issue and its relationship with the GDP in China in the period 2000-2015. They concluded that there is a balanced relationship between that country's GDP and economic growth.

In studies developed by Banerjee et al. (2021) on the relationship between GDP and economic sustainability in Colombia, 2021, through Integrated Environmental Economic Modeling (IEEM), the influence of GDP was verified.

Matese et al. (2019) report that the approach to spatial data that takes into account the spatial structure is a robust and powerful technique in agricultural and economic data analysis as it constitutes a valuable element in decision-making.

Kánská et al. (2021) investigated the spatial analysis of data on agricultural properties through digital technologies and found that their use promotes the competitiveness of rural properties, thus favoring their growth and economic development. The agribusiness scenario shows that the increase in food productivity is directly bound to the development of agro-industrial production chains and the use of precision agriculture techniques – in agreement with Cima et al. (2021a).

Čechura et al. (2021) evaluated agricultural productivity in the Theca Republic by considering spatial analysis. The results showed that agricultural productivity follows technological progress and that productivity dynamics promote economic competitiveness.

The economic scenario found in Paraná has been presenting in the current decades trends of advancement and growth favored by the use of digital technologies that make the spatial analysis of geographic data possible, as is the case with regional development and precision agriculture, which promotes economic and strategic competitiveness to boost the economy, aiming to increase its participation in the internal and external market, with exports of agricultural and livestock products (Gaffuri and Alves, 2022).

In the agricultural field, analysis involving spatial data and their interactions can be used in several activities. On a regional scale, they can be used to represent production areas and agricultural enterprises in the same place over time (Macário et al., 2020). The use of geotechnologies in agribusiness is of great relevance for studies involving geographic space, allowing efficient diagnoses in large databases of information, and creating favorable conditions for analysis, given the accelerated changes that humanity has been experiencing (Cardoso et al., 2020).

The growing offer of agricultural production observed in Paraná-Brazil has presented interests and motivation for a better understanding of its variability concerning the Gross Domestic Product of the municipalities (GDP), which represents an estimate of the generation of goods produced in a state or country. Recently, the agricultural sector has grown at expressive annual rates (IBGE, 2021a). The reported locational indicators of economic growth lack clarity about the information they seek to explain (Ferrera de Lima, 2020). A key aspect that is important to know regarding spatial interaction is the relationship between its intensity with the distance among observations (Seibert and Silva, 2021).

In the Spatial Autoregressive (SAR) model (*Spatial Lag Model*), it is possible to capture the spatial correlation structure in a single parameter added to the regression model. It is assigned to spatial autocorrelation to a response variable (Y). Grifn and Lowenberg DeBoer (2019) analyzed agricultural data through spatial regression, including the SAR method, and concluded that spatial statistical methods can provide efficient estimates in the analysis and decision-making of rural producers.

For the Conditional Autoregressive (CAR) model, the spatial autocorrelation is attributed to the model's error term (Marconato et al., 2020). The behavior of different spatial patterns plays an important role in agricultural productivity. Hoef et al. (2018) report that the SAR (*Spatial Lag Model*) and the CAR (*Spatial Error Model*) were developed to model spatially autocorrelated data considering their neighboring regions.

In the model with local spatial effect represented by Geographically Weighted Regression (GWR), the interest is to regionalize the study area by obtaining subregions with their own pattern (Fotheringham et al., 2002; Fotheringham et al., 2017; Li et al., 2020; Bergs, 2021; Kedron et al., 2021). Wei et al. (2022) found that the GWR was advantageous and effective when analyzing climatic conditions in regions of China from 2001 to 2019.

In this context, the agro-industrial sector deserves to be better evaluated as it represents a major factor in local, regional, and national development.

Paraná-Brazil is considered promising in agricultural production, and incentives to the agro-industrial system must be provided by mechanisms that aim to optimize productive resources, which corroborates IBGE's (2021b) results.

Thus, as a contribution to the field of agricultural and socioeconomic research in Paraná and Brazil, the proposal of this study was to analyze the results obtained through different analyzes of spatial regression models (SAR, CAR, and GWR), which meet with the already documented literature, in which several studies focusing on the spatial econometric data are observed (Wang et al., 2019; Pimenta et al., 2021).

The objective of this paper was to show a spatial regression study from an original georeferenced database of the Gross Domestic Product (GDP) of the municipalities, obtained from the Paraná Institute for Economic and Social Development (IPARDES) [R$], based on the soybean yield (*Rendsoy*) [kg/ha], maize yield (*Rendcorn*) [kg/ha], pig production (*Prodpig*) [quantity/head], and the tax on the circulation of goods (*Gct*) [R$], covering the period from January to December 2018, in the 399 municipalities that make up the state of Paraná-Brazil.

## Material and methods

The selection of the explanatory variables (soybean yield, corn yield, pig production, and the tax on the circulation of goods) was because they are highly relevant economic indicators for the economic and agro-industrial growth of Paraná-Brazil, since the profile of these variables refer to possible associations with the GDP, which represents a measure that indicates the sum of all final goods and services produced by a municipality, state, or country in a given year.

The global spatial correlation analysis of the Spatial Lag Model (SAR) was performed, allowing to capture the spatial correlation structure in a single parameter added to the spatial regression model. In that model, spatial autocorrelation is attributed to the response variable $y$. The SAR model hypothesizes that the variable $y_i$ is affected by the values of the response variable in neighboring areas $A_i$ (Equation 1).

$$y = \rho Wy + X\beta + \mathcal{E}, \quad (1)$$

where,

$\rho$ = the autoregressive spatial coefficient. It is a measure of spatial correlation;

$W$ = the spatial proximity matrix;

$\mathcal{E}$ = the random error vector;

$\rho Wy$ = the spatial dependence (Baller et al., 2001).

Being a matrix of spatial weights standardized by line $W$ (that is, the weights are standardized so that $W_{ij} = 1$ for all $i$), this amounts to including the average of the neighbors as an additional variable into the regression specification. This variable, $Wy$, is referred to as a spatially lagged dependent variable.

Baller et al. (2001) state that another form of spatial dependence occurs when the dependence works through the error process, in that the errors from different areas may display spatial covariance called Conditional Autoregressive Model (CAR), which is a first-order spatial autoregressive process. The model hypothesizes that the observations are interdependent and spatially correlated, in which the spatial effects are a noise since it is not possible to model all the characteristics of a geographic unit that can influence the neighboring regions (Equation 2).

$$y = X\beta + \mathcal{E},$$
$$\mathcal{E} = \lambda W\mathcal{E} + \xi, \quad (2)$$

where,

$W\mathcal{E}$ = the error with spatial effect;

$\lambda$ = the autoregressive parameter;

$\xi$ = the error parameter with constant variance.

Lesage (2015) asserts that the CAR may be seen as a combination of a standard regression model with a spatial autoregressive model in the error term $\mathcal{E}$, and hence has an expectation equal to that of the standard regression model. In large samples, point evaluation for the $\beta$ parameters of the CAR model and conventional regression will be the same, but in small samples there may be an efficiency gain when modeling the spatial dependence in terms of error. In the Geographically Weighted Regression model, the interest is to regionalize the study area by obtaining sub-regions with their own pattern. The model adjusts a regression line for each sub-region, so this method adjusts a regression model to each point observed, weighting all other observations based on the distance to this point (Fotheringhan et al., 2002). In the GWR method, the weighting function is considered constant throughout the study area and it is used to describe a family of regression models in which the parameters $\beta's$ can vary spatially (Equation 3).

$$Y(S) = \beta_0(S) + \beta_1(S)x_1 + \beta_2(S)x_2 \ldots + \beta_p(S)x_p + \mathcal{E}(S), \quad (3)$$

Where,

$Y(S)$ = variable that represents the process at the point S;

$\beta(S)$ = parameters to be estimated at the point S for each observation $i$ of location $g_i = (u_i, v_i)$;

$\mathcal{E}(S)$ random error vector nx1, with zero mean and uncorrelated constant variance (Fotheringhan et al., 2002).

The study area comprises the municipalities in the Paraná (399 municipalities). The data were obtained from the Paraná Institute of Economic and Social Development (IPARDES) from January to December 2018. SAR (4), CAR (5), and GWR (6) spatial regression models were used to verify which model best adjusted the Gross Domestic Product (*Gdp*) of the municipality based on the soybean yield (*RendSoy*), corn yield (*Rendcorn*), pig production (*Prodpig*), and the tax on the circulation of goods (*Gct*) (Ipardes, 2021). The parameters of the models were estimated using the maximum likelihood-ML method, presented in equations (4) (5) and (6), respectively:

$$\hat{G}_{dp} = \widehat{\beta_0} + \hat{\beta}_l Rendsoy + \widehat{\beta_2} Rendcorn + \widehat{\beta_3} Prodpig + \\ + \widehat{\beta_4} Gct + \hat{\rho} W G_{dp}, \quad (4)$$

$$\hat{G}_{dp} = \widehat{\beta_0} + \hat{\beta}_l Rendsoy + \widehat{\beta_2} Rendcorn + \\ + \widehat{\beta_3}\, Prodpig + \widehat{\beta_4} Gct + \hat{\lambda} W_{\varepsilon}, \quad (5)$$

$$\hat{G}_{dp} = \widehat{\beta_0}(u_i, v_i) + \hat{\beta}_l(u_i, v_i) Rendsoy + \\ + \widehat{\beta_2}(u_i, v_i) Rendcorn + \widehat{\beta_3}(u_i, v_i) Prodpig + \\ + \widehat{\beta_4}(u_i, v_i) Gct, \quad (6)$$

Where,

$\hat{\beta}_y$ = estimated parameters of each model (SAR and CAR), $y = 0,\ldots,4$;

$WG_{dp}$ = expresses the weighted spatial dependence (Baller, 2001);

$\hat{\rho}$ = estimated autoregressive spatial coefficient;

$\hat{\lambda}$ = estimated autoregressive coefficient;

$W_{\varepsilon}$ = error component with spatial effects,

$(u_i, v_i)$ = denotes the centroid coordinates of the i$^{th}$ area $i = 1,\ldots, 399$;

$\widehat{\beta_y}(u_i, v_i), y = 0, \ldots, 4$ = realization of the continuous function $\widehat{\beta_y}(u, v)$ on the centroid of i$^{th}$ area $^{i} = 1,\ldots, 399$.

The hypothesis of normality of the spatial regression was verified using plots of normal probability (Draper and Smith, 1998), among them the Moran residues index test. The QQ-plot chart was elaborated to analyze the residues normality at 5% significance. The SAR model restriction on the spatial lag coefficient $\rho$ is that it lies within the open range between -1 and 1 i.e. $|\rho| < 1$. (Almeida, 2012).

For the assumption of the SAR model, the random error vector $n$ x1 has zero mean, constant variance, and is uncorrelated (Bailey and Gatrell, 1995). For CAR model restriction, the matrix $[I_n - \lambda W^{-1}]$ must not be unique. For this to be guaranteed, the matrix $W$ must maintain the properties that the sum of its rows and columns is limited to a fixed number, provided that $|\lambda| < 1$ (Fingleton, 2008). In the assumption of the CAR model, the random error vector $n$ x 1 has zero mean, constant variance, and is uncorrelated (Bailey and Gatrell, 1995).

For the GWR model, its limitations include multicollinearity problems in local coefficients (Wheeler, 2005). The GWR model assumes that the random error vector $n$ x 1 has zero mean, constant variance, and is uncorrelated (Cima et al., 2021b).

For the comparison of linear models of spatial regression: SAR, CAR, and GWR, the best adjustment quality will be due to a higher logarithm value of the Maximum Log-Likelihood (MLL) to the data analyzed (Cima et al., 2021b). Another way to validate the results obtained is through the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) (Spring, 2003). In this study, the residues self-correlation was tested by means of the global residue Moran index ($I_r$), according to the Equation 7:

$$I_r = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(e_i - \bar{e})(e_j - \bar{e})}{s_0 \sum_{i=1}^{n} (e_i - \bar{e})^2}, \quad (7)$$

Where,

$n$ = sample size;

$e_i$ and $e_j$ = the values of the residue considered in the areas $i$ and $j$, respectively;

$\bar{e}$ = the average value of the residue in the study region;

$w_{ij}$ = elements of the normalized matrix, in which weights 0 and 1 are attributed, being 0 the regions that do not border each other, and 1 the ones that do so;

$s_o$ = sum of the elements w$w_{ij}$ of the symmetric matrix of spatial weights $W$.

To prove the best adjusted model for GDP

in 2018 among SAR, CAR, and GWR, the criterion of Cross-Validation (Uribe-Opazo et al., 2012) and the descriptive chart *Worm Plot* for residue analysis was used (Buurea and Fredriks, 2001). The data were analyzed using the free *software* R (Development Core Team, 2021). The following packages were used: Gamlss, Spdep, GISTools, and Spgwr.

## Results and discussion

The results for the spatial regression models SAR, CAR, and GWR for Gross Domestic Product of the municipalities (*Gdp*) of the state of Paraná are shown in Table 1. The results show coefficients of determination ($R^2$) ranging from 77.7% to 80.8%, which shows an expressive adjustment of the models used, as well as the best adjustment quality according to the AIC and BIC criteria. Due to the results found (Table 1), it is observed that in all the models analyzed the estimated parameters $\hat{\beta}_1$ and $\hat{\beta}_2$ were negative in all models adjusted – a fact which produced an inversely proportional effect of the variables analyzed in the GDP of the municipalities in 2018, which means that there was an inversely proportional effect on soybean yield and corn yield in the GDP of the municipalities.

The results found in Table 1 express the vast importance and applicability of spatial data analysis for decision-making by public and private managers, in the sense of better understanding of events inherent to the object of study analyzed.

Recent studies such as Mykhnend and Wolff (2019) spatially analyzed the economic behavior in Europe, after 1970, using economic indicators such as Gross Domestic Product, and concluded that the analysis of spatial data is a method of wide relevance to explain the trends of European economic convergence.

The parameters estimated $\hat{\beta}_3$ and $\hat{\beta}_4$ were positive in all the adjusted models, which means that there was a directly proportional influence on pig production and on the tax on the circulation of goods in the GDP of the municipalities in the year studied (Ipardes, 2021).

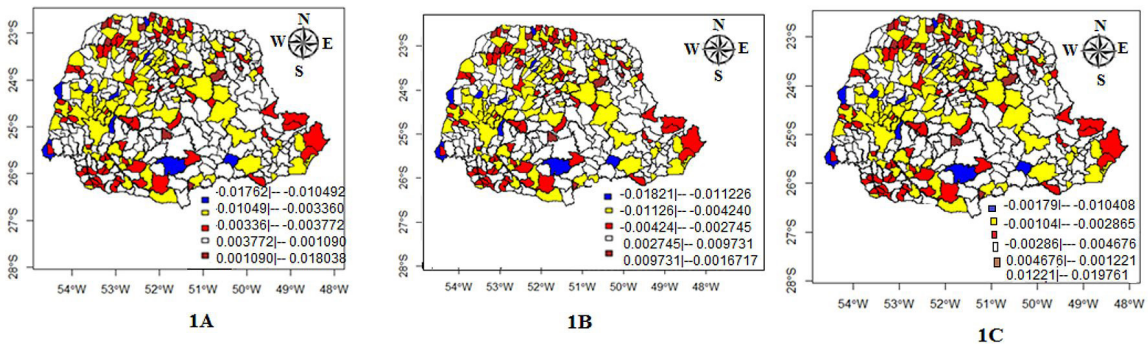
Through the SAR model, it was observed that the autoregressive coefficient ($\hat{\rho}$ = 0.362) was significant, in which the spatial autocorrelation was added to the explained variable. The CAR model showed that the autoregressive coefficient ($\hat{\lambda}$ = 0.418) was also significant, showing that the spatial dependence attributed to the term of the error was representative. And in the GWR model, it was observed that all parameters associated with covariates were significant at the 5% significance level (Table 1).

By observing the residues map ($\hat{G}_{dp}$) for SAR and CAR regression models (Figure 1A and Figure 1B), it is evident that the spatial

| Model/Statistics | $\hat{\beta}_0$ | $\hat{\beta}_1$ | $\hat{\beta}_2$ | $\hat{\beta}_3$ | $\hat{\beta}_4$ | $\hat{\rho}$ | $\hat{\lambda}$ | MLL | $R^2$ | AIC | BIC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SAR | 0.046* | 0.0312ns | -0.0341* | 0.339* | 0.238* | 0.362* | - | 1502 | 0.777 | -2951.6 | -2903.0 |
| CAR | 0.089* | 0.0948ns | 0.0352* | 0.0742* | 0.0197* | - | 0.418* | 1486 | 0.768 | -2954.0 | -2918.1 |
| GWR | 0.087* | 0.0157* | 0.0364* | 0.0465* | 0.0167* | - | - | 0.065 | 0.808 | -2998.5 | -2918.7 |

Note: ns: not significant; *: significant at 5% probability level; $\hat{\rho}$, $\hat{\lambda}$: autoregressive coefficients estimates; $\widehat{\beta}_i$: estimated parameters of models, for $i$ = 0, 1,…,4; MLL: Maximum Log-Likelihood value of the likelihood function; AIC: Akaike information criterion; BIC: Bayesian information criterion
Source: own calculations

Table 1: Statistics of the best SAR, CAR, and GWR models for the Gross Domestic Product (GDP) of the municipalities in the state of Paraná, in 2018.




Source: own research

Figure 1: Residues map resulting from the application of the spatial model SAR (1A), CAR (1B), and GWR (1C).

autocorrelation added to the response variable was eliminated, which allowed to generate non-correlated residues along the region analyzed (Batistella et al., 2019).

Pegorare et al. (2018) state that studies involving the spatial econometric data are necessary and important and that spatial autoregressive models (SAR and CAR) can influence the regional and national agribusiness scenario.

Through the analysis of the global Moran residues index for the GWR model, it was possible to verify that the global Moran index ($I_r$ = 0.01609) was close to zero and was not significant (p-value = 0.085), thus eliminating the model's spatial autocorrelation. Therefore, the GWR model also allowed to generate non-correlated residues in the study region (399 municipalities in Paraná-Brazil) (Figure 1C), which corroborates Alves and Galvani (2021) findings.

Balland et al. (2020) verified the productive spatial concentration in metropolitan areas of the United States (USA) using economic variables such as the GDP. The results suggest that economic activities were explained through the spatial investigation data.

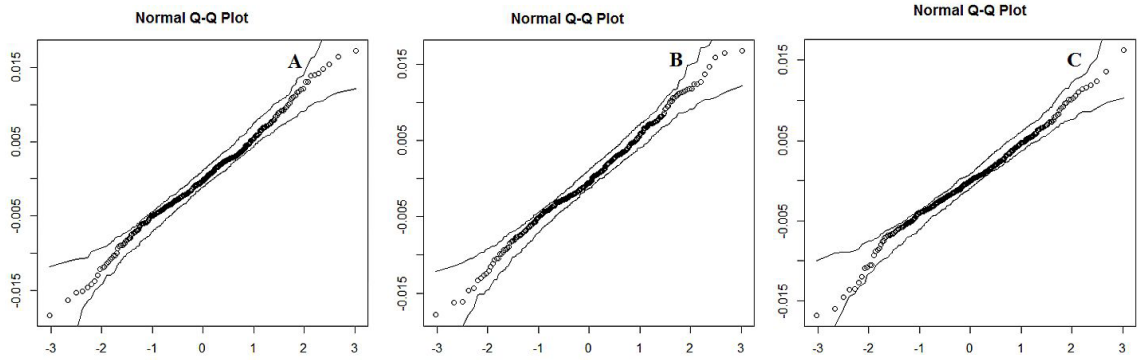
Huo et al. (2022) analyzed the characteristics of space-time variation of cultivated land and control factors in the Chinese delta region using Moran's spatial autocorrelation and the Geographically Weighted Regression (GWR) model. They concluded that both the analysis of the Moran's spatial autocorrelation and the GWR model explained the land characteristics associated with the GDP economic indicator.

According to the QQ-plot charts shown in Figure 2, it was observed that the points tend within the confidence bands, so this indicates that the residues of the SAR, CAR, and GWR models have a normal distribution, which means that the models suggest an indication of good adjustment because the points are aligned in the line that represents the identity of the theoretical and sampling quantiles – which corroborates Jaya and Chadidjah (2021) findings.

Through the cross-validation test for the Gross Domestic Product (GDP) of the municipalities, in 2018 SAR (0.0000298), CAR (0.0000319) and GWR (0.0000276), a better quality of fit was obtained for the GWR model when compared to the other models analyzed, which corroborates Uribe-Opazo et al. (2012) findings.

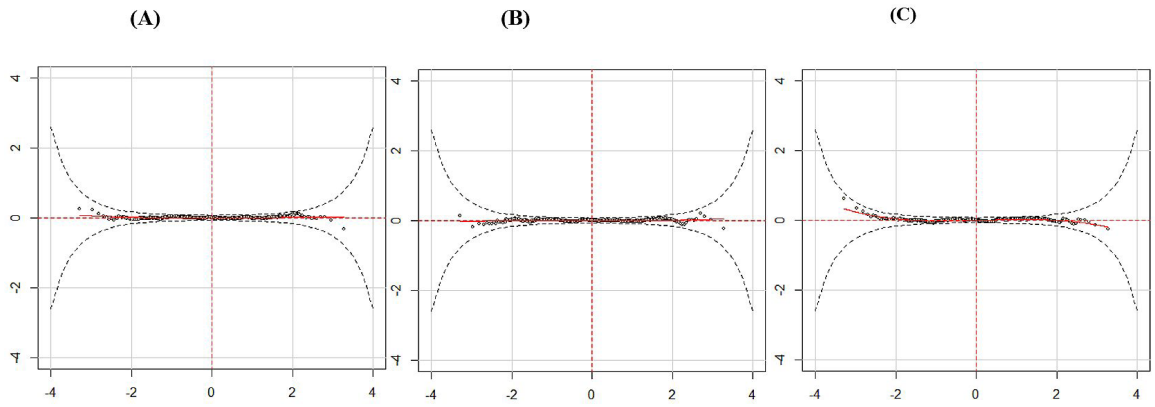
According to Harris (2019), the cross-validation test presents valuable performance mechanisms when comparing different spatial regression models, being fundamental for decision-making.

Figure 3(c) shows the worm plot for the GWR model, with the points and the red line within the confidence bands, showing a good goodness-of-fit of the GWR model. According to the results obtained through Cross Validation and the worm plot chart of residues, the local GWR model was the one that best explained the GDP of the municipalities and its relationship with soybean yield, corn yield, pig production, and with the tax on the circulation of goods. In this sense, the results found suggests that these variables contribute to the GDP of municipalities, which corroborates Cellmer et al. (2020) and Sikida et al. (2020) findings. In this focus of analysis, Zasaga et al. (2019) analyzed, through the spatial regression analysis of areas, agricultural yield and food economic growth in different regions of Europe. The results showed significant variations according to the analyzed locations and it was concluded that the analyzed spatial model explained the analyzed variables.




Source: own research

Figure 2: SAR QQ-plot (A), CAR QQ-plot (B), and GWR QQ-plot (C).




Source: own research

Figure 3: SAR worm plot (A), CAR worm plot (B), and GWR worm plot (C).

The results found through the GWR model make clear its predictive capacity to identify the spatial variability of the data, which corroborates Hu et al. (2018) findings. The same authors analyzed soybean yields in China using the GWR model in the 2015-2016 crop year and concluded that the GWR model had a significant goodness-of-fit and greater prediction accuracy in relation to other spatial regression models analyzed.

It is evident, from this information obtained, the broad driving capacity of generating wealth and foreign exchange that the state of Paraná presents. It is important to highlight the possibility of generating favorable mechanisms for the growth and economic development of the agricultural sector in the different municipalities. We emphasize the possibility of developing emerging public policies in favor of the economy that supports agricultural production in all its magnitude of coverage throughout the municipalities of Paraná-Brazil, in agreement with Vieira et al. (2019) and Evans et al. (2020) studies. In this regard Jank et al. (2020) report that Brazil's agricultural economic growth is highly complementary in relation to China and that agricultural productivity associated with economic growth indicators promote economic competitiveness between markets.

## Conclusion

There were variations in the Gross Domestic Product (GDP) of the municipalities in 2018 and the effects of soy yield, corn yield, pig production, and the tax on the circulation of goods varied significantly in the 399 municipalities that make up the state of Paraná-Brazil.

The results found here suggest that it is likely that there are differences in the GDP in relation to the yield of soybean, corn, pig production, and the tax on the circulation of goods according to each location.

The SAR and CAR models showed significant goodness-of-fit, but the GWR model behaved better, being the one that best explained the GDP of the municipalities, according to the model validation tests.

The GWR model, considered a local model, was the one that presented more stability when compared to SAR and CAR models, and its use is more consistent in studies that focus on spatial econometrics.

The results show that the indicators: soybean yield, corn yield, pig production, and the tax on the circulation of goods explained the variabilities in the GDP of the municipalities that make up the state of Paraná-Brazil, since they presented statistical significance in the year analyzed. The GWR model was the one that best explained the GDP of the municipalities of the state of Paraná in 2018.

It should be noted that the originality of the article (ineditism) is in the way in which the econometric analysis was approached considering the economic and agricultural variables analyzed, as well as in the treatment that was given in each stage itself. The agricultural and economic scenario was considered in detail, aiming at the criteria and complexity that each statistical technique studied here presents. Thus, the welcoming way the research proposes to the researcher generates exemplary motivation in the universe of scientific knowledge.

It became clear during the work carried out that

the overwhelming challenge was to understand, assimilate, and adapt the database according to the methodologies used.

It is suggested that the results found here do not exhaust the subject and that new scientific academic research will be necessary to understand the complexity that involves the spatial analysis of areas. Therefore, research of this scope benefits the economic system as a whole and it is suggestive of analysis in the decision-making of managers, whether in public or private institutions, thus contributing to the growth and development of the economy and promoting the dissemination of knowledge in the scientific community and the business sector.

Given this study, it is pertinent to suggest new works that focus on the spatial analysis of data, among them econometrics and spatial statistics of areas applied in different economic areas that emerges of great importance, considering that this relevance is regional, national, and worldwide.

Therefore, the research showed that the wealth of information contained, and which can be explored in the analysis of spatial data, acts in the sense of presenting accurate diagnoses of the possible events that can be analyzed, favoring scientific research and providing new forms of economic analysis in the broad universe of science.

## Acknowledgments

The authors would like to thank the Coordination for the Improvement of Higher Education Personnel – Brazil (CAPES) – Financing Code 001 for the financial support; the National Council for Scientific and Technological Development (CNPq), the Post-Graduate Program in Regional Development and Agribusiness (PGDRA), the Post-Graduate Program in Agricultural Engineering (PGEAGRI), and the Spatial Statistics Laboratory (LEE-UNIOESTE) of the Western Paraná State University (UNIOESTE).

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Agris on-line Papers in Economics and Informatics

Volume XV Number 2, 2023

# Digital Farming: A Survey on IoT-based Cattle Monitoring Systems and Dashboards

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## Abstract

There is a steady increase in research on livestock monitoring systems that offer new ways to remotely track the health of the livestock, early predict the diseases that may affect them and intervene in the early stages to save the situation by monitoring the various vital biodata of the livestock, as well as monitoring their feeding and tracking their location to prevent any damage or rustling. In this context, this paper comes in order to highlight and discuss the most recently published articles that study the topic of cattle health monitoring and location tracking systems using advanced IoT sensors. In addition, the research provides a review of the most important software and dashboards available in the market that can be used for this purpose. The research constitutes a reference for researchers in this field and for those who wish to develop similar monitoring systems.

## Keywords

Agriculture 4.0, cattle, precision livestock farming, smart agriculture, IoT, digital farming.

El Moutaouakil, K., Jdi, H., Jabir, B. and Falih, N. (2023) "Digital Farming: A Survey on IoT-based Cattle Monitoring Systems and Dashboards", *AGRIS on-line Papers in Economics and Informatics*, Vol. 15, No. 2, pp. 31-39. ISSN 1804-1930. DOI 10.7160/aol.2023.150203.

## Introduction

In order to check the health and the status of the cattle, the measure of the temperature and other vital biodata takes place in the barns, and it's all manually. Using these traditional methods to determine cow disease as example requires a significant amount of work. Also, cow location tracking requires a lot of effort and costs a lot. In addition, poor cow management results in the death of calves, the miss of estrus time, the loss or theft of cows, among others, and therefore a decrease in farm household income (Aleluia et al., 2022).

The livestock industry which suffers from many problems due to a decrease in livestock farms, an aging labor force, and the spread of diseases and epidemics, is looking for solutions through Internet of things (IoT) sensors and Artificial intelligence (AI) technologies. The IoT technology is used by farmers ad barn managers to monitor the livestock bio-data and analyze it with AI algorithms, thereby increasing productivity and predicting diseases by early detecting signs that even experienced people cannot detect, bringing a new era of smart livestock farming that allows remote work with fewer people (Harikrishnan and Mohini, 2021).

As IoT technology advances, it can be applied to livestock as well as actively used in smart farms that grow crops efficiently (Jabir and Falih, 2020). The goal of the livestock smart farms is to boost the quality and overcome the time and effort constraints by using the Internet and the new automated devices and sensors. It is a type of livestock farming that aims to improve the cattle wellbeing and apply intelligent and highly efficient techniques to enhance the production, and the environmental impact (Akhigbe et al., 2021).

A detailed analysis of the architecture and functionalities of the existing cattle IoT-based management systems and a discussion of its strengths and gaps, as well as an overview of the industry-available software and dashboards that can be used to manage and monitor all the aspect of the cattle are presented in this paper. It can be a useful guide for researchers planning to design and develop such an IoT-based management system, or industry specialists that want to take an in-depth look at the latest trends in this field.

This paper is organized as follows. The following section provides a comparison between traditional and modern cattle monitoring systems and describes

the recent trends of cattle monitoring. Then, in the section that follows analyzes and discuss the existing IoT-based smart cattle monitoring systems which includes health monitoring, reproduction monitoring, and location tracking systems. Then we present our own proposed smart cattle monitoring system architecture, then we highlight the existing industry-available cattle monitoring software and dashboards in use for the IoT-based cattle management, before concluding the paper.

## Materials and methods

### Traditional and modern cattle monitoring systems

The old breeding methods were manual and traditional, relying on the livestock manager's experience and intuition, while management work decisions are made through repeated trial and error and individual know-how. But smart farms are equipped and automated by sensors and network technology with the assistance of artificial intelligence, as is the case with plant cultivation (Jabir et al., 2021) (Figure 1). In the case of smart livestock management monitoring, automated facilities and Internet communication technology are combined to monitor the health status of the livestock or the breeding environment at any time and from any location (Na, 2019).

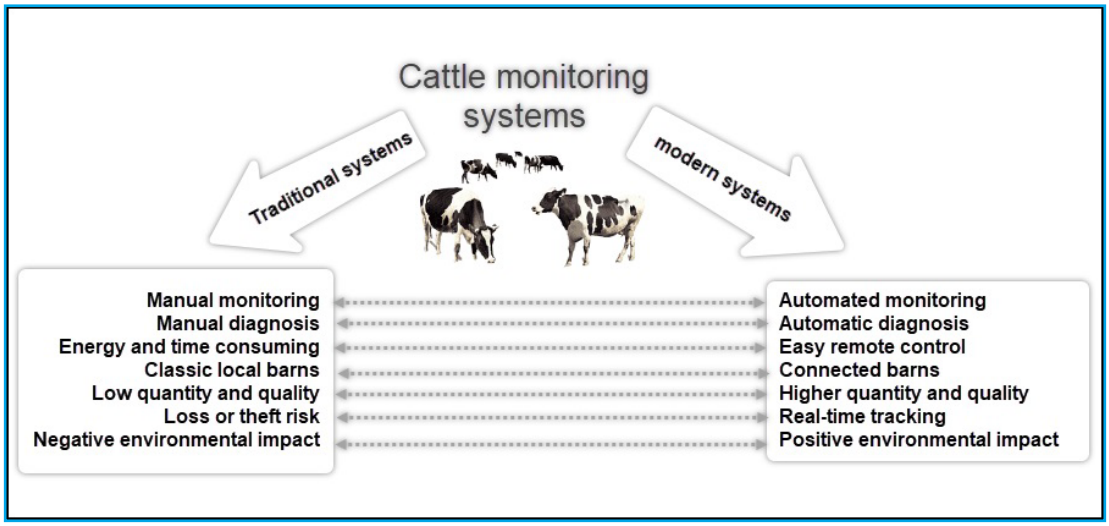
Before the development and expansion of the IoT technology, farmers and barn managers were using traditional methods that depend on periodic monitoring and manual diagnosis and rely either on the experience of the farmers or some software that does some calculations to determine some vital periods for the cattle or predict disease possibility.

Using the new advanced technology, remote cattle monitoring is possible, and all that the farmer need is to install the appropriate IoT sensors and use a software with a dashboard that relies on a monitoring system then it will be possible to continuously monitor all the aspects of the cattle using the IoT network. This way, the farmer can effectively manage the cattle by remotely checking all the changes that occur (Germani et al., 2019).

### Recent trends in cattle monitoring

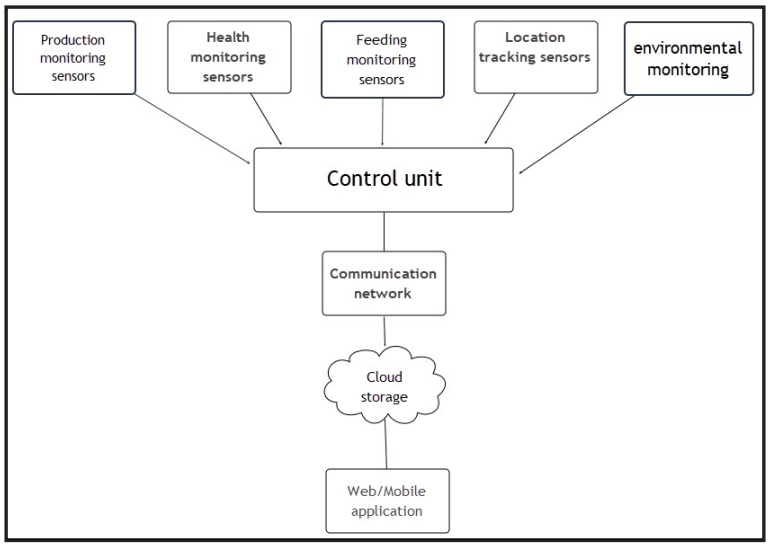
Currently, the new cattle monitoring advanced technologies are mainly used for monitoring the health, the feeding, the production and the environment, in addition to tracking the location of the cattle (Vigneswari, 2021) (Figure 2).

There are various IoT sensors available in the market that can be used for monitoring all these aspects. It can be attached to the cattle via collars equipped with network connectivity to send the biodata to a control unit that can process the data and gather it before transferring it to the cloud via a communication network, to finally make it accessible for farmers, barn managers and veterinary physicians for continuous monitoring. In this paper, we will focus both on the health monitoring and location tracking systems. Note that the health monitoring will




Source: Author's illustration

Figure 1: Comparison between traditional and modern cattle monitoring systems




Source: Author's illustration

Figure 2: The main recent trends in the smart cattle monitoring systems.

also include the reproduction monitoring. In the following section, we will discuss the latest articles on these monitoring systems that have been published in the past five years.

## Results and discussion

### Cattle health monitoring systems

In the article "Cloud IOT based novel livestock monitoring and identification system using UID" (Saravanan and Saraniya, 2017), the authors propose a new cloud-based Internet of Things (IoT) cattle monitoring system that can measure the cattle's physiological parameters, including its body temperature, stress level, ability to recognize gestures, and heart rate, as well as its environment, including the relative humidity and temperature of the surrounding air. These sensor-specific characteristics are saved in the cloud-based ThingSpeak-IoT analytics platform. Additionally, the monitoring system includes a web-based application created for improved communication between the cattle barn management, the owner, the farmer, and the veterinary physician.

Designing and creating an IoT-based smart cattle healthcare monitoring system prototype is the main objective of the research "Development of IoT Based Smart Animal Health Monitoring System using Raspberry Pi" (Kumari and Yadav, 2018). The created system uses a Raspberry Pi 3 with built-in Wi-Fi, a body temperature sensor, a heartbeat sensor, and a rumination sensor to monitor body temperature, heartbeat, and rumination in real time. They are transmitted over Wi-Fi using the IEEE 802.11 standard to the ThingSpeak cloud. Using the internet and an Android app on their smartphone, the farmers may access such data from anywhere. A farmer may quickly determine the health state of a cattle by carefully observing the information that is available in the ThingSpeak cloud.

In the research "Wearable Smart Health Monitoring System For Animals" (Khatate et al., 2018), they have presented a wearable health monitoring device that a cattle may wear in order to overcome and identify numerous health-related difficulties and challenges. This system is made up of modules that can measure things like body temperature, heart rate, blood pressure, and respiration rate. This system also uses IOT to send data to veterinarians or medical professionals. The suggested approach will make it easier for livestock owners to keep track of their cattle's health. This is applicable both in veterinary hospitals and at barns. As a result, farmers will no longer have to wait for veterinary specialists to evaluate and diagnose their cattle, this ultimately results in animal health decline and late treatment. So, this new method will help to solve one of the present health monitoring issues.

In the article "Designing of a Smart Collar for Dairy Cow Behavior Monitoring with Application Monitoring in Microservices and Internet of Things- Based Systems" (Pratama et al., 2019), the monitoring system provides judgments on the normal, less normal, and abnormal health of the cattle. The obtained data coming

from the IoT sensors is saved and subjected to machine learning algorithms. Depending on the gyro sensor and accelerometer's graphical output, it can be determined if the cows are feeding, lying down, or standing. The created prediction system can make the cattle health much better through rapid intervention to treat diseases in its first stage.

The suggested method in the "An IoT Solution for Cattle Health Monitoring" (Suresh and Sarath, 2019) article for automatically monitoring the health of cattle is very useful for detecting cattle illnesses. Since an alarm message can be issued to the owner if there is any deviation from the parameters' usual value, there is no longer a need for continuous monitoring. The IoT cloud platform and the mobile nodes are the main parts of the system created in this study. The data collection node is equipped with a variety of sensors to detect the health characteristics of the cattle. These data are then communicated to the mobile node using the TDMA protocol. The mobile node serves as a gateway to the IoT cloud platform where sensor data analysis is performed to identify cattle disease and alert the farm owner and the veterinarians.

Regarding the "IoT-Based Cow Health Monitoring System" (Unold et al., 2020) article, the created system precisely tracks the activity of dairy cows and identify certain physiological conditions, such as estrus, and certain health issues (e.g., mastitis). The Internet of Things (IoT) infrastructure, which consists of hardware devices, a cloud system, and end-user applications, supports this system. It can distinguish cow actions precisely thanks to new cutting-edge methods of data analysis. The proposed prototype devices were tested in a real setting and proved to be so effective and now being turned into a commercial system.

The "Analysis and Design of Cattle Management System based on IoT" (Cho, 2021) article proposes a system design for monitoring and predicting cattle illness and estrus using cattle temperature and 3-axis acceleration sensor. The whole architecture is demonstrated in order to develop the aforementioned IoT-based livestock management system. By demonstrating user demand analysis using object-oriented technique, flowchart, and screen design, an efficient analysis and design process for developing this system software is also demonstrated.

Regarding the article "Design of Scalable IoT Architecture Based on AWS for Smart Livestock" (Dineva and Atanasova, 2021), the architecture created in this study is a solution for a smart cattle monitoring system. The architecture's sensitive points were successfully tested, and the outcomes complies with the system's functional requirements. The established architecture is appropriate for future integration in animal farms, including its use for monitoring cattle status in smart farms. The purpose of this project was to develop a scalable cloud-based architecture for a smart livestock monitoring system that would include the monitoring of animal health, development, behavior, reproduction, emotional and stress levels, as well as the monitoring of the environment. The AWS services is in use and the activities they perform in relation to the suggested architecture are well described.

In the "Smart cattle health monitoring system using IoT sensors" (Suseendran and Balaganesh, 2021) paper, the autirs provide an IoT-based smart Cattle Monitoring Architecture. The health monitoring module is suggested as a way to reliably forecast cattle sickness far in advance. An antenna diversity system and Reliable Intra and Inter Gateway Routing Protocol (RIIGRP) are developed to enable reliable data transfer between the gateway and the collar attached to the cow. The suggested architecture is implemented in an Arduino sensor environment and simulated in the NS2 network simulator. In comparison to the current solutions, the suggested system achieves a 4% higher packet delivery ratio, a 14% lower latency, and 12% less energy consumption.

And finally, we have the "Design of a Cattle-Health-Monitoring System Using Microservices and IoT Device" (Shabani et al., 2020) article. In this study, they suggested and created a microservice-based architecture that may act as a bridge between IoT devices and other applications that use the data produced by this architecture. The suggested design was initially intended to be used to monitor the health of cattle, but it may be flexibly used in other fields. Machine-learning techniques were applied inside this architecture to predict cow health based on body temperature, heart rate, humidity, and location sensors to provide farmers with real-time information about the health of each animal. Based on the parameters supplied by the mobile node, it is feasible to use algorithms to calculate the current percentage value of each head of cattle's health. The architecture alerts the farmer in real time about any health issues the cattle may have. (Table 1).

| Article | Parameters detected | Control unit and communication protocol | Research gaps |
|---|---|---|---|
| **Cloud IOT based novel livestock monitoring and identification system using UID** (Saravanan and Saraniya, 2017) | Body temperature, Heart rate, Physical gesture, Environmental parameters. | Arduino UNO, Bluetooth, Wifi. | Involves a high cost for computation and communication. |
| **Development of IoT Based Smart Animal Health Monitoring System Using Raspberry Pi** (Kumari and Yadav, 2018) | Heart rate, Body temperature, Rumination. | Raspberry Pi, Wifi. | There is no decision-making module in the system. |
| **Wearable Smart Health Monitoring System For Animals** (Khatate et al., 2018) | Temperature, Respiratory rate, Blood pressure, Heart rate. | Arduino UNO, Wifi. | Include a lot of storage and lack a decision-making module. |
| **Designing of a Smart Collar for Dairy Cow Behavior Monitoring with Application Monitoring in Microservices and Internet of Things- Based Systems** (Pratama et al., 2019) | Body temperature, Heartbeat, Movements. | Raspberry Pi, Wifi. | Lacks diagnosing cow disease and monitoring the cattle environment. |
| **An IoT Solution for Cattle Health Monitoring** (Suresh and Sarath, 2019) | Temperature, Heart rate, Humidity. | Arduino Mega 2560, Raspberry Pi, ZigBee. | There is no decision-making module in the system. |
| **IoT-Based Cow Health Monitoring System** (Unold et al., 2020) | Cow activity, Rumination, Feeding, Walking. | A Proprietary device based on nRF52832 SoC, Wifi. | Include a lot of storage and lack a decision-making module. |
| **Analysis and Design of Cattle Management System based on IoT** (Cho, 2021) | Temperature, Movements. | A proprietary device, Wifi. | ECG and heart rate are not considered. |
| **Design of Scalable IoT Architecture Based on AWS for Smart Livestock** (Dineva and Atanasova, 2021) | Temperature, Humidity, Pressure, Movements, Noise, GPS coordinates. | A proprietary device, WiFi, ZigBe, LoRaWAN, Z-Wave. | Involves a high cost for computation and communication. |
| **Design of a Cattle-Health-Monitoring System Using Microservices and IoT Devices** (Shabani et al., 2020) | Body temperature, Humidity, Heartbeat, Position of the cattle. | A propriatary device, Wifi. | Involves a high cost for computation and communication. |

Source: Author's compilation

Table 1: Comparison of the various cattle health monitoring systems.

## Cattle location tracking systems

The article "A Study on IoT Solutions for Preventing Cattle Rustling in African Context" (Dieng et al., 2017) comes to assess the use of existing IoT technologies for preventing cattle rustling in Africa. Theft of cattle is a serious phenomenon that presents numerous challenges to African farmers. There are currently no effective solutions for this problem. Their only chance is still the new information and communications technologies. The majority of currently used solutions rely on RFID and WSN technology. The authors of the article suggested a new tracking system prototype based on LoRa technology that would enable users to track the location and determine whether a herd is experiencing an anomalous circumstance. This prototype consists of low power LoRa end-devices and a LoRa Gateway.

The main goal of the "A Low-Cost IoT-Based System to Monitor the Location of a Whole Herd" (Maroto-Molina et al., 2019) research is to provide a low-cost method for tracking the location of an entire herd. The monitoring of 50 animals on two commercial farms that raise sheep and beef cattle has been used to assess the effectiveness of the IoT system. It has been shown that the solution based on the fusion of LPWA (Sigfox) and short-range BLE sensor networks is efficient in tracking the position of each animal in a herd at a significantly lower cost than existing systems.

"Smart Farming: An Enhanced Pursuit of Sustainable Remote Livestock Tracking and Geofencing Using IoT and GPRS" (Ilyas and Ahmad, 2020) is another study that provides an architecture of a geographical paddock suggested in this work to track the spatiotemporal behaviors of the cattle. Farmers must invest physical effort in a traditional livestock monitoring system to find the cattle that stray from frequent entry points. The suggested solution takes care of these problems by making it simple for farmers to designate a geographical safe zone for the cattle herd. When they attempt to cross the designated zone boundary, the system alerts the farmers. The technology measures each animal's distance from the safe zone's geographic limit and alerts the farmer when it approaches a certain threshold.

In the article "IOT - Livestock Monitoring and Management System" (Isaac, 2021), in order to create a system that would track the cattle and allow remote process management, the paper

specifies the top-level requirements and creates the IoT technology stack. Establishing a platform or a livestock monitoring and management system is the goal of this research. The IoT framework offers IoT solutions in a variety of fields and uses in agriculture, farming, and livestock including Cattle location tracking. The Internet of Things (IoT) is the foundation of the technological stack, and it has essential sensors to help in the monitoring process. Keeping that in mind, the data flow and exchanges are thoroughly examined in this paper.

Regarding the "Farm Animal Location Tracking System Using Arduino and GPS Module" (Ramesh et al., 2021) article, by using a sophisticated tracking system that makes use of pertinent technologies like the Global Positioning System (GPS) and the Internet of Things (IoT), this research attempts to tackle the problem of cattle locating and tracking. The system is built on a cloud computing infrastructure. The only problem is when the lead-acid battery is down. Low power components and microcontrollers must be used to prevent this problem and lengthen the battery's life.

In the "LoRaWAN based Cattle Monitoring Smart System" (Joshitha et al., 2021) study, a smart automated method for tracking the livestock is suggested. The main component of this system, LoRaWAN, helps in long-distance information transmission. A GPS module is used for location identification. Sensors that measure temperature and humidity keep an eye on the surroundings environment to better protect the animals. When compared to the current traditional ways, this sort of modern smart technology ensures greater protection and better tracking of the cattle. (Table 2).

## Smart cattle monitoring system architecture

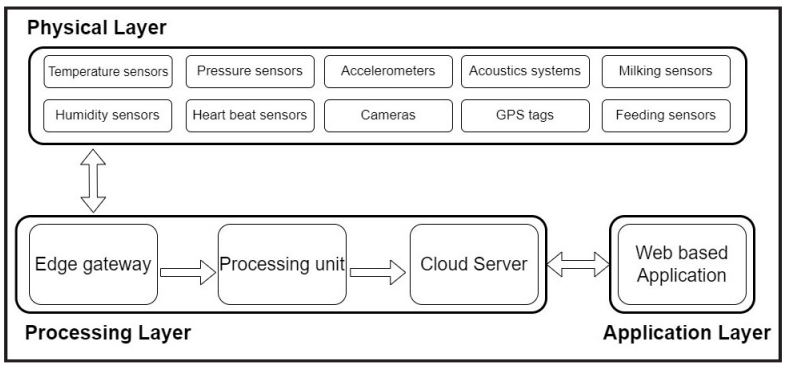
Based on the current trends and the systems proposed in previous works, for our part, we present our perception of a smart cattle monitoring system architecture that combines all the aforementioned applications that uses IoT sensors, cloud storage, and real-time data analysis into one system to continuously monitor and manage the livestock.

The smart system for monitoring cattle is structured in three layers: the physical layer, the processing layer, and the application layer (Figure 3).

| Article | Technologies used | Research gaps |
|---|---|---|
| **A Study on IoT Solutions for Preventing Cattle Rustling in African Context** (Dieng et al., 2017) | LoRa, Wi-Fi, Bluetooth. | Data transmitted by LoRa has a limited payload and may face spectrum interference problems. |
| **A Low-Cost IoT-Based System to Monitor the Location of a Whole Herd** (Maroto-Molina et al., 2019) | GPS, BLE. | BLE does not support long distances or big data rates. |
| **Smart Farming: An Enhanced Pursuit of Sustainable Remote Livestock Tracking and Geofencing Using IoT and GPRS** (Ilyas and Ahmad, 2020) | GPS, GPRS. | The data rate is lower than those of competing wireless standards. |
| **IOT - Livestock Monitoring And Management System** (Isaac, 2021) | GPS, BLE. | Due to wireless transmission and reception, BLE is vulnerable to interceptions and attacks. |
| **Farm Animal Location Tracking System Using Arduino and GPS Module** (Ramesh et al., 2021) | GPS, Wifi. | Wifi has a limited range, is prone to interference and has security vulnerabilities. |
| **LoRaWAN based Cattle Monitoring Smart System** (Joshitha et al., 2021) | LoRaWAN, GSM, GPS. | LoRaWAN has a restricted network size. It's also not the best solution for real-time applications. |

Source: Author's compilation

Table 2: Comparison of the various cattle location tracking systems.




Source: Author's illustration

Figure 3: The proposed smart cattle monitoring system architecture.

In the physical layer, there are IoT sensors and other devices that can be either attached to or remotely monitor the animals in the barn. These sensors include temperature, heart rate, and accelerometer sensors that monitor the vital signs of the cattle, as well as pressure, humidity sensors and cameras for the surveillance of the environmental parameters. In addition to the acoustic systems for early detection of potential cattle diseases, and milking and feeding sensors for performance tracking, along with GPS tags for following their location.

The processing layer comprises three units: the edge gateway, which collects the generated data, the processing unit, where advanced computational techniques are used for data processing, and the cloud server, which is used for data storage and database management. Lastly, the application layer consists of a web-based application that allows users to access the collected data from either a desktop or a mobile device.

## Cattle monitoring dashboards

In this subsection, we will provide a list of the most well-known software and dashboards in use for cattle monitoring purposes (Table 3).

For this, we propose to take a look at both cattle monitoring dashboards that uses the traditional and modern methods.

In the following table, we have a list of software/ dashboards in use for recording the cattle data manually, i.e., using the traditional monitoring methods.

This data can be used for making predictions and keep tracking the status of the cattle. We will highlight the main functionalities for each of the existing monitoring software.

In the following Table 4, we have a list of software/ dashboards in use for monitoring the cattle's health and status using IoT sensors, i.e., using modern monitoring methods. We will highlight the main functionalities for each software.

| Software | Functionalities |
|---|---|
| **Cattlemax** | Track animal inventories and production history and update them, maintain complete breeding and pregnancy records, record key performance measurements, manage herd health treatments, keep up with cattle purchases and sales, import and export records. |
| **MilkingCloud** | Lists, daily tasks and reports, animal profile, animals ready for insemination, list of those that need to undergo pregnancy check, animals getting close to delivery, animal addition and Animals in heat. |
| **HerdOne** | Store and track records of: inventory, accounting, reporting, reminders, pregnancy and breeding. |
| **Livestockmanager** | Livestock Manager is designed for the commercial livestock enterprises that need detailed livestock management records. It is flexible to handle multiple identifications while tracking treatments, animal movements, calving and milk production. |
| **Livestock Management System** | Disease management, vaccine management, purchase management, sales management, expense management, financial report, supplier database, client database and staff database. |

Source: Author's compilation

Table 3: Existing cattle monitoring software for recording cattle data manually.

| Software | Functionalities |
|---|---|
| **Cowmanager** | CowManager monitors the cows: estrus, health, nutrition and location based on temperature, activity, rumination, eating and resting sensors. |
| **Smaxtec** | Detection of metabolic diseases, heat detection, calving detection, monitoring of drinking behaviour, detection of heat stress, detection of subacute rumen acidosis (SARA) and detection of feeding issues. |
| **GEA CowScout** | Constant heat monitoring and display of the optimal insemination time, notifications of reduced eating and rumination times to enable early detection of health problems, and reliable animal identification in the milking parlors. |
| **Moocall** | Moocall software is based on a heat device that tells when a cow or heifer enters standing heat. |
| **Cowlar** | This software is based on smart neck collars that manage/monitors: reproduction, disease outbreaks, stress, feed optimization, milk yields, overuse of antibiotics, productivity and profits. |
| **Halter** | Halter is a New Zealand Agricultural technology startup producing GPS-enabled solar-powered collars for dairy cows. These collars connect to a smartphone app and provide: precise pasture management, seamless mob management in addition to health and heat detection. |
| **Allflex** | Health monitoring, reproduction monitoring and feeding monitoring. |
| **IDA** | Reproduction monitoring, health monitoring and analytics. |
| **Moovement** | Track cattle location and monitor cattle health. |

Source: Author's compilation

Table 4: Existing cattle monitoring software based on IOT devices.

## Conclusion

The aspects studied in this research present real solutions for the challenges that face farmers and barn managers every day. The new advanced Cattle monitoring systems help avoid diseases and loss of Cattle. Using these advanced systems ensures real-time monitoring of the health, production/reproduction, welfare and the environment of the cattle, which allows farmers to improve the quality and boost the profitability. In this regard, we intend to develop a new optimal cattle monitoring system based on advanced new technologies and taking into consideration the results of this study to overcome the shortcomings of the previous systems.

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Agris on-line Papers in Economics and Informatics

Volume XV Number 2, 2023

# Determining Factors of Retaining Young Farmers in Agriculture: A Case study in Turkey and Japan

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## Abstract

Young farmers have an important role as the future of food security and sustainable agriculture depends on them. However, the young farmer problem is getting serious all over the world, whether the countries are developed or developing. The objective of this study is to determine the factors that affect the willingness of young farmers to continue agriculture in the future, especially based on social and cultural factors with economic factors. Data were collected from 200 young farmers' questionnaires in İzmir, Turkey, and Niigata, Japan. Using the logistic regression model, we found that social factors play an important role in retaining young farmers in agriculture such as the respectability and importance of farming, and the multifunctional role of farming, along with economic factors such as off-farm job, farmland size, and subsidies. If countries can clarify the importance of farming and food production to young generations, they will make essential contributions to the sustainability of food security and agricultural sustainability.

## Keywords

Sustainability, young farmers, Japan, Turkey, rural development

Karahan, M., Abay, C. and Ito, R. (2023) "Determining Factors of Retaining Young Farmers in Agriculture: A Case study in Turkey and Japan", *AGRIS on-line Papers in Economics and Informatics*, Vol. 15, No. 2, pp. 41-54. ISSN 1804-1930. DOI 10.7160/aol.2023.150204.

## Introduction

Young people are the most dynamic, productive, and innovative population of any society (Aggelopoulos and Arabatzis, 2010) and they are required by agriculture. Furthermore, Hamilton et al. (2015) investigated the question of whether young farmers are more profitable, productive, and innovative than older farmers and found that the 35 and 45 age range was the highest overall in terms of the whole farm and agricultural productivity. Wairegi et. al. (2018) found that young coffee producers in Kenya have higher yields (609 kg/ha) than older producers even if they cultivate smaller land and they are willing to expand their businesses by leasing land under coffee to increase their income from coffee. Younger farmers have a longer planning vision for their farms. They tend to invest more in their farms and more frequently use loan capital to grow their business than older farmers (Davis et al., 2013). They are more open to learning new techniques on the farm and more likely to adopt innovative technologies to help improve farm productivity and enlarge their farm (Hamilton et al., 2015). Young farmers usually display better financial results and employ more modern management techniques farm (Zagata and Sutherland, 2015). Moreover, Lim et al., (2022) state that young farmers make farming more sustainable and adaptive and contribute to climate action by using modern technologies. Young farmers are more likely to engage in sustainable farming practices such as organic agriculture, environmental conservation, and animal welfare (Lastra-Bravo et al., 2015; Läpple, 2012). Hwang et al. (2017) have documented that young farmers make an effort to secure agriculture competitiveness through an increase in farm size and having quality certifications (such as organic certification, and environment-friendly certification) for their products.

However, young people are not willing to engage in farming as a profession. Many researchers have proclaimed that the number of young farmers in several developed countries has decreased (May

et al., 2019). Only 11.9% of all farm holdings in the European Union are run by farmers under 40 years of age (EUROSTAT, 2022). The proportion of farm operators aged 55 and older grew by 6% points in 2016 (54.5%), increasing to 60.5% in 2021. Conversely, Canada's share of young operators was 8.6%, down slightly from 9.1% in 2016 (Statistics Canada, 2021). In Korea, only 0.7% of farmers are under 40 years old, and the number of farms managed by these young farmers dramatically declined from 91,516 in 2000 to 6,859 in 2019 (Lim et al., 2022). The average farmer age in Taiwan is 62, with 44% of farmers aged 65 and over, and 7.92% of farmers between the ages of 15 to 44 (Kuo, 2014). The average age of Japanese farmers is 68 years of age, the highest average age for farmers in the world. And more than 80% of farmers in Japan are over 60 years old, while 12% of farmers are under 45 years old (MAFF, 2020).

Additionally, recent studies in developing countries have shown that they also suffer from the young farmer problem and that youths tend to migrate, leaving their farmlands. In Thailand, the proportion of farmers younger than 45 years old is 19%, while the proportion of those 60 years and older is 33% (Jansuwan and Zander, 2021). Moreover, 25.3% of farmers are 15 to 40 years and 43.8% of farmers are in the age group of 55 years and above in Malaysia (Abdullah and Sulaiman, 2013). According to the data of the Ministry of Agriculture and Forestry of Turkey, 13.46% of farmers correspond to 18 to 40 years of age and 67% of farmers correspond to 50 years of age and above (The Ministry of Agriculture and Forestry of Turkey, 2016).

The young farmer problem has a direct relation to the issues of efficiency, productivity, food security, food self-sufficiency, sustainability, and poverty. Therefore, numerous studies have examined the reasons or factors that affect the exit of young farmers from agriculture, prevent them from entering the farm, and sustain their activity on the farm. For instance, high land value, farmland rent (Katchova and Ahearn, 2015), and lack of available land (Šimpachová Pechrová et al., 2018) prevent young farmers from entering the farm. The price of land is an important factor in the investment and management decisions of farms and the higher price may represent a barrier to entry into agriculture (Statistic Canada, 2021). The most important factor for young people not entering farming in Benin, a West African country, is the difficulty of accessing agricultural land (Ameglagno and Soglo, 2019). And young people in Madagascar, Malawi, South Africa, Zambia, and Zimbabwe, have noted a major problem accessing farmland because of the unwillingness of parent farmers to relinquish land (Lindsjö et al., 2020; SACAU, 2013). The needs of European young farmers were addressed by Zondag et al. (2015) as access to land and financial capital. Kristensen and Birch-Thomsen (2013) reported that the most important problems are accessing the necessary capital and credit to use in agricultural enterprises for young farmers in Uganda and Zambia. It has been reported that young farmers in Kenya face similar problems in entering agriculture (Leavy and Hossain, 2014). Furthermore, Norsida (2012) in a paper titled “Unleashing youth potentials in developing the agriculture sector” found that the lack of capital (88.1%) is one of the main factors among Malaysian youth from getting involved in agriculture. Goeringer et al. (2012) reported that young farmers need an amount of capital in the initial phase, and they face problems accessing credits and loans. In addition, it is argued that low agricultural income is the most important factor that makes young farmers unwilling to continue agriculture in Akhisar Turkey (Arli et al., 2014). It was reported that young farmers tend to leave the rural area of Turkey because of income inefficiency and lack of job opportunities (Yalcin and Kara, 2016; Zirhlioglu, 2010). Young farmers in Kenya face fragmentation of land problems because of inheritance, and they could not earn enough income from small farmlands (Andhani, 2017). The migration of Malaysian youth from agriculture and rural areas is largely due to the traditional view that agriculture is a low-paying hard job and does not directly promise a good future for younger people (Abdullah and Sulaiman, 2013). Lim et al. (2022) analyzed the perception, attitude, and willingness to participate in the investment scheme for Korean young farmers. They found that young farmers have a positive attitude toward investment schemes although the fund is insufficient for capital-intensive farms. Lim et al. (2022) state that this might be because young farmers have financial constraints exist. Moreover, agriculture has many risks which are related to climate change and natural disasters, which lead to increased product costs, the volatility of the agricultural markets, and product prices (Jansuwan and Zander, 2021). It causes low and unstable agricultural income which makes farming an unattractive profession for young people. In addition to economic factors, social factors also caused young people to not be attracted to agriculture. Young people perceive farming as a profession

with a low social status and education level (Asciutti et al., 2016; Susilowati, 2015). And farming is not seen as a suitable occupation for well-educated Malaysian farmers (Abdullah and Sulaiman, 2013). Thai young farmers do not want to cultivate their land, as they see agriculture as a grueling occupation with low pay and a heavy workload. Furthermore, they think the prestige of the profession is low due to the low income of the farming profession, and non-agricultural professions can earn high prestige and a higher income (Ruiz Salvago et al., 2019). And the Philippines farmers expressed the opinion that rice farming is physically tiring and not financially rewarding (Palis, 2020).

In that respect of this background, our study aims to determine the factors that affect the willingness of young farmers to continue agriculture in the future. The research question is below: What factors have an impact on young farmers to continue agriculture in the future? Specifically, we aim to investigate the social, cultural, and economic factors that influence their willingness to continue agriculture in the future. To determine the factors affecting the willingness of young farmers to continue farming in the future, statement questions were formed the factors based on the literature. AGE, SUBSIDIES, PROFESSION, FARMLAND, and EXPERIENCE factors have been examined by many studies (Jansuwan and Zander, 2021; Hlouskova and Prasilova, 2020; Faysse et al., 2019; Morais et al., 2017). Based on young people's negative perception of farming (Rigg et al., 2018; Morarji, 2014), and their view of farming as a low-prestige and neglected profession (Ruiz Salvago et al., 2019; Aguilhon, 2017; Asciutti et al., 2016; Susilowati, 2015), we assumed RESPECTABLE and FARMING IMPORTANT will be factors in our research. FARMING NOT TIRING factor was formed from farming was seen as a tiring occupation with a heavy workload by young people (Jansuwan and Zander, 2021; Ruiz Salvago et al., 2019). In addition, we added the SOCIAL LIFE factor. WILLING TO GROW factor has associated with young farmers being highly motivated to seek productivity and tend to invest more to enhance their farms (Hamilton et al., 2015; Davis et al., 2013).

The young farmer problem is getting serious all over the world, whether the countries are developed or developing. Based on this, it has required reflection on whether the young farmers of two countries with different cultures, societies, different geological locations, as well different development levels, might be influenced by the same factors. The sub-question of the research is: What factors are common and different for young farmers in Turkey and Japan to continue their agricultural activities in the future? The young farmer is an important issue that needs to be addressed in both countries. Although Turkey has a high youth population, young people living in rural areas are rapidly leaving agriculture. Moreover, the aged population problem in Japan has apparent itself more strongly in the agriculture sector and triggered the food self-sufficiency problem, so it is a problem that needs to be seriously addressed. This research could essential contributions to the sustainability of food security and agricultural sustainability, as well as literature. However, it is believed that considering the two countries together in the research namely Turkey and Japan might add a different perspective to the young farmer problem in the literature. Hopefully, cooperation studies between different countries might contribute positively to the global image of agriculture in the future.

## Materials and methods

Quota sampling was used to obtain primary data from young farmers in İzmir and Niigata. Taking the age factor as the reference for quota sampling, surveys were conducted with the farmers in Turkey who were 20 to 40 years old, and in Japan who were aged 20 to 45 years old. These age ranges were specified by each country's young farmer definition. The Ministry of Agriculture and Forestry of Turkey has defined young farmers as those who are under 40 years, residing or wanting to reside in rural areas. And one of the conditions of the Ministry incentive called Youth Farmer Projects Support was to be less than 40 years old (The Ministry of Agriculture and Forestry of Turkey, 2018). According to Japan's Ministry of Agriculture Forestry and Fisheries, young farmers were specified as less than 45 years of age and it was one of the conditions for the Young Farmer's Fund incentive (MAFF, 2018).

According to the Farmer Registration System for İzmir, there were 47,000 farmers in 2017 (İzmir Directorate of Provincial Agriculture and Forestry, 2017), and there were 62,368 farmers in Niigata, according to the latest agricultural census (2015) (MAFF, 2015). In determining the sample size, using the proportional sampling method, for a finite population of size N, the sample volume formula according to the known or predicted proportion ($p$) of those with a particular characteristic is given

below (Newbold, 1995).

The sample size was determined as follows:

$$n = \frac{Np(1-p)}{(N-1)\sigma^2_{\hat{p}_x} + p(1-p)} \quad (1)$$

$n$ = Sample size

$N$ = Number of farmers in İzmir and Niigata (İzmir: 47,000; Niigata: 62,368)

$p$ = Young farmer proportion (taken as p = 0.50 to attain maximum sample volume)

$\sigma$ = Deviation of population (95% confidence interval and 10 % error margin)

A total of 200 young farmers were interviewed in both İzmir (96 + 4 with backup questionnaires = 100) and Niigata (96 + 4 with backup questionnaires = 100).

The survey form used in the research is composed of two main sections. The first section contains questions about young farmers' socio-economic characteristics and farming problems. The second section is made up of statement questions that determine factors affecting the willingness of young farmers to continue agricultural activities. And 7-point Likert scale (1 if strongly disagreed, 2 if disagreed, 3 if somewhat disagreed, 4 if neutral, 5 if somewhat agreed, 6 if agreed, and 7 if strongly agreed) was used to inquire about information on young farmers' willingness to continue agriculture in the future. The 7-point Likert scale was preferred as it could provide a more accurate measure of farmers` true assessment (Finstad, 2010).

Table 1 shows the independent variables that will affect the willingness of young farmers to continue agriculture (dependent variable).

The socio-economic characteristics of young farmers and the problems faced by young farmers were analyzed using descriptive statistics in SPSS 22.0. The logistic regression model estimated the factors affecting the willingness of young

| Variables | Description | Unit of measurement |
|---|---|---|
| **Dependent Variable** | | |
| FARMERPREF | 1 = young farmer is willing to continue agriculture 0 = otherwise | 1 = yes<br>0 = no |
| **Independent Variables** | | |
| AGE | The age of farmers | in years |
| SUBSIDIES | Benefiting from state subsidies when started farming | 1 = yes<br>0 = no |
| PROFESSION | Off-farming job | 1 = yes<br>0 = no |
| FARMLAND | Total cultivated area | in hectares |
| EXPERIENCE | Having agricultural experience before becoming a farmer | 1 = yes<br>0 = no |
| SOCIAL LIFE | I think workload continuity which is necessary for agricultural activities does not negatively affect my social life | 1 = strongly disagree<br>7 = strongly agree |
| RESPECTABLE | I think that the farming profession is seen as respected by society | 1 = strongly disagree<br>7 = strongly agree |
| FARMING IMPORTANT | I think that farming is seen as an important profession by society | 1 = strongly disagree<br>7 = strongly agree |
| WILLING GROW FARM | I think I am willing to enlarge my farming in the future | 1 = strongly disagree<br>7 = strongly agree |
| FARMING NOT TIRING | I think the farming profession is not a difficult and tiring profession | 1 = strongly disagree<br>7 = strongly agree |
| MULTIFUNCTIONAL | I think farming serves multifunctional such as protecting the environment, feeding the society | 1 = strongly disagree<br>7 = strongly agree |
| NOT NEED SUBSIDIES | I think that I can continue farming even without state subsidies | 1 = strongly disagree<br>7 = strongly agree |
| TECHFACILITATE | I think that developments in agricultural technology facilitate agricultural activities | 1 = strongly disagre<br>7 = strongly agree |

Source: Own processing

Table 1: Description of variables.

farmers to continue agriculture. The logistic regression model was preferred since the dependent variable is discrete, and the independent variable can take both discrete and continuous values. In the logistic regression model, the observed value of the dependent variable takes the value (1) if the farmer is willing to continue and (0) if the farmer is not willing to continue (Walker and Duncan, 1967).

The assumptions regarding the logistic regression models are briefly shown in the function below.

$$P_i = E\,(Y=1/X_i) = \alpha + \beta X_i \quad (2)$$

$$P_i = E\,(Y_i=1/X_i) = \frac{1}{1+e^{-(\alpha+\beta Xi)}} \quad (3)$$

$$= \frac{1}{1+e^{Zi}} \quad (4)$$

Here

$Z_i = \alpha + \beta X_i$

Equation (2) is called the logistic regression model, also known as the logit model (Park, 2013). Since the exponential term in the function will always be positive when $X$ takes any value, the lower limit of $P_i$ is also 0. This function fulfills $0 \leq P_i \leq 1$ condition required for probability. $\beta$ = coefficient, $\beta_i$ = the parameter to be estimated for each independent variable, $X_i$ = denotes the $i^{th}$ independent variable (İnal et al., 2006). The logit transformation of the nonlinear logistic regression function given in the equation can be applied and linearized.

$$L_i = \mathrm{Ln}\left(\frac{P(Y)}{1-P(Y)}\right) = \ln e^{\beta_0+\beta_1 X_1} = \beta_0 + \beta_1 X_1 \quad (5)$$

The linear model shows how much 1 unit of change in the independent variable x causes a change in the dependent variable. However, in the logit model, it shows how much change in logit is caused by 1 unit of change in $X$ (Aldrich and Nelson, 1984; Hosmer et al., 2013).

## Result and discussion

Descriptive and inferential statistics were used to assess young farmers' responses. Table 2 represents the socio-economic characteristics of young farmers in İzmir and Niigata. The average age of young farmers in İzmir was 32.45 years, and in Niigata was 34.62. It has been determined

| Variable | Description | İzmir (%) | Niigata (%) |
|---|---|---|---|
| Age | Min | 20 | 20 |
| | Max | 40 | 45 |
| | Mean | 32.45 | 34.62 |
| Education level | Primary | 14 | 0 |
| | Secondary | 32 | 0 |
| | High school | 43 | 17 |
| | 2 years collage | 9 | 27 |
| | Bachelor's degree | 2 | 53 |
| | Master's degree | 0 | 3 |
| Agricultural experience | Less than 1 year | 0 | 5 |
| | 1 to 5 years | 15 | 28 |
| | 5 to 10 years | 19 | 31 |
| | 10 to 20 years | 49 | 29 |
| | 20 years and more | 17 | 7 |
| Gender | Female | 7 | 32 |
| | Male | 93 | 68 |
| Having agricultural experience before becoming a farmer | Yes | 82 | 73 |
| | No | 18 | 27 |
| Off-farming job | Yes | 42 | 36 |
| | No | 58 | 64 |
| Benefiting from State supports | Yes | 69 | 52 |
| | No | 31 | 48 |

Source: Own calculations

Table 2: Characteristics of young farmers in İzmir and Niigata.

that the education level of the young farmers in Niigata (53% bachelor's degree) is higher than the education level of the young farmers in İzmir (43% High School). While 49% of young farmers in İzmir had agricultural experience between 10 and 20 years, 31% of young farmers in Niigata had agricultural experience between 5 and 10 years. In İzmir 7% of young farmers were female and 93% of farmers were male, while in Niigata 32% of young farmers were female, and 68% of young farmers were male. More than 70% of young farmers in both İzmir and Niigata stated that they had agricultural experience before starting as farmers. The study found that 42% of young farmers in İzmir and 36% of young farmers in Niigata have off-farm jobs. It has been determined that 69% of young farmers in İzmir province and 52% of young farmers in Niigata prefecture have benefited from state support provided for young farmers.

Most young farmers in İzmir (98%) and Niigata (97%) have been faced with agricultural problems while continuing their agricultural activities. It has been found that the problems faced by most young farmers in İzmir and Niigata are common. These problems were indicated as high production costs, an inability to spare time for a social life due to farming, and problems in agricultural marketing (Table 3).

Young farmers were asked if they would like to continue their agricultural activities in the future. And it has been found that 57% of young farmers in İzmir, and 89% of young farmers in Niigata are willing to continue their agricultural activities in the future.

The logistic regression model estimates young farmers' willingness to continue their agriculture activity based on explanatory variables. Table 4 shows the test of the models for İzmir and Niigata. The Hosmer and Lemeshow test of the goodness of fit suggests the model is a good fit to the data as ($p > 0.05$) for both Niigata and İzmir. For İzmir, the overall model was found to be statistically significant (Chi-squared value = 68.66, $p < 0.05$), with Nagelkerke R-squared value of .730, indicating 73% relationship between the predictor variable and the outcome variable. The overall percentage of correct recognition of the model is 76% accurate. For Niigata, the overall model was found to be statistically significant (Chi-squared value = 39.77, $p < 0.05$), with Nagelkerke R-squared value of .661, indicating 66.1% relationship between the predictor variable and the outcome variable. The overall percentage of correct recognition of the model is 93.8% indicating that the model provides a correct classification of the cases.

As a result of the logistic model, four factors affect the young farmers' likelihood of willingness to continue farming in the future for İzmir. These are as follows: I think that the workload continuity necessary for agricultural activities does not negatively affect my social life (SOCIAL LIFE, $p = 0.01$), I think I am willing to enlarge my farming in the future (WILLING GROW FARM, $p = 0.00$), I think that the farming profession is seen as respected by society (RESPECTABLE, $p = 0.01$), I think farming serves multifunctional such as protecting the environment, feeding the society (MULTIFUNCTIONAL, $p = 0.02$).

| Problems encountered | İzmir (%) | Niigata (%) |
|---|---|---|
| High production costs | 92 | 66 |
| Problems encountered in product marketing | 35 | 55 |
| The problem of not being able to spare time for social life due to farming | 66 | 49 |
| Cannot cultivate sufficiently sized agricultural land | 18 | 21 |
| Does not have own agricultural land | 13 | 16 |
| Inadequate agricultural machinery tools and equipment | 14 | 27 |
| Shortage of farm labor | 23 | 3 |
| Insufficiency of agricultural education | 6 | 25 |
| Underestimating farming profession | 4 | 11 |
| The inability of social activities in the rural areas | 25 | 7 |
| Transportation problems from residence to the urban areas | 5 | 0 |
| Lack of school, hospital around the residence areas | 7 | 0 |
| Physical challenges of farming | 14 | 7 |

Source: Own calculations

Table 3: The problems young farmers encounter problems while farming.

| | İzmir | | | Niigata | | |
|---|---|---|---|---|---|---|
| **Omnibus tests of model coefficients** | **Chi-square** | **df** | **Sig.** | **Chi-square** | **df** | **Sig.** |
| Step | 68,665 | 25 | ,000 | 39,774 | 21 | ,008 |
| Block | 68,665 | 25 | ,000 | 39,774 | 21 | ,008 |
| Model | 68,665 | 25 | ,000 | 39,774 | 21 | ,008 |
| **Model Summary** | **İzmir** | | | **Niigata** | | |
| -2 Log likelihood | 51,010[a] | | | 29,057[a] | | |
| Cox and Snell R square | ,546 | | | ,334 | | |
| Nagelkerke R square | ,730 | | | ,661 | | |
| | **İzmir** | | | **Niigata** | | |
| **Hosmer and Lemeshow test** | **Chi-square** | **df** | **Sig.** | **Chi-square** | **df** | **Sig.** |
| | 5,644 | 8 | ,687 | 2,593 | 8 | ,957 |

Note: [a] Estimation terminated at iteration number 20 because maximum iterations has been reached.

Source: Own calculations

Table 4: Test of models for İzmir and Niigata.

| Independent Variables Description | B | S.E. | Wald | df | Sig. | Exp(B) |
|---|---|---|---|---|---|---|
| PROFESSION | .013 | .562 | .001 | 1 | .982 | 1.013 |
| SUBSIDIES | 1.174 | 1.015 | 1.338 | 1 | .247 | 3.236 |
| SOCIAL LIFE | .348 | .142 | 6.003 | 1 | .014 | 1.416 |
| WILLING GROW FARM | .505 | .159 | 10.083 | 1 | .001 | 1.657 |
| NOT NEED SUBSIDIES | .218 | .124 | 3.081 | 1 | .079 | 1.243 |
| RESPECTABLE | .510 | .216 | 5.595 | 1 | .018 | 1.666 |
| TECHFACILITATE | .382 | .391 | .954 | 1 | .329 | 1.465 |
| MULTIFUNCTIONAL | -.610 | .277 | 4.853 | 1 | .028 | .543 |
| AGE | .077 | .052 | 2.210 | 1 | .137 | 1.080 |
| Constant | -6.337 | 3.273 | 3.750 | 1 | .053 | .002 |

Source: Own calculations

Table 5: Results of the logistic regression model for İzmir.

In the logistic regression model, Exp (B) value is known as the exponential value of B (coefficient of the variable) and is defined as an odds ratio. Therefore, the young farmers` agree change to one higher unit scale with the statements; I think that the workload continuity necessary for agricultural activities does not negatively affect my social life, they are 1.41 times, I think I am willing to enlarge my farming in the future, they are 1.65 times, I think that the farming profession is seen as respected by society, they are 1.66 times, more likely to be willing to continue farming in the future. However, the statement of the MULTIFUNCTIONAL B value is negative, and it was not as expected. Moreover, off-farming job (PROFESSION), benefiting from state subsidies when started farming (SUBSIDIES), farmer age (AGE), and the statements "I think that developments in agricultural technology facilitate agricultural activities" (TECHFACILITATE), and "I think that I can continue farming even without state subsidies" (NOT NEED SUBSIDIES), do not have a statistically significant effect on the willingness of young farmers to continue farming in the future (Table 5).

According to the results of the logistic model examined, seven factors affect young farmers' likelihood of willingness to continue farming in the future for Niigata. These are as follows: off-farming job (PROFESSION, $p$ = 0.02), total cultivated area (FARMLAND, $p$ = 0.03), benefiting from state subsidies when started farming (SUBSIDIES, $p$ = 0.01), I think that farming is seen as an important profession by society (FARMING IMPORTANT, $p$ = 0.01), I think that farming is not a difficult and tiring profession (FARMING NOT TIRING, $p$ = 0.02), I think that I can continue farming even without state subsidies (NOT NEED SUBSIDIES, $p$ = 0.04), I think that the farming profession is seen as respected

| Independent Variables Description | B | S.E. | Wald | df | Sig. | Exp(B) |
|---|---|---|---|---|---|---|
| PROFESSION | 3.868 | 1.691 | 5.233 | 1 | .022 | 47.857 |
| FARMLAND | .067 | .032 | 4.364 | 1 | .037 | 1.069 |
| SUBSIDIES | 3.827 | 1.551 | 6.089 | 1 | .014 | 45.913 |
| FARMING IMPORTANT | 2.364 | .925 | 6.527 | 1 | .011 | 10.638 |
| FARMING NOT TIRING | 1.682 | .735 | 5.233 | 1 | .022 | 5.375 |
| NOT NEED SUBSIDIES | 1.154 | .575 | 4.031 | 1 | .045 | 3.172 |
| RESPECTABLE | -1.833 | .740 | 6.141 | 1 | .013 | .160 |
| TECHFACILITATE | -.555 | .490 | 1.279 | 1 | .258 | .574 |
| EXPERIENCE | -.742 | 1.440 | .266 | 1 | .606 | .476 |
| AGE | -.086 | .086 | 1.006 | 1 | .316 | .917 |
| Constant | -10.819 | 5.404 | 4.008 | 1 | .045 | .000 |

Source: Own calculations

Table 6: Results of the logistic regression model for Niigata.

by society (RESPECTABLE, $p = 0.01$).

A significant difference was found between the young farmers who have off-farming job and those who have no off-farming job. Therefore, young farmers who have off-farming job are 47.85 times more likely to continue farming in the future. In addition, agricultural area harvested by young farmers was found as significant. Thus, young farmers who harvest one more unit of agricultural land, they are 1.06 times more likely to continue farming in the future. Young farmers who benefited from state subsidies when started farming have found a significant impact on their willingness to continue farming in the future. Therefore, young farmers who benefited from state subsidies when starting farming are 45.91 times more likely to continue farming in the future.

Furthermore, the young farmers' agree changes to one higher unit scale with the statement; I think that farming is seen as an important profession by society, they are 10.93 times, I think that farming is not a difficult and tiring profession, they are 5.37 times, I think that I can continue farming even without subsidies, they are 3.17 times, more likely to be willing to continue farming in the future. However, B value is negative of the statement RESPECTABLE, not as expected.

Having agricultural experience before becoming a farmer (EXPERIENCE), farmers age (AGE), and the statement "I think that developments in agricultural technology facilitate agricultural activities" (TECHFACILITATE), do not have a statistically significant effect on the willingness of young farmers to continue farming in the future, according to the logistic regression model established for the Niigata.

## Discussion

This study finds that İzmir's and Niigata's young farmers encountered common problems while farming. These problems are high production costs, marketing problems, and not being able to spare time for a social life due to farming. For the young farmers of both provinces, ensuring diversification of the marketing channels, especially directing them towards utilizing e-marketing channels, could facilitate the marketing of their agricultural products. Furthermore, the efficiency of cooperatives should be increased to reduce farm costs for young farmers. Cooperatives should be more active in young farmers' input supply, packaging, and marketing. In addition, agricultural policies for using innovative agricultural technologies might be implemented in both countries so that young farmers will decrease their workload. If appropriate governmental policies with using technology on farms incentives are laid down young educated people will move into agricultural farming were stated by Kwakye et al. (2021). It might be possible for young farmers to spare time for social life since the resources will be efficiently used, and labour productivity will be ensured on the farms where innovative agricultural technologies are utilized.

Although the agricultural problems faced by young farmers in İzmir and Niigata show similarities, the factors that affect young farmers' maintaining their agricultural activities indicate differences. Young farmers are willing to enlarge their farms, they can spare time for a social life during farming, and farming is seen as respected by society, these factors affect young farmers to continue farming in the future for İzmir. Girdziute et al. (2022) identified the factors of youth's motivation to work in agriculture toward their individual, economic,

and social perceptions case of Lithuania. They found that the opinion related to unsatisfactory social life in rural areas for young people was associated with decreased priority among young people to work in agriculture, similar to our result. In addition, 66% of the Lithuanian youth surveyed agree that a flexible work schedule can be a motivating factor for choosing to work in agriculture (Girdziute et al., 2022). Jansuwan and Zander (2022) have applied path analysis to examine what physical and psychological factors affect Thai young farmers' decisions to continue farming and how they farm. They found the full-time group farmers are the better-educated and younger ones, and they have positive attitudes towards farming and multiple non-monetary benefits. Multifunctional transitional processes in their farm business, provide safe and healthy food among the community's members and environmental benefits from more sustainable production. This result is related to our research however, we found B value of farming is multifunctional such as feeding society and protecting the environment (MULTIFUNCTİONAL) as negative. The reason might be that 43% of the young farmers' education level in high school is insufficient (only 2% of them being a bachelor's degree). This shows us that young farmers in İzmir might be less aware of the importance of farming, such as protecting the environment and feeding society. Extreme climatic events have increased in recent years, which may require farms to adapt to more sustainable practices, so it is important to provide awareness-raising policies to young farmers in this direction (Balezentis et al., 2020).

On the other hand, having support when they start farming, having an off-farming job, and increasing the harvested agricultural farmlands are more critical for young farmers to maintain their agricultural activity in the future for Niigata. With the increase in harvested agricultural land, young farmers will be able to earn higher incomes from agriculture. Girdziute et al. (2022) state that more than 73% of youth respondents agree that a higher salary could be the motivating factor for choosing to work in agriculture. In addition, Bubela (2016) argued in his research about off-farm income can sustain young farmers in smoothing the variability that farm income generates throughout the farm's economic cycle, expanding, and succeeding in agriculture. May et al. (2019) claimed that even when young farmers are highly motivated, economic conditions that negatively affect the agricultural sector can strengthen the decision to leave the farm. The effect of these economic factors on the agricultural activities of young farmers cannot be ignored.

According to the logistic regression model for İzmir, having support when young farmers start farming did not significantly affect their willingness to continue farming in the future. This might be because of the insufficient amount of support for young farmers who start farming in Turkey. Many studies are conducted in different parts of Turkey to evaluate Young Farmer Project (YFB) benefits. However, they stated that YFP in Turkey is insufficient (Tarhan et al., 2021; Çağlayan et. al., 2020; Özkan and Alkan, 2019; Gedik, 2019; Doğan et al., 2018; Unakıtan and Başaran, 2018). The payment for young farmers (PYF) scheme under the Common Agriculture Policy was introduced in 2014 to European farmers. Balezantis et al., (2020) found that analysis of the perceived benefits of the PYF scheme in Lithuania suggests this scheme mostly contributes to income level support, encourages investments, and continues farming activities. The PYF scheme has benefited small farmers, such as creating additional sources of income, helping in finding new markets for production, creating more opportunities for diversification of economic activity, determining the decisions to continue farming and to stay in the countryside, and encouraging the development of farming entities. Moreover, their finding matches Severini et al., (2016) about the importance of direct payments for small agricultural units for stabilizing their income (Balezantis et al., 2020). As the young farmers in İzmir encounter problems such as high production costs and marketing problems while farming, it is thought that it can provide a solution for young farmers in Izmir as well as in Lithuanian small farmers.

The problem of young farmers has become a common problem in all countries, and solutions have been sought with various financial support. The impact of financial support to attract young people to farming is undeniable. In addition, as well as financial factors also social influences also have an impact on young farmers to continue in agriculture. It has been found significant that the young farmers in Niigata and İzmir continue to farm in the future and that farming is regarded as a respected and essential profession by society. This shows us that when society perceives farming as a respected and important profession, young farmers might tend to farm and be willing to continue farming.

## Conclusion

This research was conducted in Japan and Turkey to estimate factors that affect young farmers' willingness to farm in the future. It is essential to support young farmers at the initial stage of farming. Therefore, to direct young people to agricultural activities, countries have tried to make farming more attractive with financial support. In addition, supporting young farmers to continue their agricultural activities is critical for sustainable agriculture and food security. To ensure that farmers continue agriculture in the future, it is necessary to understand the factors that affect these.

In this study, supporting young farmers when they start farming and increasing their farm incomes were essential for young farmers to continue agriculture in the future. Moreover, the result of this study supports that increasing the respectability and importance of farming in society provides young farmers to continue in agricultural activities. It should be emphasized that farming is a multifunctional profession, not only producing food but also an innovative, entrepreneurial, employer, and environmental protection. If countries can clarify the importance of farming and food production to young generations, they will make essential contributions to the sustainability of food security and agricultural sustainability. For future studies, cooperation between different countries might contribute positively to the global image of agriculture. Countries must retain educated young farmers and support agricultural activities to positively change the image of agriculture and use sustainable and innovative farming systems.

Ultimately, the research has limitations as the sample size of our study was relatively small and limited to specific provinces for both countries. While the methods can be applied elsewhere, the results may not be generalized across the country.

## Acknowledgments

This research was supported for the surveys conducted in Niigata province within the Global Age 2020 Project scope. Thank you to the Young Farmers in İzmir and Niigata for their cooperation.

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Agris on-line Papers in Economics and Informatics

Volume XV Number 2, 2023

# Resource Use Efficiency and Cleaner Agricultural Production: An Application of Technical Inefficiency Effects Model for Paddy Producing Zones of West Bengal

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## Abstract

It is possible to enhancement of agricultural productivity with environmental sustainability through efficient utilization of resources. This hypothesis is examined by the efficiency and the responsible factors for controlling inefficiency of the farms. The empirical analyses are conducted based on the secondary data of 14 960 farms scattered into five different paddy producing zones of West Bengal, India. The Efficiency estimates disclose that clayey soil texture zone is the most efficient and sandy and gravelly soil texture zone is the least efficient concerning paddy production. The study concludes with appropriate policy implications that the inefficiency on the part of the farms is caused by inefficient utilization of the chemical fertilizers, viz., nitrogen and potassium and insecticides and by the efficient utilization of this the farm can increase its productivity with environmental sustainability.

## Keywords

Paddy production, zonal efficiency, stochastic production frontier, technical inefficiency effects model, environmental sustainability.

Maity, S., Sinha, A., Rath, M. K. and Barlaskar, U. R. (2023) "Resource Use Efficiency and Cleaner Agricultural Production: An Application of Technical Inefficiency Effects Model for Paddy Producing Zones of West Bengal", *AGRIS on-line Papers in Economics and Informatics*, Vol. 15, No. 2, pp. 55-68. ISSN 1804-1930. DOI 10.7160/aol.2023.150205.

## Introduction

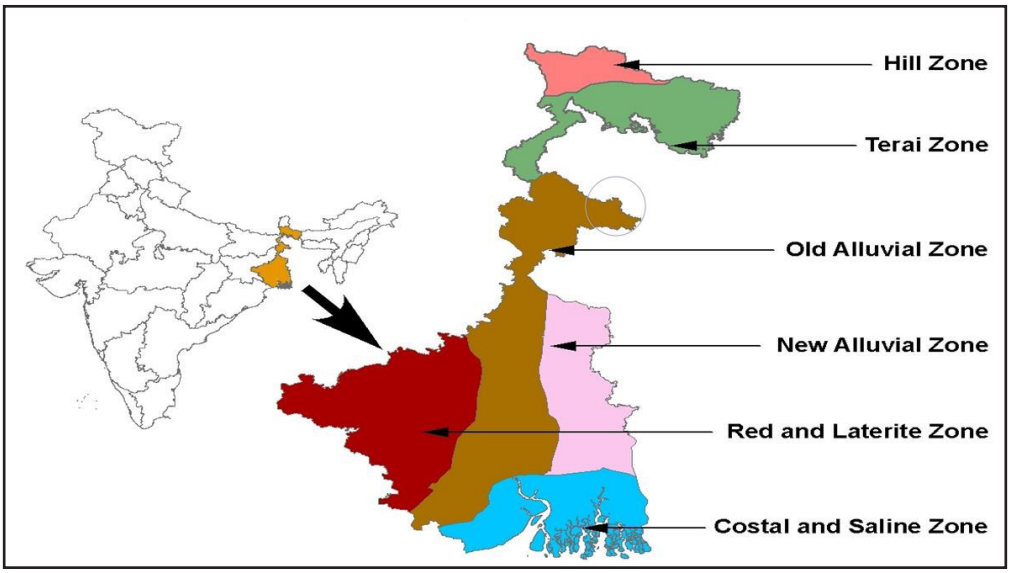
India is the second-largest paddy producer (with a production of 109.7 million tons in 2017) after China in the World (Kumari et al., 2018). According to the FAO report, rice production in India accounted for 178.3 million metric tons in 2020 and Indian rice exports touched 14.46 million tons in 2020, including 11.56 million ton of non-Basmati rice. India is the world's largest rice exporting country. West African country Benin is one of the major importers of non-basmati rice from India. Other destination countries are Nepal, Bangladesh, China, Cote D' Ivoire, Togo, Senegal, Guinea, Vietnam, Djibouti, Madagascar, Cameroon, Somalia, Malaysia, Liberia U.A.E. etc. In 2020-21, India increases export non-basmati rice to Timor-Leste, Puerto Rico, Brazil, Papua New Guinea, Zimbabwe, Burundi, Eswatini, Myanmar and Nicaragua. Basmati rice major destination countries are Saudi Arab, Iran, Iraq, Kuwait, UK, USA, Oman, Canada etc. West Bengal is the highest non-basmati rice producing state in India.

Globally main inputs for high-yielding paddy cultivation are chemical fertilizers and nitrogen (N), phosphorus (P), and potassium (K) are the most applied nutrient for paddy production. One-ton rough paddy production requires about 15-20 kg of mineral N, 11 kg $P_2O_5$, and 30 kg $K_2O$ (Roy et al., 2006). Since N use efficiency is very poor in paddy (Zhang et al., 2015), about 50%-70% of added N is lost as $N_2O$, $NO_3$, and $NH_3$ to air and water and contributes to environmental degradation. Freshwaters receive around 39-95 Tg N/year from agricultural soils (Voss et al., 2011). The impact of the application of synthetic fertilizers on increasing crop productivity and ensuring food surplus has been broadly accepted in the past (McArthur and McCord, 2017). However, excessive application of synthetic fertilizers to support increased productivity in certain regions around the globe is alarming for environmental sustainability (Cheng et al., 2019; Ren et al., 2021). Reactive nitrogen is a highly volatile element, and it diffuses through air and water (Erisman et al., 2013). The problems of nitrate leaching and runoff

to water bodies can cause environmental degradation (Vitousek et al., 2009). Many past studies have documented incontestable environmental costs (Norse and Ju, 2015) and human health-related economic costs (Gourevitch et al., 2018; Wang and Lu, 2020) because of nitrogen application in crop production. Appropriate input use in crop production is one of the pillars of agricultural sustainability (Zhang et al., 2015). Thus, a cleaner production helps in achieving the balance between the goals of crop productivity and long-term environmental sustainability is required while applying chemical fertilizer. The combination of manure and optimal chemical fertilizer application has positive impacts on soil health through changes in soil organic carbon content and microbial and enzyme activities (Ozlu et al., 2019). In our study, we consider the single Indian state, West Bengal as it is the highest paddy producing state in India (Maps of India, 2016). The West Bengal is divided into six paddy producing zones (see Figure 1 for details). This paddy producing zones are traditionally made by cross-comparing elements such as air temperature, rainfall, water deficit and soil texture. The main soil texture of Terai, Old Alluvial, New Alluvial, Red & Laterite and costal Saline paddy producing zones are sandy & gravelly, sandy loam, clayey, red & laterite and clayey loams respectively. These six zones divide West Bengal **six agro-climatic zones**.

It is important to examine whether the farm is operating efficiently or not. As efficient utilisation of the scarcer resources will result larger output with same inputs or same out with lower inputs. In both cases the farm will enjoy higher profit. This environment persuades us to reconnoitre the research question: does efficient utilisation of the scarce and costly resources enable the farm to achieve the goal of clean production, which guarantees increasing productivity with environmental sustainability? This question has twin research objectives. Initially, the efficiency of the different paddy producing zones is compared in this study and then explains the major causes of inefficiency of the paddy producing farms in West Bengal. This analysis explores whether farms are utilising chemical fertilizers and insecticides efficiently or not. As inefficient utilisation of chemical fertilizers and insecticides, not only reduces the productivity of the concerned farm also responsible for environmental degradation, means dirty production scenario. The novelty of the study lies in the fact that where resource use efficiency is investigated to manage the balance between farm productivity and environmental sustainability. Thus the uniqueness of the study is in terms of specified objectives, methodology and the choice of the study area.

The present paper is structured in an aforesaid way: after the introduction section, in Section 2, we have discussed the materials and methods utilised to explore the mentioned objectives. The empirical results are presented in Section 3. The section 4 is followed by the discussion which presents possible reasons for such empirical results. Finally, the conclusion and policies for clear production are presented in Section 5.




Source: Google map

Figure 1: Agro climatic zone of West Bengal.

## Materials and methods

The data sources to explore the said objectives empirically and the theoretical underpinning are discussed in this section. The econometric model for investigating the objectives is also presented in this section.

### Econometric model

The stochastic production function for the panel data is presented as follows:

$$y_{it} = \exp(x_{it}\beta + \varepsilon_{it}) \quad (1)$$

Where $y_{it}$ denotes the production of the $i^{th}$ ($i$ = 1,2,…., $N$) farm at $t^{th}$ ($t$ = 1,2,…, $T$) time period.

$x_{it}$ is the ($1Xk$) vector of quantities of inputs for the $i^{th}$ ($i$ = 1,2,…., $N$) farm at $t^{th}$ ($t$ = 1,2,…, $T$) time period. $\beta$ is the ($kX1$) vectors of unknown parameters which are to be estimated. $\varepsilon_{it}$ is the random disturbances of the $i^{th}$ ($i$ = 1,2,…., $N$) farm at $t^{th}$ ($t$ = 1,2,…, $T$) time period.

Following Aigner et al. (1977), Meeusen and van den Broeck (1977), the disturbances are assumed as follows:

$$\varepsilon_{it} = V_{it} - U_{it} \quad (2)$$

The are assumed to be distributed as iid $N(0, \sigma^2_V)$. It captures random variation in output due to some uncontrolled, suchlike weather, etc. On the contrary, $U_{it}$ s are non-negative disturbances reflecting *technical inefficiency* in production. It is assumed to be independently distributed. In the present study it is assumed to follow truncated normal distribution with mean $z_{it}\delta$ and variance $\sigma^2_U$ (Battese and Coelli, 1995). Here $z_{it}$ is a vector of ($1Xm$) vectors of independent variables. These explanatory variables represent the factors responsible for farm's controllable technical inefficiency. $\delta$ is the ($mX1$) vector of unknown parameters. $V_{it}$ and $U_{it}$ individually as well as mutually independent.

Consequently, the stochastic frontier production function can be written as:

$$y_{it} = \exp(x_{it}\beta + V_{it} - U_{it}) \quad (3)$$

Equation 3 represents the production function depicting the relationship between output and inputs. On the contrary, the $U_i$, the technical inefficiency effects are presented here as the function of several explanatory variables $z_{it}$ along with the unknown vector coefficients $\delta$. The variables included $z_{it}$ in may be recognized as inputs but they cannot be identified as inputs in the traditional sense, rather these inputs are used for obtaining better and greater quantity of output. Following Battese and Coelli (1995), corresponding to Equation 8, the technical inefficiency effects is specified as follows:

$$U_{it} = z_{it}\delta + \omega_{it} \quad (4)$$

The random variable, $\omega_{it}$ *Truncated normal* $(0, \sigma^2_U)$ such that the point of truncation is $-z_i\delta$, that is, $\omega_{it} \geq -z_{it}\delta$. Thus $U_{it}$ follow a non-negative truncation of the $N(z_i\delta, \sigma^2_U)$ distribution. The technical efficiency of the production of $i^{th}$ ($i$ = 1,2,…., $N$) farm at $t^{th}$ ($t$ = 1,2,…,$T$) time period is defined as:

$$TR_{it} = \exp(-U_{it}) = \exp(-z_i\delta - \omega_{it}) \quad (5)$$

For estimating simultaneously, the parameters of Equation 3 and 5, the most appropriate method is maximum likelihood estimation technique. The corresponding variance parameters are defined as:

$\sigma^2 = \sigma^2_V + \sigma^2_U$ and $\gamma = \frac{\sigma^2_U}{\sigma^2}$, where $\gamma$ lies between 0 and 1 depending on the dominance of $\sigma$ and $\sigma_U$ respectively (Battese and Coelli, 1995). All these parameters are estimated by using FRONTIER-4.1 programme (Coelli, 1996).

### Pesaran's test for cross sectional independence

Earlier studies based on panel data conclude that panel data models probably "exhibit substantial cross-sectional dependence in the errors" (Baltagi, 2005; and Pesaran, 2006). Such interdependencies will not only make the estimators biased but also inconsistent. Accordingly, it is always recommended before applying the panel data model one should test the independence of the cross-sectional error. In this regard, Pesaran, (2006), test is widely recommended. The null and alternative hypotheses are specified as follows:

$H_0$: The error term ($u_{it}$) is assumed to be independent and identically distributed across the cross-sectional unit and over-time.

$H_1$: The error term may be correlated across the cross-section.

The rejection of the null hypothesis or conversely the acceptance of the alternative hypothesis indicates serial correlation.

### Data

The study is entirely based on secondary data. The principal data source is "the Directorate of Economics and Statistics, the Department

of Agriculture and Farmers Welfare, the Ministry of Agriculture and Farmers Welfare, the Government of India". The data includes 14 960 numbers of farm-level information including five different agro-climatic zones. The information concerning the relevant variables is in the monetary (US $) form of current prices for uniformity of our study.

## Variables

To facilitate the empirical analysis, we need three types of variables. Firstly, we need a pertinent output variable. Secondly, we need an explicit set of inputs which have a strong footprint on the production. Finally, we need a specific set of inputs which have a strong influence on output however, not implicitly recognised as necessary and sufficient for production. These variables are categorized as exogenous variables.

### Output variable

West Bengal is recognized as the largest producer and consumer of paddy in India. More than 13% in 2016-17 of total paddy production in India is contributed by West Bengal (Maps of India, 2016). Accordingly, we consider paddy production as our output indicator. The inter-zonal comparison of efficiency in producing paddy is only possible if we could identify the proper output indicator. Based on earlier literature on agricultural efficiency (Battese and Coelli, 1995; Ahmed et al., 2018) we consider "Paddy production in Quantile per hectare", that is, paddy productivity as the output variable. Besides that, we can consider the total value of produced paddy or total quantity of paddy production by the farm as an output variable. In both cases there are problems. If we consider the total value of paddy as output, then zonal price variation may affect the output variable. Moreover, transportation costs from farm to market may cause a difference in the prices. On the contrary, if we consider total quantity as output we may end up with larger output that may be a result-end of a large operational landholding. Accordingly, we consider paddy productivity as the output variable for the present study.

### Input variables

To specify the production frontier after identification of the output variable we need to specify an appropriate set of inputs. Traditionally, labour and capital are considered as the two important inputs and following that traditional concept here also we have considered, any kind of labour and machineries utilized for production as inputs. Concerning inputs, we have two alternatives; either we can use the monetary expenditures on inputs or the physical inputs. It is noteworthy that the prices of the enlisted inputs are determined centrally and consequently if the monetary expenditures on the inputs are available it is always preferable to use them as inputs (Tiedemann and Latacz-Lohmann, 2013). Moreover, as the study is based on panel data the amount of physical inputs may be non-available for one or two periods. Such incidences may compel us to drop that period. The availability of the balance sheets enables us to collect all input related statistics in monetary terms. Accordingly, we consider all input variables in value terms (monetary value) in current prices for uniformity of our study. The list of the input variables along with their definition is furnished in Table 1.

We have considered Seed Value (US$), to address the quality of the paddy seeds. Here, seed value is in direct relation with the quality of the seed.

| Variables | Definition | Category |
|---|---|---|
| Product (Qtls.)($y$) | Paddy production in Quantile per hectare. | --- |
| ln($y$) | Natural logarithm form of rice production per hectare. | Output |
| Family Labour (US$) ($FL$) ($x_1$) | A system in which several members of the household including children are involves in agricultural activities and they are not financially sound to hire labour. | Input |
| Attached Labour (US$) ($AL$)($x_2$) | These type labourers are attached to some cultivator household on the basis of a written or oral agreement. Their employment is permanent and regular. | Input |
| Casual Labour (US $) ($CL$) ($x_3$) | This type of labourers are free to work on the farm of any farmer and payment is generally made to them on a daily basis. | Input |
| Hired Animal Labour ($HAL$) (US $) ($x_4$) | The farmers are hired animal for agricultural activity and paid hired charger. | Input |

Source: Authors' own specification based on data from the Directorate of Economics and Statistics, the Department of Agriculture and Farmers Welfare, the Ministry of Agriculture and Farmers Welfare, the Government of India.

Table 1: Descriptions of the variables. (To be continued).

| Variables | Definition | Category |
|---|---|---|
| Owned Animal Labour (US $) (*OAL*) ($x_5$) | The farmers are used their own animal for agricultural activities. | Input |
| Hired Machine (US $) (*HM*)($x_6$) | The farmers are hired machine for agricultural activity like combine harvester, rotary tiller, plough, tractor trailer, power harrow, leveler, ripper machine and dice harrow etc. and paid hired charges. | Input |
| Own Machine (US $) (*OM*)($x_7$) | The farmers are used their own machine for agricultural activities. | Input |
| Own Irrigation Machine (US $) (*OIM*)($x_8$) | The farmers are used their own irrigation machine for agricultural activities. | Input |
| Hired Irrigation Machine (US $) (HIM) ($x_9$) | The farmers are hired irrigation machine for agricultural activities and paid hired charges. | Input |
| Canal and Other Irrigation Charges (US $) (*OIC*) ($x_{10}$) | The farmers are paid charges for use of others people's source of water for agricultural activity. | Input |
| Seed Value (US $) (SV) ($x_{11}$) | Cost of high yielding seeds which in agriculture by the farmer. | Input |
| Fertiliser (N) (US $) (*N*) ($z_1$) | Nitrogen based fertilizer. It plays an important role in crop plant. It is involved in various critical process, such as growth, leaf area-expansion and biomass-yield production. | Exogenous |
| Fertiliser (P) (US $) (*P*) ($z_2$) | Phosphorus based fertilizer. It plays a role in plant development and, subsequently flower development. | Exogenous |
| Fertiliser (K) (US $) (*K*) (($z_3$) | Potassium based fertilizer. It is used in agriculture land to increase crop yield as proper amount of potassium in soil can enhance root growth, improve drought resistance, active many enzyme systems. | Exogenous |
| Other Fertiliser (US $) (*OF*) ($z_4$) | Other fertilizer except NPK | Exogenous |
| Manure (US $)($z_5$) | Waste matter from animals that is mixed with soil to improve the soil health and help plants grow. | Exogenous |
| Insecticides (US $) ($z_6$) | Insecticides are substances used to kill insects. They are used primarily in agriculture to control pests that infest crop. | Exogenous |

Source: Authors' own specification based on data from the Directorate of Economics and Statistics, the Department of Agriculture and Farmers Welfare, the Ministry of Agriculture and Farmers Welfare, the Government of India.

Table 1: Descriptions of the variables. (Continuation).

**Exogenous variables**

It is a well-established fact that having all necessary inputs in sufficient quantities does not ensure that we end up with an efficient amount of output (Battese and Coelli, 1995). Other than acts of God sometimes farms make inefficient utilization of some scarce and expensive resources resulting in inefficiency in the production process and the farm ends up with an output level lower than the desirable or frontier output level. Such inefficiencies on the part of the farm are controllable and efficient utilization of such resources not only escalates the farm's production (or technical) efficiency but reduce costs of production also enables the farm to operate on the cost frontier and makes it cost-efficient. These variables by no means are necessary for production and thus cannot be included in the traditional inputs set. We termed them exogenous variables. We have included these variables to facilitate the inefficiency effects analysis.

As the primal concern of the present paper is to detect the consequences of the uses of chemical fertilisers and insecticides in the agricultural production of West Bengal on the environment, we have considered expenditures on three major chemical fertilizers, viz., nitrogen, phosphorus, and potassium (NKP) uses in the main agricultural product (paddy) in West Bengal separately as three inefficiency effects variables. Along with this, we also consider expenditures on chemical insecticides as an added inefficiency effects variable. The rest two inefficiency effects variables are expenditures on manure and other fertilizers.

The complete lists of exogenous variables along with their detailed descriptions are presented in the Table 1.

After recognizing the output, inputs and exogenous variables for the present study the equations of the model are presented as follows:

$$\ln(y_{it}) = \alpha_0 + \alpha_{FL}\ln(\mathrm{FL}_{it}) + \alpha_{AL}\ln(\mathrm{AL}_{it}) + \alpha_{CL}\ln(\mathrm{CL}_{it}) + \alpha_{HAL}\ln(\mathrm{HAL}_{it}) + \alpha_{OAL}\ln(\mathrm{OAL}_{it}) + \alpha_{HM}\ln(\mathrm{HM}_{it}) + \alpha_{OM}\ln(\mathrm{OM}_{it}) + \alpha_{OIM}\ln(\mathrm{OIM}_{it}) + \alpha_{HIM}\ln(\mathrm{HIM}_{it}) + \alpha_{OIC}\ln(\mathrm{OIC}_{it}) + \alpha_{SV}\ln(\mathrm{SV}_{it}) \quad (6)$$

Where, ln is the natural logarithm (i.e., to the base e).

The technical inefficiency effects equation is presented as follows:

$$U_{it} = \delta_N \ln(N_{it}) + \delta_K \ln(K_{it}) + \delta_P \ln(P_{it}) + \delta_{OF} \ln(OF_{it}) + \\ + \delta_{Manure} \ln(Manure_{it}) + \delta_{Insecticides} \ln(Insecticides_{it}) \quad (7)$$

Both the equations are estimated by using FRONTIER 4.1, developed by Coelli, (1996).

## Results and discussion

The empirical findings are analyzed in this section.

### Pesaran's test for cross sectional independence

The test result is presented in the Table 2 and it is obtained by using the STATA-12.

The table discloses that the value of Pesaran's test of cross-sectional independence is -1.404 and the corresponding probability is 0.1602. The value of the "Average absolute value of the off-diagonal elements" is 0.448. The test result empowers us not to reject the null hypothesis, which implies no cross-sectional dependence. Accordingly, we proceed to the empirical exploration of our said objectives.

### Technical Efficiency estimates of different zones of West Bengal producing paddy

Our empirical analysis is concentrated only in five agro-climatic zones of West Bengal. Based on the availability of the data we have measured the technical efficiency of the paddy producing farms over the period 2013-14 to 2017-18. The Table 3 presents the results of technical efficiency across agro-climatic zones over the study period.

The panel mean efficiency scores, as well as the overall mean efficiency scores, are also mentioned in the table. The ranking of the different paddy producing agro-climatic zones is done based on the panel mean efficiency scores. The comparisons across paddy producing agro-climatic zones are performed considering overall mean efficiency as the benchmark (Maity, 2017; Maity and Singh, 2021). Accordingly, a paddy producing agro-climatic zone is recognized as relatively technically efficient if the efficiency score of the concerned paddy producing agro-climatic zone exceeds the "overall mean efficiency" and vice-versa. This benchmark results in three zones out of five zones being technically efficient. Accordingly, sixty per cent of the paddy producing agro-climatic zones is technically efficient. In the initial period, 2013-2014 the Old Alluvial zone was the most efficient (0.991). On the contrary, in the concerned period, Coastal Saline (0.856) was the least efficient zone. It is noteworthy that the Old Alluvial zone remains the most efficient paddy producing zone for the entire study period. Concerning the least

| Pesaran's test of cross sectional independence | Average absolute value of the off-diagonal elements | Probability |
|---|---|---|
| -1.404 | 0.448 | 0.1602* |

Note: *Evidence shows data are cross-sectionally independent

Source: Authors' own calculation based on data from the Directorate of Economics and Statistics, the Department of Agriculture and Farmers Welfare, the Ministry of Agriculture and Farmers Welfare, the Government of Indiaand Farmers Welfare, the Ministry of Agriculture and Farmers Welfare, the Government of India

Table 2: Pesaran's test of cross sectional independence.

| Year → / Zone ↓ | 2013-2014 | 2014-2015 | 2015-2016 | 2016-2017 | 2017-2018 | PME* | Ranking |
|---|---|---|---|---|---|---|---|
| II-Terai | 0.867 | 0.974 | 0.980 | 0.945 | 0.862 | 0.926 | 5 |
| III-New Alluvial | 0.979 | 0.972 | 0.980 | 0.926 | 0.963 | 0.964 | 3 |
| IV-Old Alluvial | 0.991 | 0.996 | 0.996 | 0.995 | 0.993 | 0.994 | 1 |
| V- Red & Latterite | 0.907 | 0.978 | 0.988 | 0.989 | 0.986 | 0.970 | 2 |
| VI- Coastal Saline | 0.856 | 0.891 | 0.990 | 0.948 | 0.983 | 0.934 | 4 |
| Mean Efficiency (Yearly) | 0.920 | 0.962 | 0.987 | 0.961 | 0.957 | --- | --- |
| Mean Efficiency (Overall) | | | | | | | |

Note: *Panel Mean Efficiency of the zones

Source: Authors' own calculation based on data from the Directorate of Economics and Statistics, the Department of Agriculture and Farmers Welfare, the Ministry of Agriculture and Farmers Welfare, the Government of Indiaand Farmers Welfare, the Ministry of Agriculture and Farmers Welfare, the Government of India

Table 3: Technical Efficiency estimates of different zones of West Bengal producing paddy.

efficient region, our observation is that during 2013-14 and 2014-15, the Coastal Saline zone was the least efficient on the list. For the next two time periods (2015-16 and 2016-17) New Alluvial zone became the least efficient paddy producing zone of West Bengal. However, during 2017-18, the Terai region becomes the least efficient on the list. Based on the panel mean efficiency (PME) scores we conclude that the Old Alluvial zone is the most efficient paddy producing zone of West Bengal while Terai is the least efficient.

However, it is noteworthy that the ranking of the paddy producing zones of West Bengal based on efficiency score only shows the relative performance of the concerned zone and does not designate any hierarchy concerning production. For instance, the relative "panel mean efficiency" score for the New Alluvial zone is 0.964 and the zone was recognised as the least efficient during 2015-16 and 2016-17. The Gangetic alluvial region especially the New Alluvial zone consists of Nadia, East-Bardhaman, Howrah and Hooghly and thus the third and fourth topper paddy producing districts are located here. In fact, the individual performances of these districts considering paddy production are really appreciating. The efficiency score of the paddy production system stipulates that if the New Alluvial zone could operate its paddy production system as efficiently as the Old Alluvial zone, the zone could have escalated its production as much as the current total production of the Old Alluvial zone.

Paddy in West Bengal is cultivated in 18 different districts of West Bengal. Among these 18 districts 4 districts, viz., Burdwan, Birbhum, Nadia and Hoogly belong to the high productivity group. Accordingly, two districts viz., Burdwan and Birbhum are in the Old Alluvial zone while two other districts, viz., Nadia and Hoogly are in the New Alluvial zone. Even after this New Alluvial zone is not ranked second in the list considering overall panel mean efficiency. Therefore, there must be some inefficiency lies in the execution of the existing technology which aggravates the differences in the technical efficiency of paddy production. The absence of such a study makes it impossible to cross-check the result with earlier studies. The Old Alluvial zone includes Siliguri Subdivision (Darjeeling), Dakshin Dinajpur, Malda, Murshidabad, Nadia, North 24-Parganas, Hooghly, Burdwan, Bankura, Birbhum, Paschim Medinipur. These districts are recognised as the paddy producing hub for West Bengal. In fact, the top two paddy producing districts of West Bengal are Burdwan and Birbhum (West Bengal, 2001). These two districts are in the Old Alluvial zone. On the contrary, the political constitution of the Terai and Dooars region includes different parts of three different districts of West Bengal, viz., the plains of Darjeeling District, the whole of Jalpaiguri and Alipurduar district and the upper region of Cooch Behar District. These districts are considered less fertile concerning paddy. Accordingly, our efficiency results are confirmed with reality.

### Stochastic Frontier Model: factors affecting efficiency

The stochastic frontier production function as presented by equation (6) can be viewed as the log-linearised version of the Cobb-Douglas production function. The maximum-likelihood estimators along with the estimated standard errors of equations are presented in the Table 4.

The absence of multicollinearity is confirmed by the Table A.1 in Appendix. The empirical estimates concerning stochastic production function reveal that the estimated coefficient of the inputs Attached Labour (US $), Owned Animal Labour (US $), Hired Machine (US $), Own Machine (US $), Own Irrigation Machine (US $) are statistically meaningful with expected sign. The estimated coefficients of the above-mentioned input variables indicate that an escalation of the expenditures on these inputs helps in the expansion of paddy productivity. The estimated coefficient Attached Labour (US$) is statistically significant with a positive sign. The Attached Labour (US$) is a replica of hired labour and consequently hired labour has a positive influence on productivity. Even after the modernization of the technology in agriculture, in West Bengal use of bullock labour in agriculture is still significant. Accordingly, we find the estimated coefficient of expenditure on the purchase of animal labour is in positive relation to output and the result is also statistically meaningful. In fact, ownership of animal labour has a beneficial effect on the paddy productivity across different zones of West Bengal (Shanmugam and Sundararajan, 2008). It is interesting to note that machineries have a strong influence on the paddy productivity across zones of West Bengal. As such both the estimated coefficients on the expenditures of machineries (own and hired) help in escalating the paddy productivity across zones. Moreover, we are 99% confident about the effectiveness of these results. These estimated coefficients

| | Variables | Coefficients | | S.E | t-ratio |
|---|---|---|---|---|---|
| | Constant | $\beta_0$ | 0.389 | 1.211 | 0.321 |
| Family Labour (US $) (*FL*) ($x_1$) | $\ln(x_1)$ | $\beta_1$ | 0.003 | 0.049 | 0.053 |
| Attached Labour (US $) (*AL*)($x_2$) | $\ln(x_2)$ | $\beta_2$ | 0.013* | 0.007 | 1.939 |
| Casual Labour (US $) (*CL*) ($x_3$) | $\ln(xx_3)$ | $\beta_3$ | 0.099 | 0.139 | 0.707 |
| Hired Animal Labour (*HAL*) (US $) ($x_4$) | $\ln(x_4)$ | $\beta_4$ | 0.009 | 0.011 | 0.824 |
| Owned Animal Labour (US $) (*OAL*) ($x_5$) | $\ln(x_5)$ | $\beta_5$ | 0.012* | 0.007 | 1.662 |
| Hired Machine (US$) (*HM*)($x_6$) | $\ln(x_6)$ | $\beta_6$ | 0.259*** | 0.107 | 2.424 |
| Own Machine (US$) (*OM*)($x_7$) | $\ln(x_7)$ | $\beta_7$ | 0.021*** | 0.007 | 2.848 |
| Own Irrigation Machine (US $) (*OIM*) ($x_8$) | $\ln(x_8)$ | $\beta_8$ | 0.016*** | 0.003 | 5.544 |
| Hired Irrigation Machine (US $) (*HIM*) ($x_9$) | $\ln(x_9)$ | $\beta_9$ | 0.004 | 0.01 | 0.355 |
| Canal and Other Irrigation Charges (US $) (*OIC*) ($x_{10}$) | $\ln(x_{10})$ | $\beta_{10}$ | 0.014 | 0.013 | 1.073 |
| Seed Value (US $) (*SV*) ($x_{11}$) | $\ln(x_{11})$ | $\beta_{11}$ | -0.212*** | 0.082 | -2.597 |
| Fertiliser (N) (US $) (*N*) ($z_1$) | $\ln(z_1)$ | $\delta_1$ | 2.02E-04* | 1.08E-04 | 1.876 |
| Fertiliser (P) (US $) (*P*) ($z_2$) | $\ln(z_2)$ | $\delta_2$ | 9.87E-05** | 4.96E-05 | 1.99 |
| Fertiliser (K) (US $) (*K*) ($z_3$) | $\ln(z_3)$ | $\delta_3$ | 2.21E-04 | 1.28E-04 | 0.947 |
| Other Fertiliser (US $) (*OF*) ($z_4$) | $\ln(z_4)$ | $\delta_4$ | -8.09E-04*** | 3.76E-04 | -2.154 |
| Manure (US $)($z_5$) | $\ln(z_5)$ | $\delta_5$ | -9.25E-07 | 2.95E-05 | -0.031 |
| Insecticides (US $) ($z_6$) | $\ln(z_6)$ | $\delta_6$ | 1.61E-04*** | 5.38E-05 | 2.997 |
| | $\hat{\sigma}_s^2$ | | 0.002*** | 0.001 | 2.421 |
| | $\gamma$ | | 0.472*** | 0.157 | 2.999 |
| | $\mu$ | | 0.306*** | 0.112 | 2.74 |
| | **Log(likelihood)** | | -49.538 | | |
| | **LR test** | | 14.166 | | |

Note: ***, **, * are significant at 1%, 5% and 10% level

Source: Authors' own calculation based on data from the Directorate of Economics and Statistics, the Department of Agriculture and Farmers Welfare, the Ministry of Agriculture and Farmers Welfare, the Government of Indiaand Farmers Welfare, the Ministry of Agriculture and Farmers Welfare, the Government of India

Table 4: Maximum likelihood estimates of the stochastic production frontier function of different zones of West Bengal producing paddy.

concerning machineries reveal that escalations in the expenditures on the agricultural machineries help in enhancing paddy productivity across zones. We observe that the expenditures for purchasing the irrigation machineries have a positive influence on the paddy productivity. It is interesting to note that irrigation is important as disclosed by the value of the corresponding t-coefficient of "Own Irrigation Machine (US$)" and "Canal and Other Irrigation Charges (US$)". In both cases the corresponding t-statistics exceed unity. The ownership of irrigation machineries is also important as revealed by the fact that the estimated coefficient of "Hired Irrigation Machine (US$)" is not only low in value but also the corresponding t-statistics is very low. Another input variable "Seed value" is in negative relation with the paddy productivity. The estimated coefficient stipulates that a 1% increase in the expenditures for seed reduces paddy productivity by 0.212% and we are 99% confident about the effectiveness of the result.

We next consider the particular interest of this study, that is, the estimated coefficients of the inefficiency effects model. Altogether we have considered six inefficiency effects variables. As our objective is to explore the consequences of the use of chemical fertilizers on agriculture as well as the environment, we have considered the expenditures on three major chemical fertilizers used in the paddy production in West Bengal as inefficiency effects variables. Among these three variables the estimated coefficients of the expenditures on nitrogen, and potassium are statistically meaningful. However, all these three variables are in positive relationships with the controllable inefficiency of the farm. This implies that the excessive expenditures on these chemical fertilisers result in a reduction of the paddy producing efficiency of the farm. Thus reducing the utilisation

of these chemical fertilizers, particularly, nitrogen, and potassium will make the farm more production (technical) efficient. A similar result we obtain for the inefficiency effect variable, insecticides. An increase in the expenditures on insecticides reduces the production (technical) efficiency of the farm. The corresponding estimated coefficient is significant at the 1% level. The negative sign of the expenditures on other fertilizers motivates us to encourage the farmers to use more of these types of fertilizers for paddy production. The estimated coefficient reveals that an escalation of the expenditures on other fertilizers helps the farm to approach the frontier by controlling the farm level inefficiency in paddy production. This result is supported by another estimated coefficient expenditure on manure, although the estimated coefficient is statistically insignificant.

The authors next consider the possible reason behind these empirical results.

**Discussion**

The stochastic production frontier depicts the traditional input-output relationship and our finding is that expenditures on Attached Labour (US $) are in a positive relationship with the total paddy productivity. Here Attached Labour (US $) is a replica of the hired labour. This result supports the view of Bharadwaj (1974), and Rudra and Mukhopadhya (1976). Accordingly, we conclude that Attached Labour (US$) (hired labour) is more efficacious for escalating the agricultural productivity than family labour as hired labour diminishes the likelihood of disguised unemployment in the agricultural sector which is supposed to be the dominant characteristic of Indian agriculture. Cultivation practices in India, particularly in West Bengal are dominated by the use of bullock labour. Consequently, our empirical results evidence that ownership of animal labour (Owned Animal Labour (US $) is one of the primary determinants of the paddy productivity across zones of West Bengal (Shanmugam and Sundararajan, 2008). Our input based findings reveal that machineries in any form are the preeminent factor for enhancing paddy productivity across paddy producing zones of West Bengal. Accordingly, both Hired Machine (US $) and Own Machine (US $) are in positive relationships with the paddy productivity. The estimated coefficients for these two machineries related variables disclose that there is an urgent need to introduce as well as encourage the adoption of modern techniques in agricultural practices (Feder et al., 1985). Although agriculture in India mainly relies on the monsoon, however, Green Revolution establishes the importance of irrigation. Our study also finds ownership of irrigation machineries as an important factor in enhancing paddy productivity in West Bengal. The expenditures on irrigation machineries are always positivity relation to paddy productivity however, only the expenditures on Own Irrigation Machine (US $) become statistically meaningful. The obvious reason is that the appropriate and proper utilization of the irrigation machineries only be ensured by the ownership. Sometimes farmer finds the hired irrigation machineries are not in proper order and thus fails to fulfil the purpose. This may be the reason for the statistical insignificance of the estimated coefficient. Regarding the statistic insignificance of the Canal and Other Irrigation Charges (US $), we presume that in West Bengal major irrigation types are- Surface, Drip, sprinkler, Center pivot, Lateral move, Sub-irrigation and Manual irrigation, (Geography booster, 2015) and consequently Canal irrigation is rarely used. As such the corresponding estimated coefficient becomes statistically insignificant. Seed is the raw materials for agricultural production. After the introduction of the HYV seeds in paddy from 1968 onwards, it gains popularity. The government of India provides seed subsidies. Only certified seeds are qualified for such subsidy. For the certified hybrid rice seeds the farmer receives subsidy of "Rs. 2000 per quintal or 50% of the total costs" (Agri farming, 2020). Even such, the poor farmers of West Bengal find difficulties in purchasing HYV paddy seeds. An increase in the price of the seeds aggravates their difficulties. In such circumstances, the farmers prefer to use the traditional seed. The HYV seeds are more productive in comparison to the traditional seeds. Accordingly, an increase in the seed values results in lower paddy productivity, as this increase in the seed values forces the poor small and marginal farmers to switch to traditional seeds (Mondal, 2010), which results in lower productivity.

The analysis of the results related to the inefficiency effects model is of our interest. Here the negative sign of the estimated coefficient means the concerned variable affects the efficiency of the farm positively and vice-versa. Accordingly, the positive and significant effects of the variables Fertiliser (N) (US $), Fertiliser (P) (US $) and Insecticides (US$) indicate an increase in the expenditures for purchasing nitrogen, potassium and insecticides will reduce the paddy producing efficiency of the farm. The modernization in Indian agriculture started its journey in 1960

with the introduction of the Green revolution. The farmers apply nitrogen and potassium to enhance productivity and insecticides to protect the plant. However, excessive utilization of chemical fertilizers as well as insecticides not only increases the cost of production but also increases the subsidy burden of the India government (Gupta, et al., 2020). Moreover, our estimated results reveal that the increase in the use of nitrogen, potassium and insecticides actually reduces the technical efficiency of the farm. Both these chemical fertilizers and insecticides have a strong impact on environmental degradation. The excessive use of these chemical fertilizers and insecticides mixes with the soil and causes water as well as soil pollution. As these chemical fertilizers are made available to the farmers at a subsidized rate an excessive utilization of these puts a subsidy burden on the society. The improper utilization of these expensive chemical fertilizers also increases the per-unit cost of production on the farm. Accordingly, the inefficient use of these fertilizers and insecticides not only reduces the efficiency of the paddy producing farm but also puts a social and economic burden on society. Farmers argue that concerning the climate condition of India the amount of insecticides they are using are indeed the requirements for the survivorship of the plants. However, our estimated result is opposing the farmers' argument concerning the utilization of insecticides. The positive sign of the estimated coefficient related to insecticides reveals that there is inefficiency in the application of insecticides. The reduced expenditures on insecticides will increase the efficiency of the farm. As the applied insecticides remain in grains as well as in leaves it has serious health implications also. Moreover, the applied insecticides mix with rainwater and then pollute both the surface as well as groundwater. Consequently, the over-application of insecticides contributes to environmental degradation. The positive sign of the estimated coefficient may be the outcome of all these reasons. If the farms could utilize nitrogen, potassium and insecticides in appropriate doses it will escalate the efficiency of the farm with environmental and economic sustainability (Bora, 2022). Under "Other Fertiliser (US $)" we have included the expenditures incurred by the farm to purchase organic fertilizers. The negative sign of the estimated coefficient ensures that an increase in the use of these fertilizers will help in increasing the efficiency of the farm (Chivenge et al., 2021). The utilization of such fertilizers, as well as insecticides, is environmental friendly and economic also. Thus use of such fertilizers and insecticides help to enhance farms' production efficiency without compromising environmental sustainability (Chivenge et al., 2021; Bora, 2022).

## Conclusion

The development of the agricultural sector is necessary not only for ensuring food security but also for the sustainable supply of raw materials. India is the world's biggest rice exporter. India exported 21.42 million tonnes of rice in 2020 and in 2021 its export increased by 21%. The main paddy producing state of India is West Bengal. Accordingly, the present study concentrates on examining the paddy producing efficiency of different paddy producing zones of West Bengal. Based on our empirical results we have suggested the following mitigation policies:

Firstly, agriculture in West Bengal requires commercialization by emphasizing hiring trained labour. The family labour if adequately trained and in demand then only he or she should be employed, otherwise it is better to keep the family labour aside. Secondly, the farmers should be provided with enough funds for purchasing their own agricultural and irrigation machineries. To ensure this an expansion of the institutional credit is highly recommended, particularly for the marginal and small farmers. Thirdly, the government has to restrict the seed value by fixing an upper ceiling. Under such circumstances, the government also needs to take appropriate steps to control black marketing.

To ensure clean agricultural production following policies are suggested:

Firstly, we observe that the inefficiency of the farms is caused by improper utilization of chemical fertilizers, nitrogen and potassium. The proper utilization of nitrogen, potassium and insecticides will escalate the efficiency of the farm. Accordingly, it is highly recommended that soil testing is a must for all farms. The efficient utilization of nitrogen and potassium will increase the efficiency of the paddy producing farm with environmental and economic sustainability. Secondly, the estimated coefficient of the inefficiency effect variable, insecticides is in positive relation to inefficiency and the result is statistically meaningful. As discussed earlier this means reduced expenditures on insecticides will not only increase the efficiency of the farm

but also ensure economic and environmental sustainability. If the farmers face difficulties with limited applications of the insecticides, they are recommended to switch to organic insecticides. The application of Neem (margo), and Haldi (turmeric) based insecticides will be agro as well as environmental friendly. Thirdly, we observe the increased expenditures on other fertilizers help in increasing the production efficiency of the farm. These fertilizers include mainly organic fertilizers, viz., vermicompost, natural nitrogen, etc. These fertilizers achieve the goal of increasing productivity with environmental sustainability.

By adopting these steps the West Bengal government will help the farmers to increase their income with environmental sustainability.

Concerning the limitations of the study, we must say microbes in flooded paddy, produce methane, some of which is emitted into the atmosphere. Considering the quantity of production around the world and methane is such a powerful greenhouse gas, experts say reducing those emissions is important. In fact, paddy cultivation is liable for 10% of global greenhouse gas emissions from agriculture and shifting paddy production to a set of practices that cut methane could have significant impacts. However, the non-availability of data restricts us to extend the present empirical analysis including methane emission results from paddy production. Moreover, the choice of the variables for the empirical analysis is dictated by data availability. Thus depending on the availability of data the paper can be extended by considering other dimensions of the environmental consequences of paddy production. Furthermore, the efficiency of the different paddy producing zones of West Bengal is estimated by using the FRONTIER-4.1 programme. Thus the ranking of the zones becomes time-invariant. This can also be considered a limitation of the model.

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# Appendix

| Variables | $\ln(x_1)$ | $\ln(x_2)$ | $\ln(x_3)$ | $\ln(x_4)$ | $\ln(x_5)$ | $\ln(x_6)$ | $\ln(x_7)$ | $\ln(x_8)$ | $\ln(x_9)$ | $\ln(x_{10})$ | $\ln(x_{11})$ | $\ln(z_1)$ | $\ln(z_2)$ | $\ln(z_3)$ | $\ln(z_4)$ | $\ln(z_5)$ | $\ln(z_6)$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $\ln(x_1)$ | 1 | | | | | | | | | | | | | | | | |
| $\ln(x_2)$ | -0.40 | 1 | | | | | | | | | | | | | | | |
| $\ln(x_3)$ | -0.19 | 0.33 | 1 | | | | | | | | | | | | | | |
| $\ln(x_4)$ | -0.18 | 0.19 | 0.28 | 1 | | | | | | | | | | | | | |
| $\ln(x_5)$ | -0.29 | -0.04 | -0.07 | 0.43 | 1 | | | | | | | | | | | | |
| $\ln(x_6)$ | 0.16 | 0.19 | 0.44 | 0.43 | -0.08 | 1 | | | | | | | | | | | |
| $\ln(x_7)$ | -0.07 | -0.19 | 0.10 | 0.29 | 0.05 | 0.23 | 1 | | | | | | | | | | |
| $\ln(x_8)$ | -0.13 | 0.34 | 0.24 | 0.68 | 0.14 | 0.36 | 0.31 | 1 | | | | | | | | | |
| $\ln(x_9)$ | -0.40 | 0.35 | 0.30 | -0.07 | 0.36 | -0.01 | -0.32 | -0.04 | 1 | | | | | | | | |
| $\ln(x_{10})$ | -0.37 | 0.20 | 0.47 | -0.24 | -0.07 | -0.11 | -0.03 | -0.22 | 0.19 | 1 | | | | | | | |
| $\ln(x_{11})$ | 0.31 | 0.09 | 0.04 | 0.02 | -0.34 | 0.29 | 0.06 | 0.25 | -0.48 | -0.13 | 1 | | | | | | |
| $\ln(z_1)$ | -0.21 | 0.39 | 0.48 | 0.50 | 0.31 | 0.43 | 0.15 | 0.62 | 0.09 | 0.35 | 0.10 | 1 | | | | | |
| $\ln(z_2)$ | -0.06 | 0.27 | 0.41 | 0.39 | 0.22 | 0.57 | 0.37 | 0.60 | -0.27 | 0.06 | 0.25 | 0.83 | 1 | | | | |
| $\ln(z_3)$ | 0.23 | -0.03 | 0.36 | 0.46 | -0.11 | 0.39 | 0.45 | 0.45 | -0.35 | 0.04 | 0.51 | 0.63 | 0.75 | 1 | | | |
| $\ln(z_4)$ | 0.26 | 0.15 | 0.21 | 0.02 | -0.32 | 0.37 | 0.14 | 0.21 | -0.15 | 0.01 | 0.65 | 0.23 | 0.31 | 0.55 | 1 | | |
| $\ln(z_5)$ | 0.20 | -0.36 | -0.41 | 0.11 | 0.16 | 0.14 | -0.06 | -0.23 | -0.31 | -0.34 | -0.05 | -0.29 | -0.01 | -0.15 | -0.10 | 1 | |
| $\ln(z_6)$ | 0.21 | -0.15 | 0.24 | -0.11 | -0.37 | 0.45 | 0.46 | -0.02 | -0.38 | 0.19 | 0.51 | 0.16 | 0.46 | 0.64 | 0.60 | 0.14 | 1 |

Source: Authors' own calculation based on secondary data

Table A.1: Correlation diagnostics.

Agris on-line Papers in Economics and Informatics

Volume XV Number 2, 2023

# Are Agricultural Households Resilient to Food Insecurity in Nigeria?

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## Abstract

Food insecurity remains a threat to Nigerians especially agricultural households who are the most vulnerable. This study focuses on the structure of the resilience of agricultural households to food insecurity in Nigeria using the World Bank's Living Standard Measurement Studies Integrated Survey on Agriculture (LSMS-ISA), covering four rounds (2010/2011, 2012/2013, 2015/2016 and 2018/2019) using a total of 4975, 4394, 4226 and 4797 households respectively. Data were analysed using Descriptive Statistics, Multiple Indicators Multiple Causes Model and the Random Effects Probit model. The pillars of resilience to food insecurity among agricultural households include access to basic services, asset, agricultural practice and technology, social safety net, adaptive capacity and stability. Results showed that only about 34% of households were resilient to food insecurity during the periods under review. The most essential determinants affecting food insecurity resilience are access to basic services, assets, stability, adaptive capacity and social safety net. Age of household head, livelihood strategy employed, geo-political zones and location of residence significantly influence food insecurity resilience of households. Farmers' income and food access must be improved as well as their adaptive capacity to food insecurity in order to help them become more resilient to food insecurity and inevitably help in achieving the Sustainable Development goal two of ending hunger in all its forms and improving food security which is one of the main policy thrust of the Nigeria's economic and sustainability plan and the National Development Plan.

## Keywords

Food insecurity, resilience, agricultural households, Nigeria.

Popoola, G. O., Adeniyi, O. R. and Omolehin, R. A. (2023) "Are Agricultural Households Resilient to Food Insecurity in Nigeria?", *AGRIS on-line Papers in Economics and Informatics*, Vol. 15, No. 2, pp. 69-82. ISSN 1804-1930. DOI 10.7160/aol.2023.150206.

## Introduction

Achieving food security is an important objective of the Sustainable Development Goals (SDGs) (Mollier et al., 2017; FAO et al., 2021). Globally, there is an upward trend in hunger and food crises situation. The incidence of food insecurity and undernourishment is on the increase in Africa, specifically in Nigeria. Undernourished people have increased from 791 million in 2015 to 821 million in 2018, which is around one person out of every nine globally (FAO, IFAD, UNICEF, WFP and WHO, 2018). Furthermore, the performance of Nigeria in World rankings on food security related indices remains low. For instance, Nigeria ranked 96th among 113 countries with food insecurity problems (Global Food Security Index (GFSI), 2018) in 2019, the situation was worse has it now ranked 94th (GFSI, 2019). The Global Hunger Index (GHI) remained at 103rd position out of 119 and 121 countries in 2018 and 2021 respectively (GHI, 2018; GHI, 2022). This is an indication of a serious hunger problem. The GHI score further affirmed the country as a famine-threatened country, falling in the serious and alarming categories. Reports revealed that about 4.5 million people in the northeast of Nigeria are currently battling with famine and violence caused by Boko Haram (VOA 2017; UNDP, 2017) while others experience minimal food-security concerns (FEWS NET, 2017). Also, in 2017 the UNDP Human Development Index (HDI) was 0.532 and ranked 157th out of 189 countries (UNDP, 2018). In 2021, it was 0.535 and the country ranked 163rd position out of 191 countries (UNDP, 2022). This puts the country in the low category of the human development below the sub-Saharan Africa

threshold of 0.55 in 2021 (UNDP, 2022).

About 2 billion people were reported living in moderate or severe food insecurity and the country ranks 38 out of 100 countries with food insecurity problems (FAO et al., 2019) and about 14 million people are malnourished. On the national level, there continues to be an upsurge in the demand for food as population increases but production is unable to meet the demand (Owoo, 2020). This has left a high proportion of rural households' food insecure (Akinyele, 2009; Adepoju et al., 2015). Food production is threatened due to increased food demand, scarcity, population boom, variable input and output prices, rising energy costs, administrative control, and, most critically, linked climatic changes. Over the last few years, natural, economic and political dangers have become increasingly common and severe for homes, farms, firms, economies, and even entire countries (Zseleczky and Yosef, 2014). The insurgency in the North East of the country have further worsened food security outcomes, more especially for vulnerable women and children (WFP, 2022). This has made resilience to become a major issue in policy and scholarly debates. It is also imperative for agricultural households to be able to withstand these unprecedented shocks that affect their livelihood. According to d'Errico et al. (2016), the capacity of a system to withstand these risks is termed resilience. In a food security setting, resilience is described the capacity of a household to maintain a level of well-being (i.e. being food secure) after exposure to shocks.

Previous literature has examined the concept of resilience to food insecurity and its determinants (Alinovi et al., 2008; Alinovi et al., 2010; Vaitla et al., 2012; Kasie, 2017; d'Errico et al., 2018; Ansah et al., 2019; Atara et al., 2020). Alinovi et al. (2008) emphasized household capacity to resist and absorb a shock among Palestinian households. They stated that the ability of a household to adapt to new scenarios depends on the options available to that household to make a living, such as access to assets, income-generating activities, public services, formal and informal social safety nets, institutional environment and resistance capacity. Alinovi et al. (2010) measured empirically the outcomes of different livelihoods strategies in terms of household resilience to food insecurity among Kenyan households which they classified according to their own livelihood strategies by using the Ward's cluster analysis technique on data from the Kenya Integrated Household Budget Survey 2005-2006. They found out that Kenyan household livelihood strategies are pastoralist, agro-pastoralist, smallholder farmers, large-holder farmers, entrepreneurs and wage-employees. Using resilience analysis framework developed by Alinovi et al. (2008) they revealed that the large-holder farmers' cluster is the most resilient, whilst the pastoralist is the least resilient.

Vaitla et al. (2012) examined resilience and livelihoods change in Ethiopia. They adopted a "livelihood change" approach, consisting of modelling the pre-existing conditions with assets, natural resources, physical assets, financial assets and human and social capital. These are the fundamental elements of resilience, which after interaction in a vulnerability context (factors outside human control) and an institutional context (human factors outside the household's control) enable households to react to a shock. Kasie (2017) examined shock exposure, livelihood strategies and risk response options in Ethiopia. He reported that livelihood strategies employed by households was related to food income. Similarly, diverse livelihood options increase the resilience capacity of households to food insecurity. The location of residence and the nature of livelihood option influences the choice of risk-coping strategies. It was concluded that weak adaptive capacity and high exposure to shocks were responsible for poor household resilience to food insecurity. d'Errico, et al. (2018) also investigated the resilience to food insecurity among Tanzanian and Ugandan households. The adaptive capacity of these households was the most important dimension contributing to resilience to food insecurity in the study areas. The adaptive capacity strongly depended on education and the number of income-earning members in the household. The future food security status of households depended on current household resilience capacity. Ansah et al. (2019) provided a review of concepts and methodologies on household resilience and food security. The study found that food security higher resilience capacity is positively related to food security and less child malnutrition. Evidently from the literature, there are assertions that households require some form of livelihood options to keep with a certain level of food security. Literature is also still limited in the Nigerian context on resilience to food insecurity.

This study is important given the contextual realities in Nigeria. The changing climate, increasing population, rising food prices and worsening

environmental conditions that significantly affect food security. Household resilience strategies and policy responses are therefore needed to attend to these pressing issues. These concerns are further espoused in Nigeria's Medium-term National Development Plan (2021-2025) and the Sustainable Goals 1 and 2. This study focuses on examining whether agricultural households in Nigeria are resilient to food insecurity. Despite the importance of the resilience concept, there are limited studies that have empirically examined household resilience to food insecurity. Some of those available in literature include Alinovi et al. (2010) in Palestinian households; Alinovi et al. (2010) in Kenya; and Boukary et al. (2016) in Niger; and d'Errico et al. (2016) in Tanzania and Uganda. To date, there is limited empirical research on resilience to food insecurity and its determinants among agricultural households in Nigeria. This study therefore fills the gap with respect to resilience to food insecurity studies in Nigeria.

This study is situated within a broader national policy of the government through the Nigeria's Economic and Sustainability Plan and the National Development Plan (2021-2025), with agriculture as one of the priority sectors and food security being a major component. It will help achieve the Sustainable Development Goal (SDG) two of ending hunger, achieving food security and improve nutrition and promote sustainable agriculture and provide insights to policy makers, researchers and relevant stakeholders on what they have to do in order to cope with food insecurity among agricultural households in Nigeria. The FAO Resilience Index Measurement Analysis II (RIMA-II) was employed for assessing household resilience and aims to answer these pertinent questions: How resilient are agricultural households to food insecurity? How do different resilience attributes contribute to overall resilience capacity of agricultural households? What factors influence the resilience capacity of agricultural households to food insecurity?

## Materials and methods

### Scope of the study

The scope of the study is Nigeria. Nigeria is one of the Sub-Saharan Africa (SSA) nations located in the western part of Africa. The country has 36 states and the federal capital territory. It shares its boundaries with the Republic of Benin to the west, the Niger Republic to the north, the Republic of Cameroon and Chad Republic to the east, and the Atlantic Ocean forms a coastline of about 960 $km^2$ to the south. The country has a total land mass of about 92,377,000 hectares out of which 91,077,000 hectares are solid land area. Nigeria has a population of about 217,863,698. Agriculture remains the base of the Nigerian economy, providing the main source of livelihood for most Nigerians. The agricultural sector in Nigeria employs 70% of the nation's working force and has 84 million hectares of fertile land suitable for staple food crops including cassava, yams, corn, coco-yams, cowpeas, beans, sweet potatoes, millet, plantains, bananas, rice, sorghum, fruits, and vegetables.

### Type and source of data

This research work employed the World Bank's Living Standard Measurement Studies Integrated Survey on Agriculture (LSMS-ISA), covering four rounds (2010/2011, 2012/2013, 2015/2016 and 2018/2019). The use of panel data is premised on the length of the time period covered which helps to better determine the potential of households to withstand and bounce back to the previous level of well-being. This is the only panel data available for agricultural households in Nigeria. Thus, the data is most appropriate for the study at hand.

### Analytical techniques

#### Measurement of household resilience to food insecurity

The resilience index capacity of agricultural households in Nigeria was analyzed with the FAO's RIMA II as employed by FAO, (2013). Resilience is an intricate term that can be measured through latent variable modeling, the technique that analyzes household resilience statistically. Two steps were taken in the analysis following FAO (2016). First, the principal component analysis (PCA) was used to show the pillars of household resilience. These pillars are access to basic services, asset, agricultural practices and technology, social safety net, stability and adaptive capacity. The indicators for each pillar are presented in Table 1.

| Pillar | Indicators | Indicator description |
|---|---|---|
| Access to basic services (ABS) | Access to electricity | A dummy variable indicating whether a household has electricity at home or not |
| | Distance to water source | A continuous variable measuring the time that it takes to walk to the nearest water source |
| | Credit | A dummy variable measuring whether any household member has borrowed credit over the observation period irrespective of the credit source (formal or informal) and nature (in cash or in kind) |
| | Telecommunication | A dummy variable for having access to a telephone (fixed or mobile), equal to 1 if the household shows any telephone expenditure and 0 otherwise |
| | Access to information | A dummy variable: 1 if the household head access to information through television, radio or any other means of accessing information and 0 if otherwise |
| | Distance to the nearest primary school | A continuous variable measuring the time that it takes to walk to the nearest primary school |
| Assets (AST) | Ownership of Bicycle, motorcycle, radio, TV, Car, Livestock, farm size (ha) | A dummy variable equal to 1 if the household owned asset over the survey period, 0 otherwise; Farm size in hectares |
| Agricultural practice and technologies (APT) | Fertiliser use | A dummy variable equal to 1 if the household used fertiliser over the survey period, 0 otherwise |
| | Pesticide use | A dummy variable equal to 1 if the household used pesticide over the survey period, 0 otherwise |
| | Extension contact | A continuous variable equal to the average number of contacts that the household head received during the last 12 months. |
| Social safety nets (SSN) and Adaptive capacity (AC) | Cash transfers received | A dummy variable equal to 1 if the household received cash transfers or 0 otherwise |
| | Employment ratio | It measures the ratio between the number of household members currently employed and the household size |
| | Education average | This is the mean of the years of education completed by the household's members |

Source: Alinovi et al. (2008 and 2010), FAO (2013)

Table 1: Pillars and indicators for household resilience to food insecurity.

## The Principal Component Analysis (PCA)

Each component of the PCA gives a linear weighted sum of the variable indicators, resulting in a collection of orthogonal (uncorrelated) components/indices. Filmer and Pritchett (2001) expressed PCA in terms of the original variables in an index form. This done for each household.

Assume there is a set of R-variables ($a^*_{1j}$ to $a^*_{rj}$) representing the R-resilience attributes of each householdj. PCA specifies each variable normalized by its mean and standard deviation.

For example, $b_{1j} = (b^*_{1j} - b^*_1)/s^*1$, where $b^*_1$ is the mean of $b^*_{1j}$ across household and $s^*_1$ is its standard deviation. These attributes are expressed as linear combinations of a set of underlying components for each household $j$ is shown in equation 2:

$$a_{1j} = y_{11}W_{1j} + y_{12}W_{2j} + \ldots + y_{1r}W_{rj} \quad (1)$$

$j = 1 \ldots J$

$$az1j = y_{r1}W_{1j} + y_{r2}W_{2j} + \ldots + y_{rr}W_{rj} \quad (2)$$

$W$'s = components

y's = coefficients on each component for each variable.

Secondly, Systems of equations were used to specify the link between resilience (the unobserved latent variable), food insecurity indicators (outcome variables) and the pillars.

Algebraically, it is presented as:

$$RCI_i = f(IFA_i, A_i, APS_i, APT_i, SSN_i, S_i, ACi) \quad (3)$$

Where $RCI$ = Resilience capacity index; $IFA$ = income and food access; $A$ = assets; $APS$ = access to public services; $APT$ = Agricultural Practices and Technologies; $SSN$ = social safety-nets; $S$ = stability; and $AC$ = adaptive capacity.

In this study, Agricultural Practices and Technology (APT) was included to show the technological levels in farming activities.

$$RCI = \sum_j W_j F_j \quad (4)$$

The MIMC model contains the measurement equation (4), which are the observed indicators of food security and the structural equation (5), that links the predicted attributes to resilience capacity.

$$[Food\ expenditure] = [\Lambda 1] \times [RCI] + [\varepsilon_2, \varepsilon_3] \quad (5)$$

$$[RCI] = [\beta_1, \beta_2] \times [IFAi, A_iAPS_iAPT_iSSN_iS_iAC_i] + [\varepsilon_1] \quad (6)$$

$$Food\ expenditure = \Lambda 1 RCI + \varepsilon_2 \quad (7)$$

**Random Effects Probit Model**

Following Guilkey and Murphy (1993), equation 8 presented the model to identify the correlates of household resilience to food insecurity:

$$Y_{it}^* = X_{it}\beta + \mu_i + \varepsilon_{it} \quad (8)$$

The simplified form is given in equation 9:

$$Y_{it}^* = \beta_1 + \beta_2 X_{it} + \mu_i + \varepsilon_{it} \quad (9)$$

$X_{it}$ = 1 x $T$ vector of regressor

$\beta$ is a $T$ x 1 vector of coefficients

$\mu_i \sim IN(0,\sigma_\mu^2)$; $\varepsilon_{it} \sim IN(0,\sigma_\varepsilon^2)$; $\mu_i$ and $\varepsilon_{it}$ are mutually independent.

$Y_{it}^*$ is an unobserved latent variable. The observed random variable $Y_{it}$ is defined by:

$$Y_{it} = \begin{cases} 0\ if\ Y_{it}^* \leq 0, \\ 1\ if\ Y_{it}^* > 0. \end{cases} \quad (10)$$

Hence, following Kasie (2017), households were considered as resilient to food security shocks if $R_i$, t + 1 > 0.5 where $R_i$, is the resilience measure, given a value of one and non-resilient otherwise (value of zero).

Variables used for correlates of resilience include; sex of household head (male 1 otherwise 0), Age of household head (years), Age squared (years), Household size (number), Squared of household size (number), Educational level (no education = 1, primary education = 2, secondary education = 3, tertiary education = 4), location and period of survey (wave 1 = 1, wave 2 = 2, wave 3 = 3, wave 4 = 4).

## Results and discussion

### Socioeconomic characteristics of agricultural households

The socio-economic characteristics of agricultural households is shown in Table 2. Results revealed that most household heads were male across the time periods. Across rural and urban locations, most households were male-headed. In total, it was about 84.9%, 85.1%, 85.4% and 82.3% in the 2010/2011, 2012/2013, 2015/2016 and 2018/2019 periods respectively. This position holds true for a typical Nigerian household and is supported by the Nigerian National Bureau of Statistics (2014); Ugwuja et al. (2011) reported that males are more likely to be involved in agriculture than females because of the rigorous nature of the work, however women are involved in harvesting, processing and marketing of agricultural produce. According to National Survey and Segmentation of smallholder households in Nigeria, nine in ten smallholder household heads in Nigeria are men (Anderson et al., 2017). The age of individuals in a nation reveals the extent to which there will be economic growth and development (Bloom et al., 2010; Maestas et al., 2016). Most of the household heads were between 25-54 years of age across rural and urban location. However, the proportion within this category decreased between the periods 2010/2011 to 2015/2016 and increased in 2018/2019 season. The average age of household heads was 49.6 ± 15.5, 51.8 ± 15.1, 53.4 ± 14.4 and 49.8 ± 15.5 years respectively for the periods. This implies that majority of the household heads are in their active or productive age and are involved in various agricultural activities. This result is consistent with the findings of Folorunso et al., (2018) and Oyetunde-Usman and Olagunju (2019) who reported that most agricultural households are in their productive years. This is contrary to the old believe that the average farm population is aging and as reported in the International Fund for Agricultural Development (IFAD) rural development report in 2019.

These agricultural households were mostly married. In total, 79.7%, 80.8%, 81.1% and 77.5% were married in 2010/2011, 2012/2013, 2015/2016 and 2018/2019 respectively. This implied that the married were more involved in agricultural production. Results also showed that most households across rural and urban area in Nigeria had between four to six household members. The mean household size was slightly lower in urban households than rural households across the survey time periods. In total, there was an average of six household members in 2010/2011 and 2012/2013 seasons, increased to seven household members in 2015/2016 and however decreased to six members in 2018/2019 season. This reflects the preponderance of large households in Nigeria. The presence of large household size among

agricultural households might be so that family members could be useful as a source of labour. This position is consistent with the assertion of Oluwatayo et al. (2008) who said that higher household size provides enough persons for family labour. In line with this reasoning, large household size may serve as an advantage or disadvantage. This can be explained in terms of increased family labour which may create the need for farm expansion which can only be achieved when household members receive sufficient and higher incentives for working on family plots than participating in other household activities (Jerumeh and Omonona, 2018). However, Shapiro (1990) presented a different opinion that there could be a decline in farm size as household size increased due to incentive problems as well as diversification issues. With respect to education of household heads, the same percentage of household heads mostly had both primary and secondary education (39.7%) in 2010/2011. In 2012/2013 and 2015/2016 seasons, higher proportion of household heads had primary education (40.3% and 36.8% respectively). However, in 2018/2019, most heads had secondary education (35.1%). This implies that most household heads in rural areas in the sample have at least primary education. This could have negative effect as opined by Nyako (2013) or positive effect as observed by Mohammed et al. (2016) on their food security status. The mean farm size was 1.01 ± 1.6 ha, 0.90 ± 1.3 ha, 0.88 ± 1.5 ha and 0.95 ± 1.7 ha in the 2010/2011, 2012/2013, 2015/2016 and 2018/2019 seasons respectively. This is because agriculture is practiced mainly by smallholder farmers in Nigeria and about 88 percent of them are considered small family farms (FAO, 2018). Extension visits was about two visits in 2010/2011, 2012/2013; almost no visits in 2015/2016 and about 2 visits in 2018/2019 period. Results showed that irrespective of location (rural or urban), frequency of extension visits was very low. The results therefore reflected the precarious state of agricultural extension services in the country as coverage and visits were extremely low. This will hinder the dissemination of improved agricultural technologies with resultant effect on agricultural production. This finding is in line

| Socio-economic characteristics | 2010/2011 | 2012/2013 | 2015/2016 | 2018/2019 |
|---|---|---|---|---|
| **Age of Household Head (in years)** | | | | |
| Mean+SD | 49.6±15.5 | 51.8±15.1 | 53.2±14.5 | 49.8±15.5 |
| **Sex of Household Head** | | | | |
| Male | 4225 (84.9) | 3740 (85.1) | 3609 (85.4) | 3947 (82.3) |
| Female | 750 (15.1) | 654 (14.9) | 617 (14.6) | 850 (17.7) |
| **Marital status** | | | | |
| Never Married | 215 (4.3) | 126 (2.9) | 86 (2.0) | 249 (5.3) |
| Married | 3965 (79.7) | 3554 (80.8) | 3426 (81.1) | 3720 (77.5) |
| Widowed | 628 (12.6) | 584 (13.3) | 571 (13.5) | 663 (13.8) |
| Divorced/Separated | 167 (3.4) | 130 (3.0) | 143 (3.4) | 165 (3.4) |
| **Household Size (in persons)** | | | | |
| Mean+SD | 5.5±3.1 | 6.2±3.2 | 7.0±3.5 | 6.0±3.7 |
| **Level of education** | | | | |
| No formal education | 499 (10.0) | 573 (13.0) | 483 (11.4) | 485 (10.1) |
| Primary education | 1977 (39.7) | 1770 (40.3) | 1554 (36.8) | 1576 (32.9) |
| Secondary education | 1559 (39.7) | 1432 (32.6) | 1297 (30.7) | 1685 (35.1) |
| Vocational training | 54 (1.1) | 33 (0.7) | 28 (0.7) | 51 (1.1) |
| Tertiary education | 869 (17.5) | 865 (19.7) | 860 (20.3) | 985 (20.5) |
| Adult education | 17 (0.3) | - | 9 (0.2) | 16 (0.3) |
| **Farm Size (ha)** | | | | |
| Mean±SD | 1.01±1.6 | 0.90±1.3 | 0.88±1.5 | 0.95±1.7 |
| **Extension Visit** | | | | |
| Mean+SD | 1.8±3.2 | 2.11±2.5 | 0.24±1.1 | 1.67±1.1 |
| **N** | **4975** | **4975** | **4975** | **4975** |

Source: Authors' computation, 2022

Table 2: Socioeconomic characteristics of agricultural households.

with studies of Ogunsumi (2008) and Ajala et al. (2013) that farmers-extension ratio continues to decline and there remains little or no contact with extension agents. Thus, a proactive step to remedy this situation is crucial.

## Resilience capacity of agricultural households

The FAO-RIMA-II approach gives an estimate of RCI and the correlation of different attributes to resilience. In order to profile household resilience to food insecurity, the continuous measure of resilience $R_i$, $t + 1$, were used to categorize a household as resilient or not resilient with reference to the normative minimal threshold probability, ($P = 0.5$), under which a household's probability of meeting or exceeding the normative well-being threshold intolerably low. Hence, following Kasie (2017), households were classified as resilient to food security shocks if the measure of resilience, $R_i$, $t + 1 > 0.5$, and non-resilient if otherwise. Results showed that only about 34% of households were resilient to food insecurity during the period under review. This is presented in Table 3. This low proportion is a worrisome situation for the country as it depicts that most agricultural households are vulnerable to shock exposure, lack access to basic services, in poor safety nets and low in adaptive capacity, poor in agricultural practices and low in technology and weak asset base. There is therefore the need to address these pillars among agricultural households as they hold the key to national food security. This resilience index further reveals the low capacity of agricultural households in Nigeria to withstand shocks.

| Resilience status | Percentage (%) |
|---|---|
| Resilient | 33.97 |
| Non-resilient | 66.03 |
| **Total** | **100** |

Source: Authors' computation, 2022

Table 3: Resilience status of agricultural households to food insecurity.

## Linking resilience and food security

The MIMC was used in linking resilience and food security (Table 4), the coefficient of the variable access to basic services was fixed to one by default, so as to estimate relative size and level (FAO 2016). Coefficients estimated are statistically highly significant at 1 percent with the expected sign, meaning that greater access to assets, agricultural practice and technologies, social safety net influence RCI positively, and promote better adaptive capacity. For a single standard deviation change in an exogenous variable ceteris paribus, the RCI response is stated in units of standard deviation (Bollen, 1989). The effect of assets, agricultural practice and technologies, social safety net and adaptive capacity in the model on RCI reveal that a one standard deviation positive change in AST, APT, SSN_AC positively affect the magnitude of the RCI by 1.59, 1.08, 8.54 standard deviations respectively.

Per capita food expenditure was also positively and significantly correlated with resilience capacity index by 0.034 standard deviations. This implies that households will become more resilient with increase in per capita food expenditure.

| | Coefficient | Standard error | Z | P>\|z\| |
|---|---|---|---|---|
| **Structural component** | | | | |
| Access to basic services (ABS) | 1 (constrained) | | | |
| Assets (AST) | 1.5945*** | 0.2681 | -5.95 | 0.000 |
| Agricultural Practices and Technology (APT) | 1.0761*** | 0.2188 | -4.92 | 0.000 |
| Social Safety Nets and Adaptive Capacity (SSN_AC) | 8.5419*** | 2.9734 | -2.87 | 0.004 |
| **Measurement component** | | | | |
| Per capita food expenditure | 0.0342*** | 0.0024 | 14.030 | 0.000 |
| Goodness of fit | | | | |
| $X^2$ | 162.492 | | | |
| p-value | 0.000 | | | |
| RMSEA | 0.020 | | | |
| Pr RMSEA | 1.000 | | | |
| CFI | 0.843 | | | |
| TLI | 0.824 | | | |

Source: Authors' computation, 2022

Table 4: Resilience Capacity Index (RCI)

The implication of these findings revealed that the interaction of social safety nets and adaptive capacity mostly affect resilience among these households. This position is consistent with the findings of D'Errico et al (2018), Devereux and Getu (2013), Gallopin (2006) where social safety nets and adaptive capacity contributed significantly to resilience capacity in the sampled countries. The positive relationship between household resilience and food security revealed that the probability of households becoming food secure increases with improved resilience capacity of agricultural households. It is therefore instructive to conclude that the FAO RIMA-II approach has been able to establish that the resilience capacity of agricultural households is dependent on a number of pillars, with which the operationalization of resilience can be tackled at the policy level. In this study, we have used it over a panel data covering four periods which further reinforced the appropriateness and relevance of the resilience measure.

**Pillars of resilience to food insecurity**

**Access to basic services (ABS)**

Table 5 shows the contribution of the different attributes of resilience. Access to basic services help households become more resilient, such as increasing the effectiveness of their asset access. Access to electricity, distance to water source, access to credit, telecommunication, access to information and nearness to the nearest primary school were considered. The variables positively impact distance to the nearest primary school, mobile phone access (telecommunication), access to information and access to electricity on access to basic services (ABS). However, access to credit negatively affects the latent variable ABS.

**Assets (AST)**

The component asset is computed with variables such as ownership of bicycle, motorcycle, radio, television, car, livestock and farm size. These variables demonstrate a positive impact of ownership of radio, motorcycle, television and car on the latent variable agricultural assets. However, livestock ownership, farm size and ownership of bicycle negatively affect the latent variable AST.

**Agricultural Practice and Technologies (APT)**

Fertilizer use, pesticide use, frequency of extension contact, herbicide use, machinery use and animal traction were the variables used for this pillar. The variables show the same trend and demonstrate a positive impact of the use of pesticide, animal traction, herbicide and machinery on the latent variable agricultural practice and technologies. However, frequency of extension contacts negatively affects the latent variable APT as shown in Table 5. The reason might be use of agricultural practices and technology helps increase productivity.

**Social Safety Net (SSN) and Adaptive Capacity (AC)**

This component captures social safety net in the form of cash transfers available to agricultural households. Also, the adaptive capacity also considers the level of education and the employment ratio. Both were used to capture the level of safety nets and adaptive capacity of households. Results showed that there is a positive impact of employment ratio and level of education on the latent variable social safety net and adaptive capacity. However, cash transfers received negatively affect the latent variable SSN_AC as shown in Table 5.

| Pillar | Indicators | Factor scores |
|---|---|---|
| Access to basic services (ABS) | Access to electricity | 0.2592 |
| | Distance to water source | 0.0865 |
| | Credit | -0.0401 |
| | Access to information | 0.3214 |
| | Telecommunication | 0.5136 |
| | Distance to the nearest primary school | 0.5577 |
| Asset (AST) | Bicycle | -0.0847 |
| | Motorcycle | 0.3841 |
| | Radio | 0.6343 |
| | TV | 0.3833 |
| | Car | 0.1975 |
| | Livestock | -0.4894 |
| | Farm size | -0.1327 |
| Agricultural Practice and Technologies (APT) | Fertilizer Use | 0.4126 |
| | Pesticide use | 0.4677 |
| | Extension contact | -0.038 |
| | Herbicide | 0.4521 |
| | Machinery | 0.4445 |
| | Animal Traction | 0.4557 |
| Social Safety Net (SSN) and Adaptive Capacity (AC) | Cash transfers received | -0.1148 |
| | Level of education | 0.6650 |
| | Employment ratio | 0.7379 |

Source: Authors' computation, 2022

Table 5: Principal Component Analysis results of the attributes of resilience.

### Disaggregation of resilience to food insecurity by selected characteristics

The distribution of agricultural household resilience score by selected characteristics is shown in Table 6. With respect to livelihood strategies, the results show that households that engaged in wage employment have the highest resilient score (0.5214) followed by services (0.0912). Those primarily engaged in agriculture are the least resilient (-0.0413). This imply that the more agricultural households engage in agriculture, the less likely they are resilient to food insecurity.

With respect to geo-political zones, it can be seen that households in the South South are the most resilient (0.1557), followed by South West (0.0999) and North Central (0.0646). The worst-off are those in the North East (-0.2550), North West (-0.0054) and South East (-0.0917). The possible reason for this could be due to insecurity in the Northern East and West geopolitical zones which has caused the displacement of people and worsened the living conditions of households.

Finally, on the location of residence of agricultural households, it is shown that households who reside in urban areas are most resilient (0.1422) while those in rural areas are worst-off (-0.0737).

| Characteristics | Factor loadings |
|---|---|
| ***Livelihood strategies*** | |
| Agriculture | -0.0413 |
| Services | 0.0912 |
| Wage employment | 0.5214 |
| ***Geo-political zone*** | |
| North Central | 0.0646 |
| North East | -0.2550 |
| North West | -0.0054 |
| South East | -0.0917 |
| South South | 0.1557 |
| South West | 0.0999 |
| ***Location of residence*** | |
| Urban | 0.1422 |
| Rural | -0.0737 |

Source: Authors' computation, 2022

Table 6: Disaggregation of resilience by selected characteristics.

### Correlates of agricultural household resilience to food insecurity

Findings of the binary probit panel regression are as presented in Table 7. Chi-square distribution and log-likelihood ratio showed that the model is fit. The factors that significantly influenced household resilience to food insecurity were geo-political zones, location of residence, increase in price of inputs, increase in the price of main food items and time.

The geo-political zone in which agricultural households are located greatly affect their resilience to food insecurity. Households in the Northern East and West geopolitical zones, Southern East and West geopolitical zones are negatively and significantly related with resilience to food insecurity at 1%, 1%, 1% and 10% respectively. This implies that being located in these zones reduces the probability of being resilient to food insecurity at a decreasing order from North East to South West. This explains that no geo-political zone of the country is immune to the persistent food insecurity challenges in the country and the worsening state of basic services, asset base, production technologies and exposure to shocks of various kinds.

Households residing in rural areas were significant at 1% and negatively related with the likelihood of being resilient to food insecurity. Households who live in rural areas are less probable to be resilient to food insecurity than households residing in urban areas. This infers that food security is more pronounced in rural areas than in urban. The reason for this is not far-fetched. There are no infrastructures available to the rural poor, little or no access to basic services, no safety nets and there is high exposure to shocks. All these predispose households to food insecurity with little or no adaptive capacity.

Resilience capacity can be reduced substantially by shocks (FAO, 2016). Gustafson (2013) reported that spike in price of food items, drought, floods and economic crises greatly impact food and nutrition security state of households which causes poverty and inability to access sufficient food. Increase in price of inputs and major food items significantly influenced household resilience to food insecurity. Increase in price of inputs was significant at 1% and negatively related with the likelihood of households' resilience to food insecurity. This means that increase in price of agricultural inputs decreases likelihood of the households being resilient to food insecurity. The probable reason for this is that agricultural households are mostly vulnerable to high prices, most especially for inputs used in their production activities. In a similar vein, increase in price of major food items was significant at 1% and negatively related with the likelihood of being resilient to food insecurity. Households who experience increase in price of major food

items are less probable to be resilient to food insecurity. Therefore, increase in food prices will likely decrease their resilience to food insecurity.

Time was significant at 1% and negatively related with the likelihood of households being resilient to food insecurity. It is observed that as agricultural households progressed through time, the likelihood that they become less resilient to food insecurity increase. This could be attributed to the worsening state of the Nigerian economy in recent times in terms of access to basic services, infrastructure, agricultural production technologies, poor safety nets and asset base that has weakened agricultural households' adaptive capacity.

| | Coefficient | Standard error | Z | P>\|z\| |
|---|---|---|---|---|
| Female-headed household | 0.0313 | 0.0479 | 0.65 | 0.514 |
| Age (years) | -0.0055 | 0.0052 | -1.06 | 0.288 |
| Age squared | 0 | 0 | 0.63 | 0.530 |
| Household size | 0.0139 | 0.0106 | 1.30 | 0.193 |
| Household size squared | -0.0001 | 0.0006 | -0.24 | 0.808 |
| Marital status | -0.0083 | 0.0283 | -0.29 | 0.770 |
| ***Livelihood strategy*** | | | | |
| Services | 0.0893 | 0.0802 | 1.11 | 0.266 |
| Wage employment | -0.0005 | 0.0623 | -0.01 | 0.994 |
| Level of education | | | | |
| Primary Education | -0.0082 | 0.0463 | -0.18 | 0.860 |
| Secondary Education | 0.0042 | 0.0469 | 0.09 | 0.928 |
| Tertiary Education | 0.0648 | 0.0507 | 1.28 | 0.201 |
| ***Geo-political zone*** | | | | |
| North East | -0.1371*** | 0.0487 | -2.81 | 0.005 |
| North West | -0.1598*** | 0.0485 | -3.30 | 0.001 |
| South East | -0.1613*** | 0.0498 | -3.24 | 0.001 |
| South South | -0.0007 | 0.0475 | -0.02 | 0.988 |
| South West | -0.0831* | 0.0501 | -1.66 | 0.097 |
| ***Location of residence*** | | | | |
| Rural | -0.1105*** | 0.032 | -3.45 | 0.001 |
| ***Shocks*** | | | | |
| Death or disability of a working adult | 0.0662 | 0.0583 | 1.14 | 0.256 |
| Death of one who sends remittances | 0.0932 | 0.0754 | 1.24 | 0.216 |
| Poor rain that caused harvest failure | -0.1388 | 0.096 | -1.45 | 0.148 |
| Flooding that caused harvest failure | -0.0341 | 0.0736 | -0.46 | 0.643 |
| Increase in price of inputs | -0.2753*** | 0.0941 | -2.93 | 0.003 |
| Fall in the price of outputs | 0.095 | 0.0713 | 1.33 | 0.183 |
| Increase in the price of major food items | 0.1592*** | 0.06 | 2.65 | 0.008 |
| ***Time*** | | | | |
| 2012/2013 | -0.1818*** | 0.0643 | -2.83 | 0.005 |
| 2015/2016 | -0.4342*** | 0.1515 | -2.87 | 0.004 |
| 2018/2019 | -0.3544 | 0.3035 | -1.17 | 0.243 |
| Constant | 0.1451 | 0.2097 | 0.69 | 0.489 |
| lnsig2u | -2.7367 | 0.7652 | | |
| Sigma_u | 0.2545 | 0.0974 | | |
| Rho | 0.0608 | 0.0437 | | |
| Log likelihood = -5832.1001<br>N= 4226 | Prob > chi2 = 0.0000 | | | |

Note: ***, **, * represent 1%, 5% and 10% significance level respectively
Source: Authors' computation, 2022

Table 7: Determinants of household resilience to food insecurity.

## Conclusion

This study examined the resilience capacity of agricultural households in Nigeria using the General Household Survey Panel dataset covering four rounds of survey (2010/2011, 2012/2013, 2015/2016 and 2018/2019). A total of 4,975, 4,394, 4,226 and 4,797 agricultural households were examined for those periods. Information on socio-economic characteristics, household expenditure, shocks, social safety nets, access to basic services, assets, agricultural production technologies and adaptive capacity were examined. Agricultural household resilience to food insecurity result revealed that only about 34% were resilient to food insecurity during the period under review. Attributes of resilience influence resilience capacity positively and promote better adaptive capacity. This implies that these attributes are key to explaining resilience to food insecurity among households in the study area, most especially, social safety net and adaptive capacity pillar. The factors that significantly influenced household resilience to food insecurity were geo-political zones, location of residence, increase in price of inputs, increase in the price of main food items and time. There is therefore the need for measures to enhance agricultural households' income and food access, and adaptive capacity towards food insecurity. The food insecurity situation should be addressed in all geo-political zones of the country especially in the northern zones as they were least resilient to food insecurity. Rural households should also be given more attention through improvement in access to basic services, assets, agricultural practices and technology, social safety net and adaptive capacity. Increase in price of inputs and food items negatively affects households' resilience to food insecurity. As such, efforts should be targeted at addressing increase in price of food items and subsidize farm inputs for agricultural households.

## Acknowledgements

I appreciate Bowen University for the all-round support in providing a conducive environment for the study. No financial support was received for this study.

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Agris on-line Papers in Economics and Informatics

Volume XV Number 2, 2023

# An Assessment of M-Commerce Adoption Amongst Women Fish Vendors in Coastal India Using System Dynamics Approach

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## Abstract

The digital revolution in India has played a significant role transforming traditional organizations through adoption of mobile commerce (m-commerce) and transforming the way they do business. For the successful implementation of m-commerce, a thorough understanding of the stakeholder perspectives is always important. Hence, to summarize the issues and perspectives of the women fish vendors (WFVs) and to study the effect of crucial parameters on the implementation success of m-commerce a system dynamics (SD) approach was used. SD methodology is used to develop a simulation model to understand the m-commerce adoption rate amongst WFVs considering multiple scenarios. The research findings reveal that, word of mouth (WOM) and user experience plays a major role towards the adoption of m-commerce. However, the WFVs were sceptical about the capabilities of m-commerce and weren't well equipped with infrastructure. This approach will enable the academicians and social entrepreneurs to formulate strategies to empower WFVs by using technology. Also, it opens a new area of simulation-based policy modelling in the fisheries retail sector.

## Keywords

Fisheries, m-commerce, participatory system mapping, system dynamics, policy making.

Prabhu, R., Kamath, V., D'Souza, D. J. and Joshi, H. (2023) "An Assessment of M-Commerce Adoption Amongst Women Fish Vendors In Coastal India Using System Dynamics Approach", *AGRIS on-line Papers in Economics and Informatics*, Vol. 15, No. 2, pp. 83-91. ISSN 1804-1930. DOI 10.7160/aol.2023.150207.

## Introduction

Indian fisheries with 8129 km coastline and aquaculture are an important sector providing nutritional security to the food basket and engaging about fourteen million people in different activities. This sector contributes to 1.1% of India's GDP and 5.15 % of the agricultural GDP of India. Currently India stands the third position in fisheries and second in Aquaculture. Karnataka State in the southern part of India has 320 Km long coastline comprising of three districts Dakshina Kannada, Udupi and Uttara Kannada collectively called as coastal Karnataka. There are about 9.61 lakh people involved in fishing activity in the state who are engaged with different fisheries exercises. Different communities live on fishing, fish trading, sellers or act as middlemen to other giants of this industry. There are some specific communities involved in fishing activity in coastal Karnataka. Mogaveera community is predominant in Dakshina Kannada and Udupi district where as Kurmi community are the majority in Uttara Kannada district when it comes to fish related activities. As it is community rooted activity, there is trust amongst the people and word of mouth (WOM) plays a vital role in any adoption or rejection of the new process. Men in the community associated with catching of fish whereas woman are employed in drying and selling of fish. These communities largely depend on woman in monsoon season (June – August) for their daily needs as catching fish in deep sea is banned at this season.

With the raise of technology driven super markets and lack of infrastructure and necessary technology awareness, it is affecting the business of several woman fish vendors (WFVs) in this part of the state (Gunakar and Bhatta, 2016). Digital illiteracy/ adoption among WFV's is one among a significant cause for their marginalisation and cause a drop in their commerce (Aswathy, Sathiadhas and Narayanakumar, 2011). Prabhu, Kamath and Joshi (2019) explored the socio-economic

perspective of WFV's on their current digital adoption, their readiness to move towards and their willingness to go digital in their business. This study reveals that WFVs make use of the traditional method to sell the fish. Even though most of the WFVs own a feature phone (no internet, only calling and SMS service), their current adoption of m-commerce is in the nascent stage. It was encouraging to see most of the WFVs have a bank account (89%), Aadhaar card (Unique Identification number given by Govt. of India) (100%) and mobile phone (93%), which provides an infrastructural base for building m-commerce solutions. It was found, WFVs who are below 45 age and whose education is higher than 4th standard have shown significant interest in the adoption of m-commerce. Finally, it was observed that awareness about cashless economy amongst WFVs had positive attitude towards getting digitally trained and use m-commerce in their day to day business (Prabhu & Joshi, 2018).

### System Dynamics

System Dynamics (SD) is a methodology proposed by Forrester (1961). SD is used in different systems where the processes are dynamically complex (Sterman, 2002). SD distinguishes itself from other simulation approached due to its ability to deal with non-linear behaviour of the dynamic systems (Morecroft & Heijden, 1992) and to describe any given system mathematically using qualitative or quantitative modes due to the inherent feedback structures. SD modelling comprises of following steps viz. problem identification, system conceptualisation, model formulation, simulation & validation, and policy analysis & improvement (Sushil, 1993).

Many studies have built SD models among fishers (Scheffran, BenDor and Hannon, 2006), shrimp commodity cycle (Arquitt, Honggang and Johnstone, 2005), management of specific fisheries (McGlade, 1989), strategic planning for fisher groups (Otto and Struben, 2004) and other fisher related models (Moxnes, 2000; Moxnes, 2005; Ruth and Lindholm, 2002).

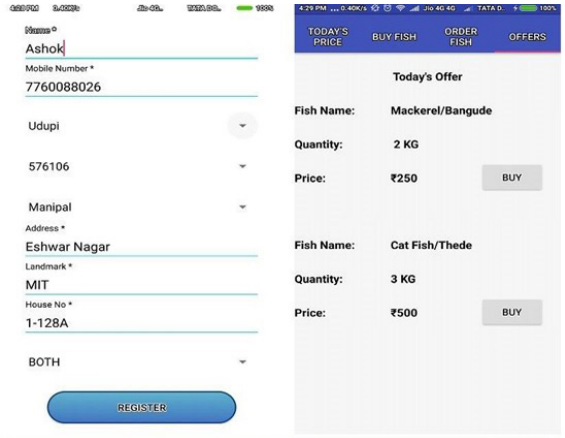
However, it is an interesting observation that there are limited literature, discussing the application of SD to understand the rate of technology adoption among WFVs. Hence, the study focuses on developing a SD model to analyse unorganized fish retail business and identify the determinants that would play major role in sustenance of the business.

## Materials and methods

They study was conducted using quantitative approach using questionnaire and qualitative approach using participatory system model (PSM). The quantitative analysis gave a grounding into the current situation concerning the demographic details and the level of awareness about m-commerce (Prabhu and Joshi, 2018). Hence this paper focuses on the qualitative approach using PSM activity.

For the PSM activity, unlike other statistical techniques, the sample size in PSM is primarily dependent on the nature of the interaction, the complexity of the system being considered (Stave et al., 2017). There is, however, no literature to determine the appropriate participant size. However, researchers viz. (Malard et al., 2015; Sedlacko et al., 2012) have used numbers ranging between 8-10 in their research. The WFVs were chosen randomly using the lottery method. In the first round, seven respondents were selected, but they backed out due to the unwillingness to participate due to a trust deficit. The exercise was repeated, and another seven respondents were selected. This time they were approached through the officer of the fisheries department. The seven respondents agreed to be a part of the PSM activity, but only three turned up. Participants in the interviews were primarily academicians (2), fisherwomen (3), entrepreneurs (2), and customers (3). In total 10 participants were selected for the PSM activity.

In order to makes these participants aware of m-commerce, a mobile application named "m-Fish Market" was developed (see Figure 1 and Figure 2). The participants were made aware of the role of m-commerce to bridge the gap between consumers and sellers.



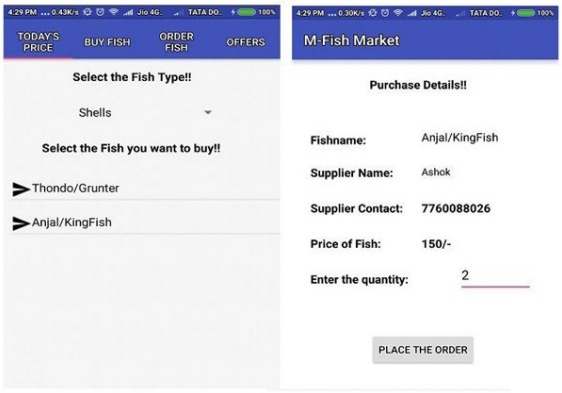

Source: Author

Figure 1: WFV interface of m-Fish market app.

The application was designed to work like an aggregator used primarily in hotel bookings (www.booking.com). The app prototype was developed on the Android platform. Both parties (WFVs and the customers) had to create an account by providing their details in the app.

On the client side of the app (Figure 2), the app could identify the different sellers in the area/ locality, the types of fishes available and the prices and seamlessly order them. Also, the pre-ordering facility was available. The app had the capabilities to get it integrated with m-banking facilities.

Also, going forward, it was thought that the app could also be connected to the wholesalers and the middlemen for getting information on the stock available with them and the daily prices. With additional services like intermediate delivery systems during the day by delivery boys, the stock availability at the WFV level could be ensured leading to high serviceability.




Source: Author

Figure 2: Customer interface of m-Fish market app.

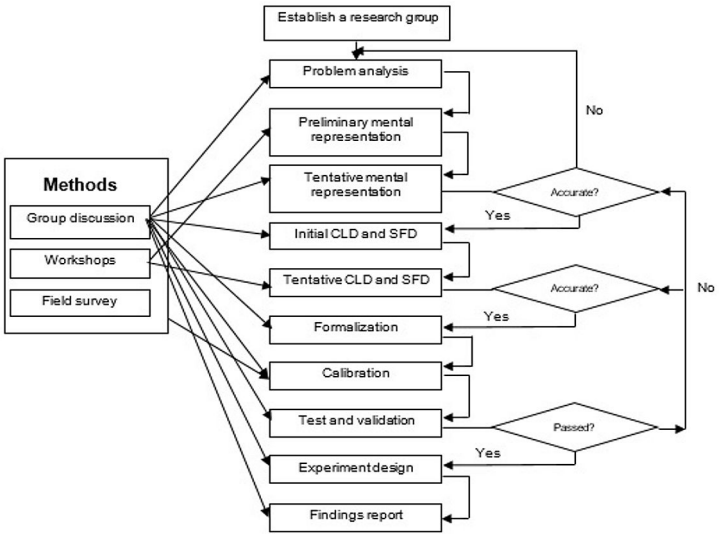
## Participatory systems mapping activity

The participants were asked to classify the underlying issues on a day to day basis for the technology adoption (m-commerce) amongst different stakeholders of fishery industry. This was used to identify the essential gaps that exist in the system. These qualitative interviews enabled in identifying the significant issues and enabling factors for the adoption of m-commerce in their day to day business.

Further, a case study was conducted to analyse how WFV's business would progress under different scenarios of adopting m-Commerce in the day to day business. The study makes use of PSM framework (Wang & Cheong, 2005) to develop a reliable model. This framework was considered to be practical (see Figure 3) for building an SD model for fisheries. To develop the model, the study was conducted by combining several group process techniques like group discussion, brainstorming sessions, workshop and fieldwork.

The model uses several group process techniques to incorporate varied knowledge, which includes expert views, domain knowledge, systems thinking and SD. The PSM framework incorporates different stages of model building process proposed by (Streman, 2002). The stages include problem identification, framing hypothesis, building a simulation model, testing, and policy design and evaluation.

In the modelling stage, the PSM framework was used to develop a mental representation, identifying the variables (Annexure 1), a causal loop diagram (CLD) and a stock and flow diagram (SFD) through




Note: CLD = causal loop diagram; SFD = stock and flow diagram
Source: Wang and Cheong, 2005

Figure 3: The PSM framework

which a simulation model is developed. The CLD links variables that have a causal interpretation and the SFD represents the structure of a target system with denotations of rates and accumulations.

The model was tested for its causality as suggested by (Roy & Mohapatra, 1999), and robustness as proposed by (Barlas, 1996; Sterman, 2002). The simulation results were analyzed and dimensional consistency of each variable was tested. Vensim® 9.00 version software is used to develop the SD simulation model.

## Result and discussion

Outcome of PSM Activity (see Table 1) are highlighted with the key issues and enabling factors of the stakeholders of fisheries sectors towards the adoption of m-commerce.

The model studies the effect of the enablers and barriers towards the adoption of the "m-Fish market app" amongst WFVs. The study simulated the effects of the above-mentioned parameters on the app users in the context of Udupi fish market.

Overall, the Udupi fish market houses 104 WFVs, this is identified as the variable market size. Amongst the 104 WFVs, there are 74 WFVs who have no access to smart phone which is a major factor for not adopting the app. Hence, it is considered 0.7 (74/104) as the factor for barriers of adoption. Effectiveness of WOM by their peers is considered as 0.3, 0.6, and 0.9 respectively representing low, medium and high levels of would be WOM adoption. Simulation start with introducing the app to 2 WFVs, which is reflected in the seed customers. Our assumption is that since it is an easily replicable product, there exists a scope for competitors to bring in new applications. Based on experience, it is assumed 12 weeks as the minimum duration which the people remain loyal to the application before switching over.

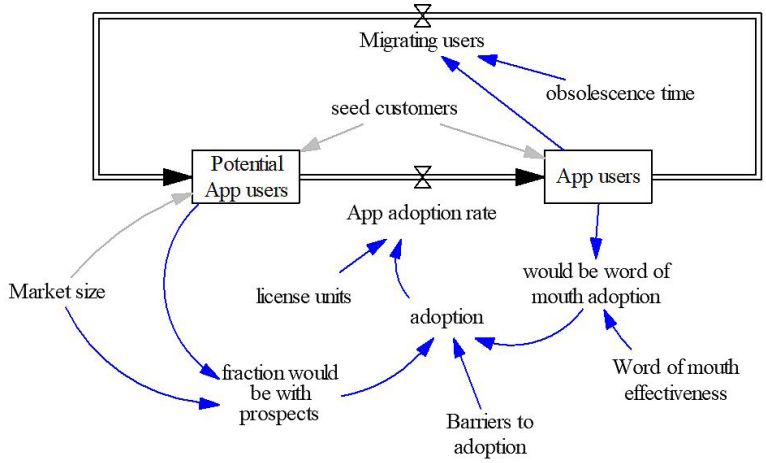
The study simulates 3 cases:

Case 1: Varying WOM effectiveness with same barriers of adoption: This scenario represents that the fisheries federation only encourages the WFVs to adopt "m-Fish market" app. But it doesn't provide adequate support of setting up infrastructure like encouraging the WFVs to buy smart phones, and providing training on using the app, digital payments etc. This study consider it as business as usual (BAU).

| Participant | Issues and Enablers |
|---|---|
| Experts | Technology adoption in the marketing of fish is in the nascent stage among all the stakeholders. |
| | Technology apprehension and lack of awareness amongst the fisherwomen community is hindering the implementation of m-commerce. |
| | It is challenging to create awareness and trust in the technology amongst WFVs to adopt m-commerce. Since it is community based enterprise, word of mouth amongst their peers may inculcate trust towards the technology. |
| Entrepreneurs | When the catch is low, in order to fulfil the commitment, dependency on other traders to fulfil the supply side. |
| | When the catch is low, to fulfil the commitment of the client, we need to buy the fish from other traders. Contacting the traders is a tedious job. |
| | An app that can connect traders, wholesalers, and fishmongers would benefit them by buying additional stock or by selling left out stocks. |
| Woman Fish Vendors | Constrain in carrying more than 30 kgs (two baskets) restricts them from selling more quantity when the demand is high. |
| | It was noted that WFVs sell off the fish abruptly when the demand is low at a meagre price. |
| | It was observed that the lack of trust in the modern retailing method is hindering them to explore a better way of conducting business. |
| | It was an interesting observation to see, at least one member in their family has a smartphone. |
| | There is an urge to earn more as they are the ones who support their children's education and household duties. |
| Customer's | They were delighted to know the concept, as it shall help them to locate the right market place to buy a variety of fish. |
| | They thought that home delivery would save a lot of time and transportation cost. |
| | With the advent of e-commerce and m-commerce flourishing in India, it was observed that customers would support the adoption of m-commerce to buy fish as it would enable them to buy quality fish at their convenient time. |

Source: Author

Table 1: PSM Activity for different stake holders.




Source: Author

Figure 4: System Dynamics Model.

Case 2: Varying barriers of adoption with same WOM effectiveness: This scenario represents that the fisheries federation encourages the WFVs to adopt "m-Fish market" app by providing support in setting up infrastructure and training processes, however, the WFVs don't promote the app usage amongst themselves as they don't find it simple to operate.

Case 3: Varying both WOM effectiveness and barriers of adoption: This scenario depicts a situation where the fisheries federation not only involves in setting up infrastructure and training, also the app is made simple and easy to operate amongst the WFVs leading to good WOM.

Based on the above depicted cases, runs were simulated for two scenarios.

Scenario 1: App adoption rate amongst WFVs for the period of 50 weeks.

Scenario 2: Effect of varying barriers to adoption of the app by WFV's at the end of 50 weeks.

Figure 5 represents the Scenario 1 i.e. app adoption rate amongst the WFVs. In case 1, paper studys the effect of varying would be WOM adoption on the total app users. The factor is varied between 0.3, 0.6, and 0.9 respectively representing low, medium and high levels of would be WOM adoption.

It is seen that, under low condition, there is marginal increase the adoption rate at the end of the 50 weeks period. The adoption rate is approximately 2.2 at the end of 40 weeks ass 30 percentage of WFVs have access to smartphone.

In the second case, with a medium condition, it is observed that the adoption rate increasing week by week and reaching the maximum at the end of 20th Week. Though this is more than the previous outcome, it is slightly significant as promotion with 0.6 WOM shall facilitate the adoption rate amongst the WFVs.

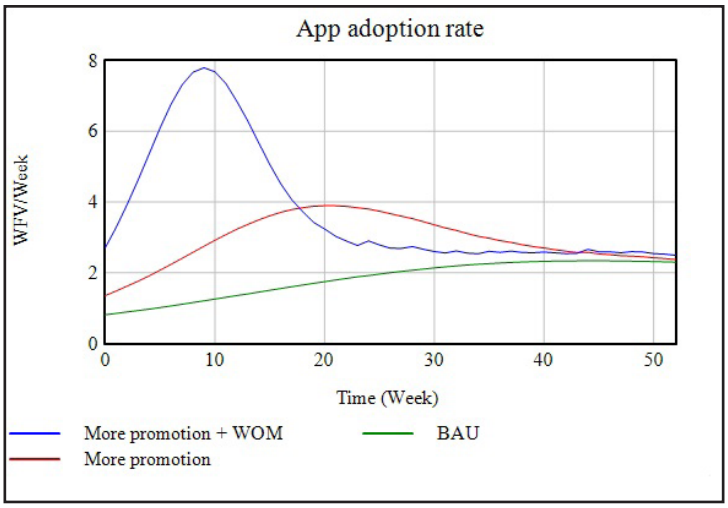
Whereas, in the third case, with a high condition i.e WOM effectiveness is .9, the adoption rate increased significantly reaching to maximum point at the 8th week.

It is worth noting that, the ease of app usage is a parameter that effects the usage amongst the WFVs, but at a higher level, one must observe that, though the willingness to adopt the m-commerce application is significant in the case of the WFVs, mere simplifying the app making it easy to use doesn't help much. Since, it is community based enterprise, WOM places a major role in the adoption of m-commerce.

Figure 6 represents the scenario two. Here paper attempts to study the effect of varying barriers to adoption on the total app users. The factor is varied between 0.7, 0.5, and 0.3 respectively representing high, medium and low levels of barriers to adoption.

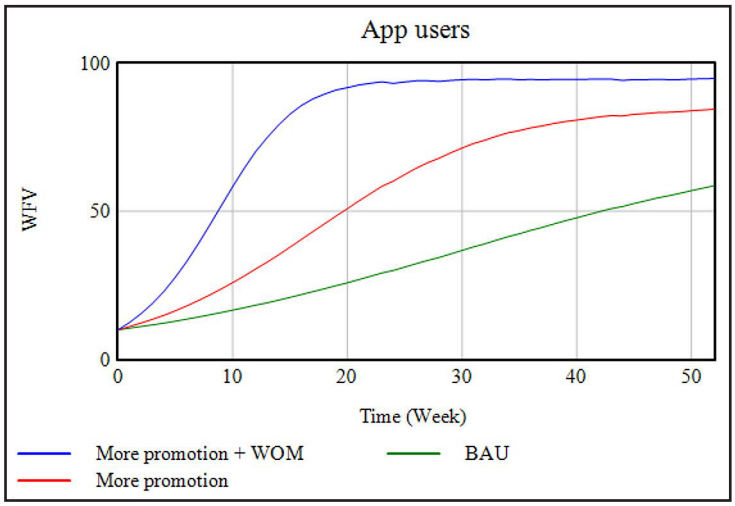
Interestingly, the trend remains to be very similar to what is observed in the previous scenario. Under high condition, i.e higher the barriers for adoptions, there is gradual increase in the number of app users at the end of the 50 weeks period. We see approximately 60 WFVs adopting the m-commerce at the end of the 50 weeks period.

In the second case, with a medium condition, it is observed that the number of app users increase




Source: Author

Figure 5: App Adoption rate amongst WFV's.




Source: Author

Figure 6: App Adoption rate amongst WFV's.

to 60 at the end of 24th week. Total app users increased to 85 at the end of 50 weeks period. Though this is better than the previous outcome, it is not significant.

Whereas, in the third case, with a low condition, the number of app users reached 60 at the end of 10 weeks. There is significant increase in the app adoption by decreasing the barriers of adoption.

It is worth noting that, the barriers to adoption is a parameter that the study assumed would affect the usage amongst the WFVs significantly. One must observe that, though the willingness to adopt the m-commerce application is significant in the case of the WFVs, there existed barriers to adoption in the form of not having adequate hardware infrastructure support and associated training that was mandatory. Hence, it should be noted that, the compound effect of the increased WOM adoption and reducing the barriers of adoption remains a good strategy in the current context.

## Discussion

This study is not to show how the results are varying from similar studies, but rather a different methodology to understand the technology adoption among the farmers or the people who fall under base of the pyramid.

To explain user adoption of new technologies number of models and frameworks have been developed. These models explain the factors that can affect the user acceptance such as Theory

of planned behaviour by Ajzen (1985), Diffusion of Innovation theory by Rogers (2003), Technology acceptance model by Davis (1986, 1989), Social Cognitive Theory by Bandura (1977), Unified Theory of Acceptance and Use of Technology by Venkatesh, et al. (2003).

Many studies have used these models on empirical study and rest have combined previous models or added a new component to develop modified models for their research. Very few studies have used system dynamics model to understand the technology adoption amongst the farmers. We have chosen to analyse fisheries sector by using system dynamics model. This is a novel approach to understand the impact of variables on the outcome without conducting an empirical study. In the modelling stage, the PSM framework was used to develop a mental representation, identifying the variables, a causal loop diagram through which a simulation model is developed.

Simulation based study helps the policy maker to visualize the impact of different factors towards the adoption technology over the years of time. This study has considered barriers of adoption and word of mouth as the factor influencing the adoption. Further study may be conducted by identifying each barrier and how it impacts the adoption rate and also research may be conducted on the behavioural aspects of woman fish vendors towards technology adoption and the impacts created due to it.

## Conclusion

The WFVs have been the backbone of the last leg of the fisheries supply chain in India in the context of B2C sales. They are considered socially and economically backward. The fisheries co-operatives have been taking additional efforts to empower them. Hence the study of adoption of m-Commerce technology amongst the WFV community is critical for their sustenance as it would provide them with a larger market.

Using System Dynamics, the study was able to demonstrate WOM amongst WFVs and better user interface increased the rate of adoption of the m-commerce. However, it is observed that, due to the under-education levels of the WFVs, significant efforts must be put up to educate them about the benefits of the same. As the WFVs work every day, setting up time for training shall be a challenge. This must be done at the level of the co-operative societies, especially during events like annual congregations etc.

From an academician's perspective, this work presents a new direction towards using system dynamics approach to solve a technology adoption scenario. More specifically, the model developed using SD provides a new direction in the context of model-based policy support in the fisheries sector. This will also be helpful for the policymaking bodies to alter or redefine the policies on a timely basis.

It is still too early to tell whether this approach will lead to a new direction for the WFV empowerment using technology, but this study makes a significant contribution to the literature regarding collation of data and to any researcher willing to apply SD in a related context.

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Agris on-line Papers in Economics and Informatics

Volume XV Number 2, 2023

# A Connected farm Metamodeling Using Advanced Information Technologies for an Agriculture 4.0

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## Abstract

The agriculture 4.0 revolution is an opportunity for farmers to meet the challenges in food production. It has become necessary to adopt a set of agricultural practices based on advanced technologies following the agriculture 4.0 revolution. This latter enables the creation of added value by combining innovative technologies: precision agriculture, information and communication technology, robotics, and Big Data. As an enterprise, a connected farm is also highly sensitive to strategic changes like organizational changes, changes in objectives, modified variety, new business objects, processes, etc. To strategically control its information system, we propose a metamodeling approach based on the ISO/IS 19440 enterprise meta-model, where we added some new constructs relating to new advanced digital technologies for Smart and Connected agriculture.

## Keywords

Agriculture 4.0, metamodeling, advanced information technologies, digital agriculture, connected farm.

Rabhi, L., Jabir, B., Falih, N., Afraites, L. and Bouikhalene, B. (2023) "A Connected farm Metamodeling Using Advanced Information Technologies for an Agriculture 4.0", *AGRIS on-line Papers in Economics and Informatics*, Vol. 15, No. 2, pp. 93-104. ISSN 1804-1930. DOI 10.7160/aol.2023.150208.

## Introduction

The Digitalization of agriculture refers to the use of modern machinery, computerized tools, and information and communication technologies in the agricultural sector (Sung, 2018). These technologies make it possible on the one hand to access, store, transfer, and manipulate information, but also to analyze it and give it meaning, to transform agriculture into a more profitable, sustainable, and inclusive sector (Fielke et al., 2020).

Today agriculture is a highly variable area. It is subject to climate change and impacted by diverse and varied parameters that make the farmer ask several questions about which fertilizer to use? And with how much quantity? Is it profitable? Which phytosanitary treatment to use for a particular disease? What is the estimated harvest at the end of the season? What measures should be taken to limit the impacts of climate change? These are repeated questions for the farmer and the entire agricultural value chain. Of course, the farmer's experience and his ability to react to similar events and situations are important in this regard. What is even more important today is that we have data more digitalized and with large quantities coming from the farm. This data can be management data, climate data, data fed back by IoT sensors, or data that come from satellite imagery or drones... (Triantafyllou, Tsouros, et al., 2019). The Internet of Things has the potential to impact every part of modern life from healthcare to education, to manufacturing, and agriculture will be no exception. Connected sensors, cameras, and other devices will give farmers a better understanding of what is going on in their fields. These smart farming equipment, ranging from tractors to planters to sprayers, will be able to monitor problems and fix issues without the farmer's direct involvement (Marcu et al., 2019).

Some IoT devices are developed for specific tasks. For instance, instead of digging ditches by hand or with an excavator, farmers can use robot mowers to trim weeds and grass around ditches. Other devices may be more application-specific. For example, the agricultural drone which connects

to a tablet or phone for controlling and viewing video from a drone can be used to count cows or scout for pests (Radhi, 2018). The cost of connected devices will decline as the number of manufacturers producing these products increases. It will make it easier for smaller farmers to afford internet-connected devices. As more farming equipment incorporates connected features, farmers will be able to manage their operations from home or on the go and forego having expensive IT infrastructure at their farms.

One of the goals of big data is to process massive data to get out knowledge. So typically, processing images from drones or satellite images help to estimate the harvest over large areas. Moreover, through this imagery, it is possible to detect deficiencies or diseases, or pests in plants in a very automatic way and with a high level of precision. Then, by capturing patterns and agricultural practices, for example, we can know the impact of using such fertilizer with such a quantity on a given crop and variety. Therefore, the combination of this data, which can be of different forms and different quantities with a high generation speed, allows having metrics in hand to make the right decisions at the right time. Big Data is a technological tool for the farmer that precisely makes him achieve a high level of productivity and profitability, monitor the quality of production, and respect the environment with precision (Li and Niu, 2020).

This article is structured as follows: in section 2, we first recall Related works of Smart agriculture based on digital advanced technologies. Section 3 deals with the ISO 19440 metamodel to understand the different views of the model. Then, a new connected farm metamodel is proposed as a research method. For each view of the model, we specify the IT entities and their contribution to the farm. In section 4, we describe the 4 views of the irrigation scheduling process case study. The conclusion of this work situates the action plan proposed in this article to underline its contribution as well as the future investigations to be developed.

## Materials and methods

### Smart agriculture based on digital advanced technologies: Related works

Agriculture 4.0 is the most recent technological development in agriculture based on Big Data Analytics, the Internet of Things, and Artificial Intelligence (Symeonaki et al., 2020). It is expected to enhance productivity, efficiency, and sustainability in agriculture. Agriculture 4.0 will be a game-changer that can lead to more productivity in agriculture and increase the incomes of farmers by using high-technology sensors, satellite imagery, and remote sensing applications. Together with the use of drones, artificial intelligence, and robotics, agricultural transformation towards agribusiness entrepreneurship can be achieved.

Smart agriculture is the application of modern information and communication technologies in the practice of agriculture. It implements a variety of techniques including sensors, robotics, drones, and data analytics technologies. Several processes in smart farming are candidates for digitalization such as irrigation, plowing, fertilizing, and breeding...

- *Breeding*

Animals and parcels are connected using IoT tools. This technology is used to manage herds of animals, and it's based on the physiological processes of animals. With this system, farmers can control the animals' heat by monitoring their temperatures and sending a mobile message to the owner if their temperature reaches the reproductive period. In this case, the example comes from connected collars for cattle and sheep farms. This very advanced technology allows breeders to know precisely the heat periods of cows but also, for dairy farms, the quantity of milk produced per day or their need for food supplements. This means that digital affects agriculture as a whole, upstream and downstream. Also, these sensors can be set to detect different behaviors of animals and automatically update data about their health. They are connected to networks and servers and send information over the internet. Modern farmers can now improve their genetics with the help of wireless sensor networks and save time, while also knowing where the animals are and what they're doing.

- *Weather forecasting*

Environmental factors like weather influence crop growth and agricultural production in general. This latter has spatial yield variability, partly because of spatial variability in soil properties and interactions with the weather, which is also spatially varied. Artificial intelligence techniques, like machine learning, could be used to predict the weather for farmers to assist them in their decision-making (Yang et al., 2018).

Authors (Verma et al., 2020) implement a real-time weather prediction system that can be used in agriculture. The system utilizes a temperature

and humidity sensor. Then the sensed data are uploaded to a cloud server. A logistic regression model is used for setting up the machine learning environment. The result of this model is compared with other works available that used Decision Tree and Artificial Neural Network models. The proposed system is slightly better in terms of accuracy.

- *Crop yield prediction and crop selection*

Popular artificial intelligence techniques such as artificial neural networks and machine learning techniques have proven to be effective in crop selection and yield prediction. They are based on various factors such as weather, soils, natural calamities, famine, and other inputs. Using several soil characteristics such as soil depth, phosphorous, potassium, salt, organic matter, and magnesium saturation as input of artificial neural networks, (Coble et al., 2018) confirmed the prediction of corn and soybean yields.

- *Irrigation*

The irrigation system scheduling is one of the most critical processes in agriculture that could affect crop productivity and quality. A farmer must answer the questions "When do I water?" and "How long do I water?" during irrigation scheduling. Watering crops is an important part of crop management. To ensure adequate and timely water supply, it is essential to select the most effective irrigation system to meet the needs of crops. Both overwatering and underwatering can cause crop damage, reduced yields, and poor crop quality which hurt crop yield and profit margins. This latter can improve the water use efficiency by a better understanding of soil moisture, crop health, and weather forecasting and providing only as much water to the plants as needed. Wireless sensor networks are used to automate irrigation systems. They transmit water information from sensors to irrigation controllers, which decide when to measure soil moisture and adjust the irrigation system. The farmer doesn't have to be at the field all day or argue about when to water plants with someone else (Muangprathub et al., 2019).

- *Nurturing and crop protection*

The easiest way to meet the growing need for food is by applying Fertilizers. Measurement of soil Nitrogen (N), Phosphorus (P), Potassium (K), temperature, and humidity of the soil is necessary to determine the suitable fertilizer. Authors (Naresh et al., 2020) and (Bondre and Mahagaonkar, 2019) have researched the topic of Crop Yield Prediction and Fertilizer Recommendation. They tented to provide an accurate decision in predicting crop yield and deliver the end-user with proper recommendations about the required fertilizer based on atmospheric and soil parameters of the land (N, P, K, moisture, rainfall, etc.). They have used data mining techniques to organize the data set and gather the required data using machine learning and algorithms. These goals are achieved by applying data science models on agriculture data to recommend a suitable fertilizer for every particular crop.

Bindu et al. (2020) have realized a review on Smart Fertilizer Distribution System with Crop Yield Prediction. They conclude that with the help of technologies like IoT, Machine learning, Data mining, and big data, they can achieve yield prediction and proper fertilizer distribution. Fertilizer distribution is feasible based on Nitrogen (N), Phosphorous (P), and Potassium (K) NPK values of soil. Alex and Kanavalli (2019) design, prototype and implement intelligent computational techniques for the prediction of crop yield based on the big data from a large number of scattered agriculture fields. They built a big data analytics model for precision agriculture and fertilizer management to improve the agriculture field using a convolutional neural network (CNN). Dahikar et al. (2015) proposed an Artificial Neural Network Approach for Agricultural Crop Yield Prediction based on various parameters. They allowed suggesting fertilizer by using ANN. They confirmed that the result was satisfactory.

- *Plowing*

Tractors have been used in agriculture for a long time, but the advent of autonomous tractors underlines and allows you to use them effectively. These tractors can be equipped with machines that spray liquid fertilizers or plant protection products. With this equipment, farmers can improve their production by reducing labor costs. An autonomous tractor operates on a private road whose operation can be automated through route planning and automatic or manual deflection of the vehicle to avoid incidents. The invention also has techniques for detecting obstacles and automatic or manual deflection of the vehicle to avoid collisions with them. It can even stop and start automatically within the presence of a moving barrier. with GPS-guided features, it allows farmers to operate under better conditions and improve their crop production. However, obtaining an expensive transporter is not enough for many farmers; they need more assistance to develop this strategic business model.

- *Agricultural policy and trade*

Big Data Analytics can be beneficial when simulating agricultural policy impacts. Indeed, A larger quantity of data like crops' production, changes in costs' input, market demand, market supply, market price trends, cultivation costs, wages, transportation costs, and marketing costs could be learned by Advanced algorithms to predict support prices for farmers by governments in both developed and developing countries.

- *Poultry farming*

Poultry farming is the process of raising domesticated birds such as chickens, turkeys, ducks, and geese to farm meat or eggs for food. Weatherproof sensors can be attached to the bird or the building to track such parameters as the birds' location, temperature, and humidity and monitor their health and hygiene. The sensors can send alerts when a flock is on the farm where they should be and if there is an unauthorized movement. Also, sensors can be implanted under the skin of chickens to provide information on their sleep cycle which can then be used by software to predict egg production.

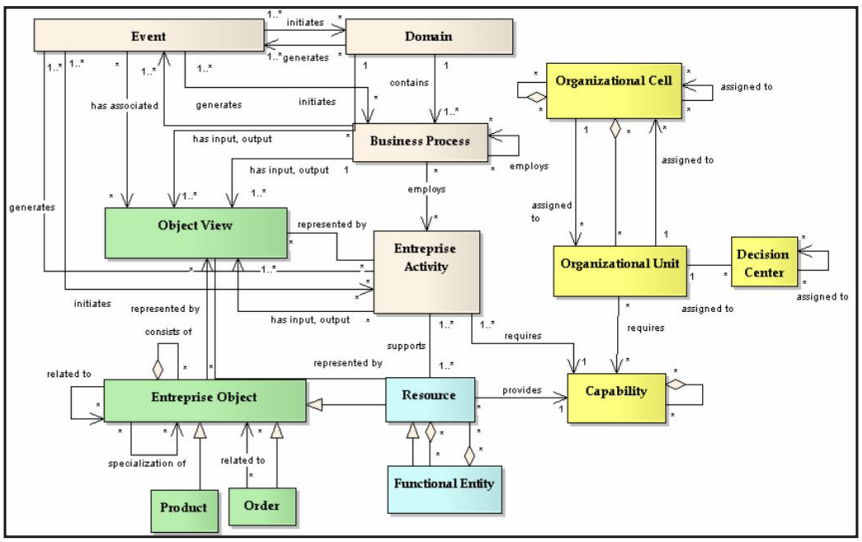
To sum up, agriculture is becoming impacted by various parameters, namely climate change, crop and soil conditions, etc. What is even more important today is having Big Data that is increasingly digital and with large amounts coming from the farm. Moreover, the mastery of data is a wealth for the actors of the agricultural world whose actors use it wisely. Big Data, for its part, makes it possible to analyze data and thus guide farmers in their choices and procedures.

## ISO 19440/DIS 2007 Enterprise Metamodel

Researchers done in1990s, in terms of enterprise modeling, led to a standardized framework that meets the needs of a systemic approach to the enterprise. It's the ISO 19440 meta-model-oriented process model. The standard offers four views on these models: the organizational view, the informational view, the functional view, and the view of resources (Falih et al., 2019). The ISO/IS 19440 standard proposes a set of modeling elements for the representation of the enterprise. In this section, we present the meta-model proposed in the framework of ISO/DIS 19440. This model integrates the four views (Figure 1).

The functional view aims to model enterprise functionality and enterprise behavior. It describes the tasks or activities that must be done and in which order they must be accomplished. It contains Domain, event, Business process, and Enterprise Activity constructs. A domain represents the boundary and the content of an enterprise or a part of an enterprise. A business process represents a part of the enterprise's behavior. It is an aggregation of the business process and/or business activity and the information described by the business rules. The business activity is the realization of a transformation from inputs to outputs by specific resources. An event initiates the execution of a business process or an activity.

The informational view aims to model objects




Source: Boulmakoul, Falih, and Marghoubi, 2009)

Figure 1: Meta-model ISO 19 440.

of the enterprise, their states, and their flows (Vernadat, 2020). Enterprise Object and Object view constructs constitute the informational view. Enterprise Object represents the set of information that describes a generalized or a real or an abstract entity. Object View defines the object's nature (material or information) and represents the object state by a subset of the Enterprise Object attributes.

Resource view aims to model human, technical, or IT agents and components required to execute operations and which roles, capabilities, and skills are required. The resource represents the provided capabilities required to execute an Enterprise Activity. A functional Entity is a specialization of the Resource construct able to perform a functional operation(s) required by an Enterprise Activity. Capability Set represents the capability characteristics of either a Resource or an Enterprise Activity.

The organizational view aims to model organization units, decision centers, decision levels, and their relationships as well as associated responsibilities and authorities. Organization Unit represents an entity of the organizational structure of the enterprise. Below, we briefly recall the semantics of each construct (Kosanke et al., 2014).

## A new Connected Farm Metamodel

In this section, we propose a holistic meta-modeling based on a formal extension of the ISO/DSI 19440 meta-model. This meta-modeling highlights the alignment between functional, informational, organizational, and resource views and supports an arrangement of constructs allowing to deal with a connected farm to model an agriculture 4.0. Our proposed formal extension of the meta-model integrates aspects of Big Data Analytics into smart farms.

Modeling the farm as a complex socio-technical dynamic system is an indispensable means of organizational research to extract useful knowledge. The modeling of relationships between the different entities of the farm and the analysis of their impacts on the overall performance is called structural analysis (Jones et al., 2017). By highlighting associations between specific entities, the analysis can define different views of an enterprise and, therefore, gain in-depth insight into the performance from multiple points of view. Structural analysis can be used to produce a functional, organizational, informational, or resource viewpoint. Such analysis is helpful in a wide range of business scenarios, from business design to real-time performance monitoring.

The figure below (Figure 2) presents our holistic meta-modeling incorporating the Big Data Analytics approach and allowing us to look at the farm from an overhead perspective to establish the different views of the farm. The proposed meta-modeling provides a formal framework that gives global representativeness through a holistic view of the farm. In this paper, our study goes beyond the explicit definitions of functional, organizational, informational, and resource entities to also delve into the relationships and associations linking these entities.

The main contribution is a proposal for an extension of ISO 19440 enterprise

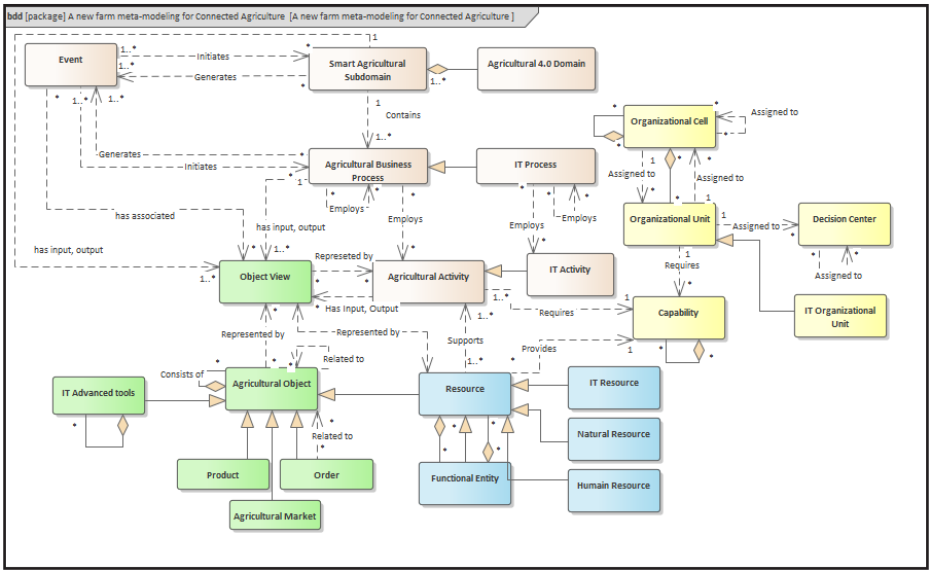



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Figure 2: A new Connected Farm Metamodel.

Metamodel to allow a semantic representation of a digital farm. Agriculture 4.0 is a concept that combines ideas of precision farming with sensors, cloud-based analytics, and artificial intelligence (AI) in the context of a new IoT farm model. The agriculture 4.0 model proposes a new set of stakeholders and entities, relationships between these entities, and models of how the actors interact with the various entities. It is enabled through a combination of new sensor technologies, cloud-based analytics, artificial intelligence (AI), mobile technology, robotics, and autonomous control systems. Smart farming modeling provides a holistic view using interlinked components that work together to provide innovative design solutions required to meet future agricultural needs in increasing productivity, improving sustainability, and supporting rural communities (Cho Yongbeen, 2019).

*- Functional view of the extended Metamodel*

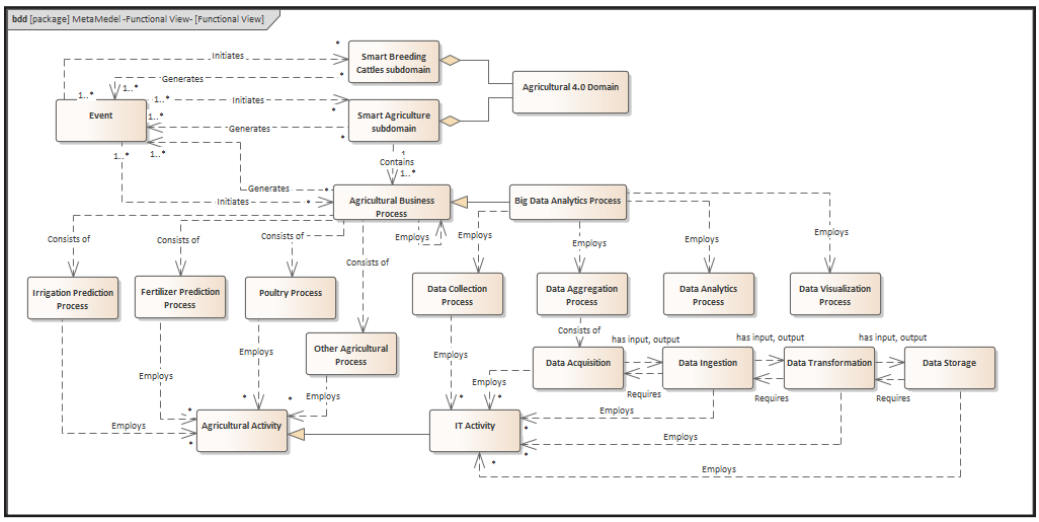
Agriculture 4.0 in general refers to two domains. The first one concerns land issues (smart agriculture) like plowing, Fertilizing, harvesting, afforestation, etc. The second one concerns breeding cattle issues. The functional view of smart agriculture aims to meet the different processes and activities involved in smart agriculture (Figure 3). To carry out these processes and activities in a smarter manner, it is important to exploit IT processes (Perakis et al., 2020). They can be done towards increasing the efficiency of irrigation, selecting the optimal stage of planting or harvest, identifying anomalies, and more services by the analysis of large data sets to find useful information that helps make decisions. Based on the data collected by sensors, farmers can also modify their processes to improve their land yields. For example, the amount of fertilizer that is required for optimal growth can be determined.

Furthermore, soil type and moisture levels can be identified which will allow farmers to make adjustments to their irrigation methods based on the needs of the crops. Indeed, based on the data that is being collected from agricultural sensors and gathered from weather satellites it is possible to maintain finer control over irrigation systems. This will allow for optimal water usage to save money and replenish groundwater stores for later use. Climate data from satellites and ground stations allows for early forecasting to minimize risks such as floods and droughts. This information collects data on soil moisture levels, surface temperatures, precipitation patterns, and more are fed into climate models that then simulate future conditions thus allowing farmers to plan accordingly. By utilizing this technology, it is possible to predict droughts before they happen to help prevent crop loss (Rabhi et al., 2021b).

IT Process refers to the Big Data Analytics process. We inspired it by the Functional big data analytics-based framework for connected agriculture (Rabhi et al., 2021a). It includes Data Collection, Data Aggregation, Data Analytics, and Data Visualization processes.

*- Informational view of the extended Metamodel*

The informational view regroups the used sources of agricultural data (Figure 4). Data is the core of the proposed extension of ISO 19440 metamodel. It is based on a comprehensive set of agricultural objects. It classifies agricultural objects according to the functionalities they support. Each process requires data information such as climate data, soil moisture content, real-time crop status, etc. (Ngo, 2020). Agricultural objects are now more and more




Source: author

Figure 3: Functional view of the extended Metamodel.

connected by using sensors and IA (Wang et al., 2021). They are part of the Internet of Things (IoT), which incorporates a variety of objects, systems, and services that communicate information using Internet connections. Agricultural objects include tractors, harvesters, GPS devices, robots, drones, etc. (Triantafyllou, Sarigiannidis, et al., 2019). The set of these agricultural objects is classified into functionalities entities that they support such as planting, spraying, harvesting, repairs, etc. Sensors are placed on the ground or on the plant to characterize its soil and its health (water, temperature), as well as drones that fly above the farm to measure certain parameters such as the presence of snow or insects. The proposed extension metamodel highlights machine learning (ML) and deep learning (DL) technologies that are necessary for handling massive amounts of big data produced by sensors (Jabir et al., 2021). Besides, IoT enables the collection of huge amounts of agricultural data using sensors. Machine learning can be used by exploiting this data with Big Data and cloud technologies to create a new level of intelligence in agriculture practices (Symeonaki et al., 2020; Rabhi et al., 2021a).

*- Resource view of the extended Metamodel*

The proposed metamodel is a classification of different types of agricultural resources (Figure 5). The resource is a superclass that defines

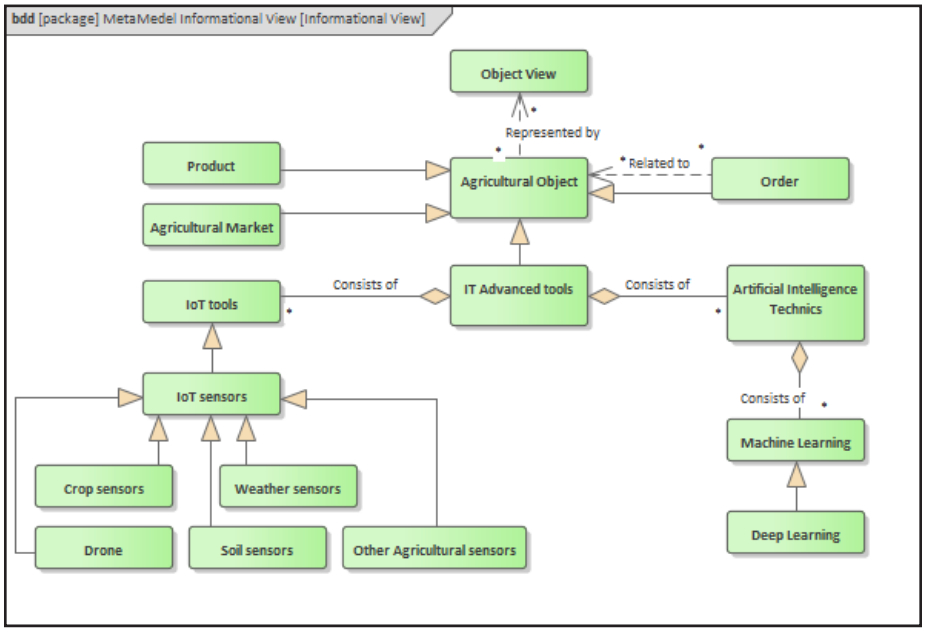



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Figure 4: Informational view of the extended Metamodel.

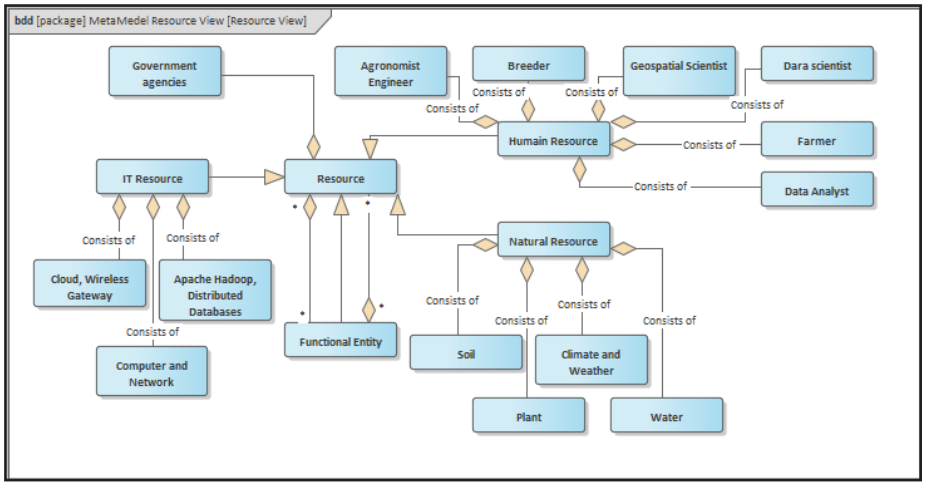


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Figure 5: Resource view of the extended Metamodel

all the natural, human and IT resources entities of the farm. The agricultural resource is presented as a hierarchy of different levels, each level representing an aggregation that contains other resources within it.

Smart agriculture is a collection of technologies that use computers, sensors, systems, and communication networks to track farm data in real-time and use it for decision-making. A diversity of IT tools are used (Rabhi et al., 2021a) like Hadoop, Hive, Pig, Spark, etc.

Among human resources in smart agriculture is a data scientist, he is a person who excels at the practical application of statistics and mathematics to solve practical problems. He is good at acquiring, cleaning, and processing large amounts of data and also analyzing this kind of data using sophisticated algorithms (for example machine learning algorithms) to extract meaningful information. He can be responsible for developing new analytical tools, for example, machine learning ones; for preparing and managing large amounts of data needed for their research; for preparing interactive visualizations that help with problem-solving in complex domains; or even for alerting people about possible problems in their environment.

- *Organizational view of the extended Metamodel*

The Organizational view is a farm model view that enables the representation and modification of the organizational and decisional structure of the farm and the responsibilities and authorities of the persons and organization units within the farm. It describes the relations between the different organizational entities on the farm and identifies their responsibilities. These responsibilities can be on different levels of the organization and are usually carried out by members of the organization entity authorized for the decision-making.

The Organizational Unit is a construct that represents an entity of the organizational structure of the farm such as IT Governance, Data Security, Data Analytics, and Data Visualization Units. The organizational Unit's content shall be determined by naming the assigned entities for which it has authority or responsibility, or both. Indeed, Each Organizational Unit shall contain at least one relationship to an Organizational Role specifying the required or provided organizational skills and responsibilities.

IT governance is a construct that aims to improve the overall management of IT and derive improved value from investment in information and technology. It enables organizations to manage their IT risks effectively and ensure that the activities associated with information and technology are aligned with their overall business objectives.

Risk consideration in smart agriculture modeling is of increasing importance since the business environment is becoming more and more competitive and unpredictable. This need has given rise to the risk-aware agricultural business process management paradigm. It consists of the integration of risk aspects into business process management to increase the risk awareness of a farm's business processes (Lamine et al., 2020) (Figure 6).

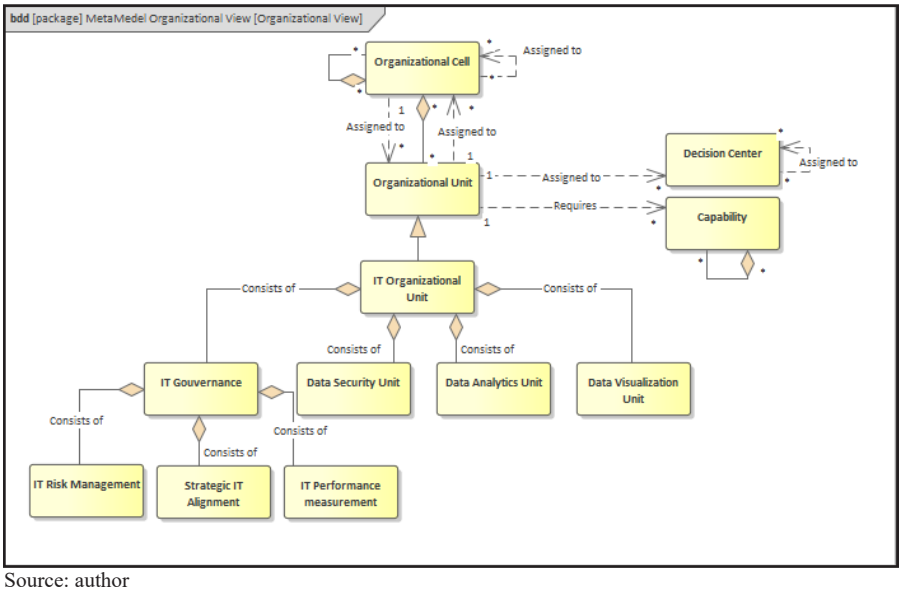


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Figure 6: Organizational view of the extended Metamodel.

## Results and discussion

As an application of the meta-model explained above, we will use the case study treated in one of our previous articles named "Digital agriculture based on big data analytics: a focus on predictive irrigation for smart farming in Morocco" (Rabhi et al., 2021b). This article deals with the issue of predictive irrigation using the Big Data Analytics approach. In this section, we will show the 4 views of the metamodel: Functional, Informational, Organizational, and Resource views.

- *Functional view*

The goal of the irrigation scheduling process is to control the timing and amount of water used on a given field or farm. Irrigation scheduling is used on crops to help manage growth, optimize yields, and improve fertilizer efficiency. It also helps reduce soil erosion and improve crop yields. When a crop is unnecessarily watered too much, either so it's overwatered or has irrigation water sitting in the soil without being taken up by the plant roots. This can cause plant damage and reduced yields. With so many ways to damage crops, it's important to implement a smart irrigation system. With the big data analytics process, we can catch how much water is being lost and track areas that need more water. This way can maximize crop yields while minimizing the financial and practical impact of damage on crops (Figure 7).

We have predicted whether the soil is dry or not based on its state of moisture and crop temperature. Thus, we used Big Data Analytics technics to predict the position of the pumping motor. If the soil is dry, the pump will be set to "ON" else to "OFF".

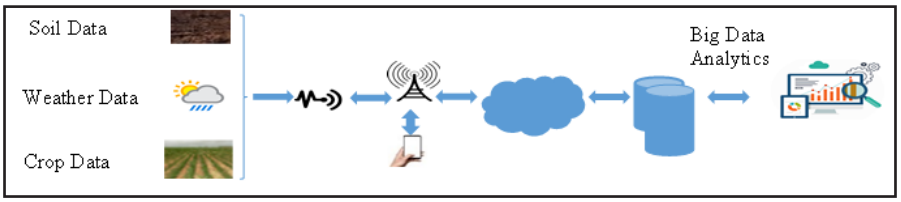
- *Informational view*

Through sensors placed directly on the plant and soil, connected devices allow measures that concern soil and crop conditions. Coupled with weather data, these Big data will be transmitted via a wireless sensor network and then stored and analyzed with advanced tools of big data analytics to extract useful insight (Figure 8). We worked with an existing dataset where information is collected from sensors (temperature and moisture). We used a dataset containing a large amount of data. If the pump state contains one, that means the pump is ON and the soil is dry. If it contains zero, that means it's OFF and the soil is watered. We've imported a CSV file with information on the moisture and temperature. The first columns have the parameters of moisture and temperature, while the last one represents a class (pump).

The Databricks platform is also used to create a combination of big data storage and analytics to quickly build, manage and share data pipelines. It is a big data processing platform founded by Apache Spark. The data is analyzed in the Databricks platform using machine learning technics: SVM and Artificial Neural Network models.

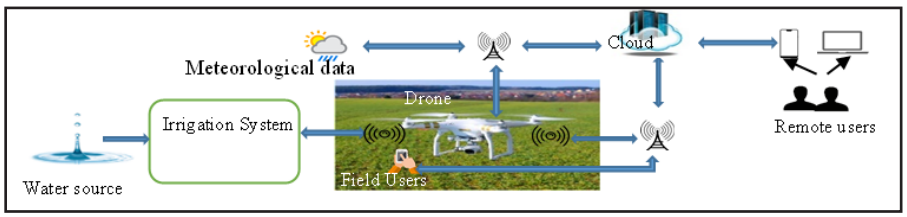
- *Resource view*

Smart irrigation scheduling is a collection of technologies that use computers, sensors, and communication networks to track irrigation data in real-time and use it for decision-making. A wide range of technologies is used in this study like Hadoop, Apache Spark, Databricks, etc. The main actor who can contribute to solving the Irrigation




Source: author

Figure 7: functional view of Irrigation 4.0.




Source: author

Figure 8: Logical view of Irrigation 4.0.

scheduling problem is a Data scientist. He is an analyst having statistics and mathematics skills. Its goal is to make sense of the data being manipulated and extract insight from it to help taking decisions. He can be responsible for collecting agricultural data (Data Ingestion), storing data (Data Storage), Transforming (Data Processing), Analyzing data, and restituting the final result (Data Visualization). All of these operations can be done using analytical tools (Databricks, HDFS, Apache Spark ML, Graphx…).

- *Organizational view*

The Organizational Unit is a main organizational structure of a farm that closely represents the entity of the farm. It can contain aspects such as Data Security and Data Analytics units, as well as Data Visualization units. The case study presents graphs and plots to visualize the result of the data analysis. Comparison criteria are used to assess the effectiveness and accuracy of the proposed models.

## Conclusion

Agriculture 4.0 is the future of farming, integrating cutting-edge technologies like data management and analytics, communication infrastructures, sensor technologies, robots, artificial intelligence, and blockchain. Through the use of these technologies, farmers can automate their crop management, produce higher quality yields, save resources, and have access to data-driven insights to aid their decision-making process. By transitioning to smart agriculture, farmers can create a more efficient agricultural market and ensure a secure, sustainable food supply for generations to come. So, investing in advanced technologies for smart agriculture is a small step to ensuring a more hopeful and prosperous future.

The paper presents a novel conceptual Metamodel for a digital farm based on the concept of IoT technologies and Artificial intelligence. This new Metamodel aims to provide dairy farmers with all the tools they need to manage their farms in an intuitive and user-friendly way while benefiting from a powerful tool that helps make decisions. As a consequence, metamodeling is an important research topic for supporting the development of smart agriculture platforms. Researchers are invited to technically develop 4.0 platforms based on this proposed "Connected Metamodel". In our future work, we will present case studies detailing how each view of the proposed metamodel works in practice.

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Agris on-line Papers in Economics and Informatics

Volume XV Number 2, 2023

# Marketing Management of Electronic Commerce in the Process of Current Marketing Management

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## Abstract

Electronic commerce is booming and has become a phenomenon of our time. While it only existed for a relatively short period of time, it left a significant mark on the current form of business, which can be referred to as the era of the information revolution. In the newly forming conditions, companies must adapt. Otherwise, they will disappear sooner or later. The article discusses the marketing management of electronic commerce with agricultural and food commodities. Its main purpose is to suggest a solution of possibility to strengthen the competitive position of companies with agricultural and food commodities trading mostly electronically by using a marketing management model n order to accomplish this. E-commerce provides opportunities for identifying the main weaknesses in marketing management of the company and recommending how they can be addressed. In addition, the best e-commerce marketing practices and tools are identified and recommended. The current ones are analysed and summarised as well as generalised knowledge of marketing management and electronic commerce and designated for solving problems in marketing management in e-commerce among selected companies that trade predominantly in research savings.

## Keywords

E-commerce, marketing, management, strategic management process, trade, entrepreneurship, e-strategies.

Stuchlý, P., Hennyeyová, K., Janšto, E., Šilerová, E. and Vaněk, J. (2023) "Marketing Management of Electronic Commerce in the Process of Current Marketing Management", *AGRIS on-line Papers in Economics and Informatics*, Vol. 15, No. 2, pp. 105-113. ISSN 1804-1930. DOI 10.7160/aol.2023.150209.

## Introduction

The field of e-commerce is booming and has become a global phenomenon. Its relatively short existence greatly influenced the current form of business, which has been referred to as the era of the information revolution (Collins et al., 2006). Changes in these areas inevitably alter the lifestyles of buyers and traders alike. Unless companies adapt to the newly forming conditions, they will eventually disappear, according to Kumar et al., (2011). Business transactions are changing due to the development of information and communication technologies. In the past, buyers had to satisfy the asymmetry of information in favour of sellers and were therefore passive recipients of marketing information (Maglio et al., 2009). With the creation of internet media, this situation changed completely. Consumers can learn a great deal about products and companies easier to search and verify than ever before, according to Erumban et al., (2006) and Jai Arul et al., (2011). Therefore, the absence of active participation in new communication platforms is practically impossible for a successful seller. In this new era of technology, orienting yourself and using these new aspects to your business advantage is essential.

The historical development of marketing shows that some approaches and orientations have survived and are still applicable today. However, others have disappeared or are only used in limited situations and cases with the company's development, competitive market, and customer needs (Vaněk et al., 2011). In addition to the definition of marketing, the work discusses the shift from traditional marketing to modern marketing. It has been clearly stated by Rusu et al., (2015), Wielky et al., (2017) and Tullis et al., (2013) that the digital revolution is influencing modern marketing, resulting in a substantial increase in purchasing power, a greater diversity of products and services, a greater amount of information about practically anything, more accessible contact, submission and acceptance of orders, or comparison of product and service reports.

A successful company operating on the current market follows and uses modern marketing concepts that support traditional marketing tools, as reported by Bolková et al. (2012) and Azavadar (2011). However, a successful company does not reject any marketing concept but integrates its individual components into the context of traditional and modern marketing approaches to managing complex activities (Boer et al., 2003; Leede et al., 2005). Research results have shown that companies with marketing activities that are not solved separately but as a system of activities optimise business management and achieve business and marketing goals more effectively.

According to Vaněk et al. (2009) and Leach et al. (2008), marketing began with the information age. The priority is to focus on the customer as a follow-up to the individualised one marketing, transitioning from traditional market-oriented marketing to market-oriented marketing to the digital market and changing traditional market-oriented marketing to marketoriented marketing for the digital market, as well as integrating what has been known so far as procedures and principles into a complete marketing approach. Many authors, such as Bresnahan et al. (2002), Zairi et al. (1995), Miller et al. (2012) and others, argue that they have evolved over the years with the development of new communication media and the approach of customers to specific forms of marketing (specific marketing), which reflect both traditional and modern marketing principles. It is argued by Hassenzahl et al. (2006) that specific marketing focuses on a specific area to which all marketing activities, including its tools, are subordinated. When new communication media emerge and consumer needs change, the subsequent forms of specific marketing appear. As a result of their declining effectiveness over time, other forms of marketing have emerged. According to Smith (2003), traditional marketing becomes more and more expensive if it wants to be as effective as in the past. Over 90% of respondents trust references (most often on social networks and in virtual environments), while 14% trust traditional advertising in traditional media (television, radio, press, etc.). As a result of long-term mass marketing, consumers have become increasingly immune to companies' marketing campaigns. As a result, new forms of marketing are today more significant than traditional forms, not by the volume of funds spent but by effectiveness. This determines the dynamics of the researched department.

Teamwork is crucial in the final process of marketing management, according to Corso (2011) and Manas (2005), and it should be concentrated in a defined or determined work team (for example, the marketing department that cooperates closely with other departments within the organisation). The process of marketing management should become an integral part of corporate identity, which is co-created by a marketing manager who performs several managerial and marketing functions. Jones (2003) talks about some managerial and strategic instruments that create synergy in the marketing process. This includes, for instance, the decision-making process, the development of a competitive, growth, and rescue strategy, the cooperation between top management and other departments of the company, and other external and internal factors. According to Jensen (2010), the development of the Internet market and information technology, in general, offers new opportunities for marketing management. It is mainly due to globalisation, which makes it possible to obtain a large amount of input information and compare them for an effective marketing process. Thus, knowledge management and marketing management can work together. Rao (2007) presents the main themes of contemporary marketing management in relation to general societal and consumer protection themes. Marketing management topics are mainly focused on the classic 4P marketing mix while respecting other external factors that significantly influence the marketing management process.

Different opinions have developed over time regarding the marketing management concept, reflecting the field's effectiveness. The consensus in practice and theory (in this form taught at universities) includes phases such as analysis, planning, implementation and control. However, the validity of this model is limited since it does not consider factors such as the external environment or opportunities for creating a marketing program or business strategy. According to Corso (2011), it eliminates these shortcomings in the marketing management model.

Miller (2012) suggests that it should be refined and formulated based on an analysis of business strategy and strategies at the strategic business units (SBU) level. A marketing program is based on the classic 4P marketing mix, which includes decisions on product policy, price policy, distribution policy and promotional communication policy. On this basis, it should be consistent with the marketing program creating the primary strategy according to the scope in the main markets. It is in the last stage created strategy

according to the marketing program, which is implemented in the planned process, and at the end a control is performed based on the created system measurements and monitoring whether the main business and company strategy has been achieved.

Strzebicki (2015) states that in agribusiness it is important to address the decisionmaking process, the development of a competitive, growth and rescue strategy, cooperation between top management and other company departments and other external and internal factors. Although e-commerce has a great potential to provide many benefits for both consumers and businesses, its development in Poland is still at a lower level compared with the highly developed countries of the European Union. However, electronic commerce affects the operation of many enterprises and agricultural markets. In Poland, one can observe two main directions of development of B2B e-commerce in agribusiness. On the one hand, traditional enterprises of agri-food chain try to use e-commerce solutions to strengthen their market position and to better conduct existing functions. On the other hand, there are beginning to appear new cybermediaries who try to take advantage of the fragmented Polish agricultural market.

Rusu et al. (2015) identify this principle of marketing management. Wielky et al. (2017) emphasise analysing individual environmental factors to follow up on the central marketing strategy concept and apply the basic management principles. Tactical and operational tools should correct the main strategic points. Azavadar (2011) adds that the entire process up to its implementation had to be customer-oriented and connected to their needs. The entire marketing process, according to them, management should be socially (holistically) oriented.

Additionally, Azavadar (2011) emphasises the importance of precise targeting of marketing information systems in the process of marketing management. Electronic commerce constantly impacts a company's management system, including factors such as online and offline competition, online and offline customers, suppliers, Internet and classic market conditions, and expected and unexpected changes. Through the strategic management process, an Internet company's main e-strategy is created based on its vision and mission. Among the lower management units, she discusses are personnel, IT, marketing, logistics, production, and finance. Collaboration and participation in the company's overall output are essential. All these aspects co-create the corporate culture of an Internet company. The system of management and coordination targeted support contributes to the efficiency of the output of the entire process, creativity or effective communication, motivation and cooperation of all marketing members. The output, which is the result of the systematic work of all company units, affects the ecommerce environment.

## Material and methods

We collected material and verified hypotheses based on theoretical preparation and knowledge of the current level of problem-solving. Before starting the research process, it was necessary to analyse and characterise the current internet market with agricultural and food commodities. Data from the Statistical Office and other portals that deal with companies primarily involved in the trade were used for this purpose electronically.

In the first stage of the research process, the work was carried out in accordance with the main objective of the article qualitative research, which is to analyse and evaluate the process of marketing management in e-commerce and the possibility of using individual marketing management tools in electronic commerce with agricultural and food commodities. The results of qualitative research serve as a basis for refining hypotheses and research questions formulated in quantitative research. A qualitative study was conducted using an electronic questionnaire with prominent representatives (managers and leaders of the sales and marketing departments). Several departments, directors or owners of five selected companies agreed to participate in this research. The empirical research was conducted in January and February 2020. Choosing these months for the personal inquiry was intentional, as there has been a long-term trend of lower sales during this time period, so there is a more significant assumption that companies are more willing to participate in the research. There is a vast onslaught of internet companies before Christmas when sales can make up to 80% of the total sales for the year. There were 20 open questions divided into sections in the electronic questionnaire:

There were 20 open questions divided into sections in the electronic questionnaire:

- Questions aimed at marketers.
- Questions focusing on marketing strategy and strategic processes.
- Questions targeting suppliers and customers.
- Questions focusing on e-commerce.

On the basis of a previous agreement, these questions were uniformly presented to the selected companies.

On the basis of a previous agreement, these questions were uniformly presented to the selected companies.

The quantitative research sample for our article focuses on online retail sales which concerns agricultural and food commodities such as oils and fats, canned products, soft drinks, processed fruits and vegetables, nuts and oilseeds, but also coffee, tea and snacks. Retail sales focus on smaller volumes of final consumers with a B2C model (business-to-consumer). In retail, there is a high degree of economic competition and pressure to reduce consumer prices. Salespeople in specialised and non-specialised stores, merchants (e.g. classic stone stores), internet sellers, and merchants with a preponderance of mail order services and other merchants make up retail companies, depending on how they sell. Retail sales on the Internet are blurring the lines between traditional and Internet retail, and the lines between mail orders and online sales are almost nonexistent.

69 companies that primarily trade electronically agreed to participate in quantitative research (questionnaire survey). A total of 57% of questionnaires were returned. This sample set can be considered sufficiently representative, and with the help of statistical induction methods applied to this sample set, meaningful conclusions can be drawn for the entire base set. Our empirical research was based on theoretical information from domestic and foreign literature, as well as our practical experience.

H1: Marketing management does not directly impact the competitiveness or size of companies that trade primarily electronically.

H2: In e-commerce, all phases of the marketing management process are equally important and equally distributed.

We interpret data from quantitative research using the following statistical methods and test the hypotheses formulated in our article:

Pearson's $\chi^2$ - test of independence uses a two-dimensional basis set with a discrete distribution (X, Y). The variables X and Y can represent both quantitative and qualitative statistical characteristics, i.e., both statistical characteristics have a finite number of values. Chi- square tests are included among conformity tests because they assess the conformity of the distribution to the basic set of probabilities. Assume that (X1, X2, ..., Xn) is a random selection. This random sample is formed from a population with some particular probability distribution, which we are testing statistically. Results obtained from measuring elements of the sample set must be representative, i.e. they must reflect the properties of the entire basic file.

## Results and discussion

This chapter aims to provide more accurate results by providing summary descriptive statistics for selected survey questions (i.e. mean, median, mode, standard deviation, variance, maximum, minimum). In all sections of the questionnaire survey, these questions were asked (i.e. companies that use the concept of marketing management, companies that do not use the concept of marketing management, but consider it, and companies that do not use the concept of marketing management but do not consider it). Table 1 summarizes the results for all groups (n = 69). In the first group of questions, specific marketing forms were discussed. Generally, companies attribute the greatest importance to internet marketing (on average 5.12 points, mode 4 points, and median 4 points). Printed media marketing (average 3.87 points, mode 5, median 4), radio marketing (average 4.11 points, mode 4, median 4) were placed at other places with the importance that companies attribute to individual forms of marketing and television marketing (average 3.31 points, mode 5, median 3).

A buzz marketing strategy (on average 1.13 points, mode 1, median 1), a holistic marketing strategy (on average 2.4 points, mode 3, median 3), an event marketing strategy (on average 2.4 points, mode 2, median 3) and a behavioral marketing strategy (on average 4.49 points, mode 1, median 2). The low rating of the last mentioned form of marketing may be attributed to general ignorance of them. This confirmed the stereotypes that companies apply in practice. This proves that most internet businesses do not follow new trends in marketing, in most cases they rely on internet marketing tools. Another group of questions focused on the use of selected forms of Internet marketing. Internet companies attribute the greatest importance to website optimization (on average 6.12 points, mode 5, median 4). Companies attribute the second highest importance to the PPC (Pay per click) system, which means that the company pays for the published advertisement when the customer clicks on it and other similar systems (average 6.79 points, mode 5, median 4). The next step is

| | N | Average | Median | Modus | Freq. | Min | Max | Lower quartile | Higher quartile | Var. | St. deviation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Price strategy | 69 | 38.8 | 50 | 50 | 16 | 10 | 60 | 30 | 30 | 245.12 | 14.78 |
| Distribution strategy | 69 | 12.9 | 10 | 10 | 25 | 0 | 59 | 5 | 20 | 100.18 | 8.7 |
| Propagation | 69 | 15.1 | 10 | 10 | 35 | 0 | 58 | 10 | 20 | 98.45 | 6.8 |
| Production strategy | 69 | 8.8 | 10 | 0 | 23 | 0 | 23 | 10 | 40 | 87.54 | 7.7 |
| Segmentati on | 69 | 3.6 | 2.5 | 0 | 34 | 0 | 60 | 10 | 30 | 78.56 | 2.6 |
| B2B | 69 | 2.4 | 0.5 | 0 | 18 | 0 | 60 | 0 | 10 | 15.56 | 5.7 |
| Positioning | 69 | 3.8 | 5 | 0 | 19 | 0 | 45 | 0 | 10 | 13.45 | 4.8 |
| Marketing strategy | 69 | 8.1 | 10 | 10 | 16 | 0 | 40 | 0 | 10 | 12.45 | 6.1 |
| E- strategy | 69 | 5.9 | 5 | 0 | 18 | 0 | 45 | 0 | 10 | 5.13 | 4.7 |

Source: own research and processing

Table 1: Statistical expression of the basic set of observed quantities of empirical research.

to analyze web traffic and banner advertising (on average 6.22 points, mode 5, and median 3). According to the interviewed companies, online public relations is the least important tool of Internet marketing (on average 1.1 points, mode 1, median 1), followed by viral marketing (on average 3.21 points, mode 1, median 1), behavioral advertising (on average 1.25 points, mode 1, median 1), and discussion forums (on average 4.98 points, mode 1, median). The use of discounts on discount portals and marketing in social networks, as a current phenomenon, received rather below average ratings (marketing in social networks - on average 2.05 points, mode 1, median 1.5; discounts on discount portals - on average 7.81 points, mode 1, median 2).

These results indicate that modern forms of internet marketing are not useful for e- commerce and do not contribute to conversion marketing's ultimate goal. The last set of questions evaluated the importance of selected marketing activities. On average, internet companies gave the pricing policy the highest rating (45.71 points, mode 30, median 40). Distribution policy (average 16.55 points, multiple mode, median 10) and product policy (average 12, 82 points, multiple mode, median 10) followed with a great distance (average 13.83 points, mode 10, median 10). Based on this analysis, companies implement their marketing processes tactically. Marketing strategy gets the most attention (on average 8.4 points, mode 10, and median 10), customer targeting gets the least (on average 5.35 points, mode 0, median 0.5).

Qualitative research and simulation of the created model of marketing management in electronic commerce will confirm the hypotheses formulated in our article (H1, H2).

H1: It is not clear whether using marketing management has a direct impact on the competitiveness and size of companies that trade primarily electronically, i.e. marketing management does not affect a company's position or size on the Internet.

As a result of the comparison between the significance level of 0.05 and the p value of0.06 of Pearson's 4-test of independence, the null hypothesis was rejected, since p = 0.006. Consequently, it can be argued that the concept of marketing management has a direct impact on the competitive position of companies that trade electronically, i.e. the concept of marketing management determines the company's competitive position.

Using individual marketing management tools and the entire concept of marketing management in e-commerce more effectively (i.e., a better competitive position) was revealed by qualitative research. In comparison to firms in a lower or average competitive position, they use intensively and synergistically available marketing management tools and apply the knowledge of responsible employees, including following trends. It can be concluded from these partial results that marketing management is dependent on the ability of firms that primarily trade electronically.

Pearson's $\chi^2$ - test of independence, which tests the hypothesis at a significance level of 5%, i.e. A = 0.05, in which the study seeks to determine whether there is a relationship between firms that trade primarily electronically utilizing marketing management (denoted as a random variable X) and their number of employees (denoted as a random variable Y), i.e. in our article's questionnaire research, questions number 1 and 6.

In order to reject or confirm a verified hypothesis, the P-values need to be compared, which is the minimum significance level for rejecting a null hypothesis. It was decided to establish two hypotheses: a null hypothesis (H0) and an alternative hypothesis (H1): H0: X and Y are independent (E-commerce marketing management is not dependent on the size of the company). Qualitative and quantitative research confirmed the relationship between the competitive position of the firm and the marketing management concept, but not the relationship between the firm's size and the concept. Therefore, hypothesis H1 was rejected.

In e-commerce, all phases of the marketing management process are equally important and equally distributed. A comparison p-value is used to determine the rejection or confirmation of the verified hypothesis, which is set at 5% for the tested hypothesis, i.e. $\alpha = 0.05$. To verify the hypothesis H2, the statistical method of the goodness-of-fit test using Chi-test square. Hypothesis verification is carried out using the Statistica program, which evaluated the results. They clearly demonstrated that the observed frequencies differ from expected frequencies. According to the results, the significance level of p is less than 0.01, i.e. $P \leq \alpha$, so the null hypothesis is clearly invalid. So it can be argued that the use of marketing management tools by companies that trade predominantly electronically, is not evenly distributed. The rejection of hypothesis H2 supported the answers of the quantitative research, which focused on the shortcomings of the companies in the process of marketing management in e-commerce. Internet companies are aware of the shortcomings in not using some marketing management tools, in particular the strategic ones. From this it can also be argued that companies marketing management tools do not use e-commerce evenly, i.e. some are preferred over others. The results of quantitative research confirmed that Internet companies attach individual phases that have different meanings and individual tools of marketing management are not evenly used. Therefore, hypothesis H2 was rejected. The results of quantitative research proved that the concept of marketing management is used in 62.31% of cases. Most companies indicated that they do not use marketing management, but think about it, and that they do not use marketing management and do not think about it. It is most common for companies that do not use marketing management to indicate a lack of knowledge and experience about the concept or an unimportance of the entire concept. Internet businesses are also interested in learning more about this subject, according to research. It is possible for Internet companies to significantly increase the effectiveness of their marketing activities with this recommendation. In the field of electronic trading, marketing is considered very important by the majority of Internet companies which trade in agricultural and food commodities (80.8%).

Most of the surveyed companies implement their marketing activities within their marketing departments or specifically within their marketing departments (17.95%). Small and medium-sized companies are all included in the category of small and medium-sized businesses. According to quantitative research, companies using the marketing management concept underestimate the analysis phase and do not view all phases of the marketing management process equally. The analysis phases and all remaining phases of marketing management, as well as the implementation and control phases, differed significantly. The use of tools in individual phases of marketing management is also not equally distributed. These tools are also given different weights and importance by companies (although theoretically, all tools should be used equally). In addition, quantitative research has confirmed that internet companies place the greatest importance on internet marketing. Often, it is the only form used by the companies approached. Additionally, companies use relationship marketing and print marketing. The fact that television marketing and radio internet companies do not actually use marketing is surprising (although literature searches undermine the effectiveness of these traditional forms of marketing). Due to their ignorance, companies rarely use other modern forms of marketing (such as low-cost marketing and holistic marketing). Marketing in electronic trading is mostly limited to internet marketing, while other traditional and modern forms of marketing are not used. However, this reduces the complexity implementation of marketing on the Internet market, which can again lead to its lower efficiency.

In addition to qualitative research, quantitative research focused on selected forms and tools of Internet marketing. As part of Internet marketing, Internet companies often use website optimization, PPC, similar systems, and website traffic analysis. Modern forms of marketing, such as social networking, are used by companies, but they do not

consider them significant. They only marginally use discount portals.

In spite of the fact that viral marketing is one of the most powerful tools in today's Internet marketing, most companies do not use it or do not give it much attention. Tools that lead to conversion marketing are the current trend. The majority of Internet companies do not use it, according to quantitative research. Even internet marketing is not used effectively by internet companies. Quantitative research has shown that Internet companies differentiate between strategic and tactical processes, i.e. strategic processes are significantly underestimated compared to tactical processes. Internet companies identify marketing with the tactical elements of the classic marketing mix, neglecting other processes. Like other business processes, marketing processes need to be implemented strategically and conceptually, preferably through marketing management processes. Overall, the quantitative research shows that marketing and marketing management in e-commerce are not carried out comprehensively and efficiently, and at the same time, they do not follow modern trends in the field, which can have a significant impact on results.

## Conclusion

It is clear from our empirical research that marketing management has a significant impact on the competitiveness of companies that trade predominantly electronically. In some companies, however, its potential is not fully utilized. It reduces the importance and effectiveness of marketing in e-commerce in companies which trade in agricultural and food commodities. All disciplines in the field of electronic commerce can benefit from marketing management. Most companies have the concept of marketing management in e-commerce, but a significant percentage do not use it or do not know how it works. Participation in company processes is no longer important and effective for the marketing team. It is necessary to identify shortcomings and suggest measures to eliminate them as part of the marketing management process. In electronic commerce, the process of identifying individual instruments followed a similar pattern. The results of quantitative research served to formulate the main conclusions and verify established hypotheses.

The main findings from the research process are the inefficiency and uneven use of individual tools in the process of marketing management in e-commerce in companies which trade in agricultural and food commodities. The importance of strategic tools in the process of marketing management is strongly underestimated in e-commerce marketing. Significantly, companies that use the marketing management concept undervalue the analysis phase compared to the other phases. They attach the greatest importance to companies to insufficient risk analysis, insufficiently formulated marketing goals, insufficiently determined marketing strategy, inability to adapt to unexpected events, poor timing, the impossibility of good feedback from customers, and the process that accompanies all phases of marketing management – insufficient internal communication, employee motivation and targeted creativity support.

During the research process, it was confirmed that companies are using the elements of the marketing mix incorrectly as strategic tools. In most cases, all internet companies only use internet marketing tools and only use other traditional, modern and alternative marketing forms in limited amounts. Despite the literature search finding that traditional forms of marketing are less critical for the final results (especially when compared to new forms of marketing), Internet companies place great importance on them. In addition to internet marketing tools, the study examined conversion (modern) marketing tools, which are not used at all or, to a limited extent, compared to traditional forms of internet marketing. We find a very similar agreement in the partial results between our empirical research and the research conducted by SmartSites in 2017. The same results can also be found in the research conducted by Strzebinski (2015) in agribusiness in Poland.

Nowadays, if they have two people, they can implement the same idea in two ways, according to research. Using both traditional and online marketing methods. Marketing services are typically provided 5 days a week, 8 hours a day, and are used to reach the local market. Advertising in newspapers, magazines, billboards, and radio are all used to promote traditional marketing. 24 hours a day, 7 days a week, online marketing is available. It is used when addressing the global market. It does not matter what it is according to the old marketing rules, which are based on disruption. To promote our products or services online, we can use several methods. Websites, e-shops, social networks, e-mail marketing, and advertising campaigns are

the most common. Customers' individual needs are at the center of the new marketing philosophy. In addition to higher quality products, customers expect customized products tailored to their specific needs. As a result, they perceive alternative products less and are less loyal to brands.

As a result, they have access to a large amount of information, which increases their demands. The consumer value of products and services is also becoming more sensitive to prices. The future marketing trend is to be on the market before the need arises, before the demand for the product, push this demand and purposefully shape consumer awareness.

**Acknowledgements**

The results and knowledge included herein have been obtained owing to support from the following institutional grant: Internal grant agency of the Faculty of Economics and Management, Czech University of Life Sciences Prague, grant no. 2022B0006 – "Life Sciences 4.0. Plus".

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Agris on-line Papers in Economics and Informatics

Volume XV Number 2, 2023

# Innovation to Improve the Village Economy Through the Development of Local Wisdom-Based Agro-Tourism, in North Kalimantan, Indonesia

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## Abstract

Several villages in North Kalimantan Province have been potentially suitable to be developed through local wisdom-based agro-tourism. The development of agro-tourism is considered as research background because of the positive impact of agro-tourism on social, economic and environmental aspects of the villages. The objective of this research is to identify development potentials of villages in North Kalimantan Province and to select village to be developed through local wisdom-based agro-tourism. Research type is descriptive research using methods of scoring and Analytical Hierarchy Process. Data type is primary and secondary. Research sample is tourist villages in North Kalimantan Province. Several results of research were obtained. One result showed that three main criteria for developing villages through local wisdom-based agro-tourism are agricultural and plantation resources, facility and accessibility. Other result revealed that Panca Agung Village in Bulungan Regency of North Kalimantan Province is selected for the project of local wisdom-based agro-tourism. Agro-tourism development is expected to contribute the sustainable development at local, regional, national and international levels.

## Keywords

Agro-tourism, tourist villages, local wisdom, innovation, north kalimantan, environmental economics.

Utomo, M. N., Kaujan, K. and Mubarak, A. (2023) "Innovation to Improve the Village Economy Through the Development of Local Wisdom-Based Agro-Tourism, in North Kalimantan, Indonesia", *AGRIS on-line Papers in Economics and Informatics*, Vol. 15, No. 2, pp. 115-131. ISSN 1804-1930. DOI 10.7160/aol.2023.150210.

## Introduction

Village development innovation is a catalyst to village economic growth. This innovation refers to tourism because tourism development has been proven as capable to contribute national economic growth (Shaffril et al., 2015). The contribution of tourism sector to Gross Domestic Income of Indonesia was reported as still one digit, which is, 5.25 percents (2018) but this percentage was still capable to go up (CNN-Indonesia, 2020). In 2018, tourism sector has given foreign exchange of IDR 229.5 trillions, which increases by 15.4 percents from previous year and absorbed workers for 12.7 millions individuals or 10 percents of total population (CNN-Indonesia, 2020). Agro-tourism is one of key contributors to tourism industry. Agro-tourism is a set of activities in which the tourists relate their tourism journey with the experience in agriculture area, agriculture product services and education concerning agriculture (Maetzold, 2002; Arroyo et al., 2013).

Tourism experts consider agro-tourism as an innovative way to develop village area (Marwanti, 2015). In line with this consideration, the Regulation of Indonesia Republic No.110 of 2015 on Agro-Horticulture Tourism was issued. By this regulation, the purpose of agro-horticulture tourism would be the diversification of agriculture works to increase farmer welfare, provide jobs, improve aesthetical and beauty values of the environment, and strengthen the emphasis on natural resource conservation. Agro-horticulture tourism is a variant of agro-tourism. Therefore, agro-tourism will be a proper and innovative solution to the matter of how to manage the development and economic growth of village.

Realizing the importance of this innovative solution, the government of North Kalimantan Province proposed to develop several villages into tourist villages. In 2021, five villages have been put on the project plan and ten villages wait on the list for the next year (Adpim, 2021). Villages

in North Kalimantan Province have potentials to be developed as tourist villages. One of those villages is Setulang Village in Malinau Regency. People in Setulang Village work at their farm land and plantation. Setulang Village is surrounded by 5,300 ha land comprising customary forest and protected forest. The majority dweller, which is Dayak Kenyah, has for a long time maintained the natural scenery of the village, conserved the village culture including language, daily habits, and customary law, and most importantly, taken care of village customary hall, or known as Balai Adat (Lamin Adat). All these constitute local wisdom in Setulang Village (Kabupaten-Malinau, 2019). Other village that resembles Setulang Village is Panca Agung Village in Bulungan Regency. This village is rich of tourism objects and wide agriculture land. However, so far, the stakeholders of both villages do not yet take initiatives to develop their villages toward agro-tourism.

In this research, several villages were reviewed to identify which village has potential to be developed as local wisdom-based agro-tourism. Village width was mapped to facilitate the initiation of agro-tourism development project but the map was used only if the village is selected for agro-tourism. North Kalimantan Province has been declared as suitable for the development of agro-tourism villages because the Province has two privileges, namely potential extensive area and agriculture excellency (Liputan6.com, 2021). Moreover, agriculture is the second biggest contributor to Gross Regional Domestic Income after the mine sector. In 2020, the contribution of agriculture reached IDR 10,922.84 millions (BPS-Kaltara, 2020).

Researches on village economic development through local wisdom-based agro-tourism are never conducted in North Kalimantan Province. Therefore, the current research on the development of agro-tourism based on local wisdom in North Kalimantan Province is academically a fresh novelty. Besides, this review will be in conformity with the national focus of the Main Plan of National Research from the Ministry of Education, Culture, Research and Technology of the Republic of Indonesia. Meanwhile, the focus of this research is on sustainable development at local, regional, national and international levels. There is an expectation that this research contributes the development and management of local wisdom-based agro-tourism villages in North Kalimantan Province. Later, the establishment of agro-tourism villages will contribute the sustainable development at local, regional, national and international levels.

This research needs two years to complete. First year is used for selecting one village for the development of local wisdom-based agro-tourism. Meanwhile, the second year is for constructing the model of development and management of local wisdom-based agro-tourism. This paper is written as a product of the first year research where one village with the highest potential to be developed as agro-tourism is selected. This village is Panca Agung Village which is located in Bulungan Regency, North Kalimantan Province. The paper is outlined into five sections, respectively introduction, literature review, methodology, result, and conclusion.

## Literature review

Innovation on various products or services is an entrepreneurial strategy to increase the demand of those products or services. An innovation in economic activity is considered valuable if this innovation is able to solve social issue and the solution is regarded crucial by stakeholders (government, community association, individuals/ companies) (Santos, 2012; Utomo et al., 2022). Sustainable tourist village will need a systemical integration between resources and stakeholders and this integration can be made happen through service innovation (Peng and Lin, 2016). Innovation for village development is related with a tourism sector that synergize with agriculture sector, and this synergy is known as agro-tourism.

Agro-tourism is a tourist destination that provides agriculture based scenery to the visitors. Worldwide tourists are already familiar with agro-tourism since the early of 20$^{th}$ century (Wicks and Merrett, 2003). Therefore, agro-tourism is a set of activities in which the tourists relate their tourism journey with the experience in agriculture area, agriculture product services and education concerning agriculture (Maetzold, 2002; Arroyo et al., 2013). Main characteristic of agro-tourism is that there is a direct contact between tourists and agriculture activities done by farmers in which later, the tourists get actual experience in or about agriculture (Flanigan et al., 2014). In agro-tourism, visitors not only get tourism journey but also sense new sensation and positive behavior from the environment, especially agriculture community and farmer culture (Wicks and Merrett, 2003). Agro-tourism can also be described

as a set of tourism activities that utilize agriculture potentials as tourist attraction, including agriculture landscape, various agriculture-based production activities, agriculture technology, and farmer culture (Gunarta and Hanggara, 2018).

New strategy has been conceptualized to be the base that underlies the development of agro-tourism and this strategy refers to local wisdom-based agro-tourism. The phrase "local wisdom" is associated with the conservation of local culture. Indeed, local wisdom represents a tradition performed by the conserver community throughout generations (Saeroji and Wijaya, 2022). Else, local wisdom can also be understood as a local idea or concept that emphasizes on norms and values which are respected and daily practiced by local community (Komariah et al., 2018). The development of local wisdom-based agro-tourism needs a precise planning and a proper master plan. Other requirements include optimization of village potentials, cooperation with stakeholders (private, government and community), education and training on tourism for the manager and the community, and comprehensive socialization to the community through community empowerment (Sriyadi and Istiyanti, 2020). By all these opinions, the development of agro-tourism must correspond to or support the local wisdom of the village.

Agro-tourism enables local economic to develop and grow (S. Karabati et al., 2009). Referring to the opinion given by Songkhla and Somboonsuke (2012), agro-tourism provides job opportunity to all ages and gives a quick response to unemployment issue. Agro-tourism can reduce urbanization and alleviate number of migration because the qualities of life and work in the village are improving. Pursuant to the opinion of Ohe a nd Kurihara (2013), agro-tourism helps village community to attain two main goals, respectively (1) to produce more jobs that can generate more income and (2) to provide space for the community members who want to diversify their farming works and produce more money from the works. Indeed, agro-tourism intrigues local businesses to emerge and develop because agro-tourism creates demand for local products, which later leads to regional marketing and also involves any efforts to build added-value and to avoid intermediary cost. Principally, agro-tourism allows the village community to get more income from diversification of their economic activity (Iario and Corsale, 2010).

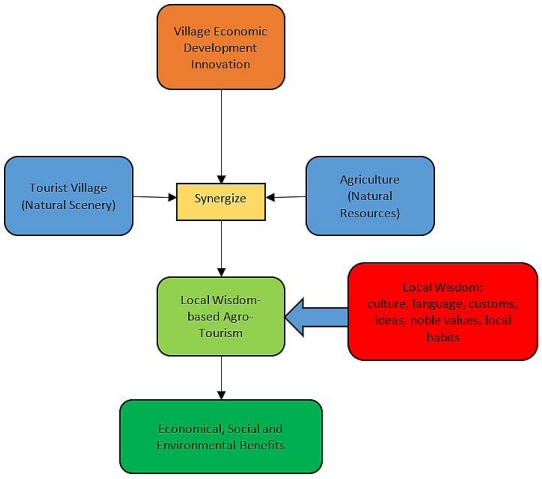
In relation to the explanations above, agro-tourism is a catalyst to village economic growth that can be used to conserve natural, historical and cultural resources. The conservation is facilitated by income generated from presenting the resources to the tourists. Such presentation offers opportunity to the people to share their culture with tourists, build self-confidence about their culture, and increase their life quality through income raised from the presentation (Karabati et al., 2009). Else, agro-tourism becomes a path toward cultural transformation that make the tourists to become more appreciative, more understandings and more respectful to valuable local resources (Maruti, 2009). In addition, agro-tourism tightens social relationship across villagers because agro-tourism requires the cooperation among them to manage and promote the diversification of local legacies and cultural landscape (Aikaterini et al., 2001). Other benefit is that agro-tourism can reduce gender bias issue because agro-tourism gives equal opportunity to men and women in tourism activity (Chadda and Bhakare, 2012).

Furthermore, agro-tourism benefits local natural environment. Clearly, the main benefit is that agro-tourism changes the approach of village people to ecology, which at least makes the villagers more sensitive to and more care about their environment and thus leads them to be more protective to the environment (Ciervo, 2013; Utomo et al., 2019; Utomo et al., 2021). Village people begin to understand that the well conserved environment may affect regional attraction and this attraction can be used as income source (Rilla et al., 2011). Such perception on the nature will initiate the friendly posture to the environment and encourage people to invest themself in natural protection and even to promote the use of environmentally friendly technology. Most importantly, the development of agro-tourism not only facilitates the protection and renovation of cultural and historical sites as well as other legacies but also creates positive climate in conservation of customs and traditions.

According to Marwanti (2015), agro-tourism development strategy consists of a lot of activities, such as: facilitating farmer community to develop businesses that utilize agriculture resources; creating business groups with farmers as the member; developing agriculture potential that attracts tourism; improving and increasing accessibility to village area; promoting agro-tourism by cooperating with related institutions; helping farmer groups to increase their knowledge and skill; giving extension, direction and explanation to farmer

community concerning the importance and benefit of tourism; strengthening the cooperation with the related institutions; disseminating information about agriculture resources that can be developed as tourist attraction; organizing exhibitions to promote agro-tourism; developing facilities that support agriculture-based tourism development; and directing farmer groups to develop creative economic by using agriculture resources to make agriculture become tourist attraction.

Taking into consideration of the elaborations above, the concept of local wisdom-based agro-tourism can be depicted as follows in Figure 1.




Source: Developed from several results of empirical research.

Figure 1: Concept of local wisdom-based agro-tourism

As shown in Figure 1, the concept of local wisdom-based agro-tourism is preceded by village development innovation to increase the added-value of the village and to solve social issues in the village. Natural resources of the village are used synergically in two activities, namely tourism and agriculture, plus any potential capitals owned by the village. Synergistic village development will give birth to new activity called agro-tourism in which tourism entertainment and agriculture activity are connected one another. This agro-tourism still keeps and maintains local wisdom (culture, customs, ideas, noble values, and local habits). And therefore, the offered product is local wisdom-based agro-tourism. The activities in local wisdom-based agro-tourism can help improve village economic, strengthen social relationship and enforce environmental conservation. In the end, the concept of local wisdom-based agro-tourism is able to create sustainability in economical, social and environmental aspects of the village.

## Materials and methods

The type of this research is descriptive research because this research is intended to produce description, illustration, or drawing in systemic, factual and accurate manners about events, characteristics and relationships across the targeted phenomena (Sugiyono, 2012). Research population encompasses all villages at four regencies in North Kalimantan Province. The regencies are Malinau Regency, Tana Tidung Regency, Nunukan Regency and Bulungan Regency. Sampling technique is purposive sampling because the research sample is selected through certain condition or criterion. Two criteria are used, which respectively are: (1) the village has land resource that is available to be used for agriculture commodities and (2) the village has structure (infrastructure) that can support agro-tourism system, such as road, water system, standard water source, telecommunication network, production processing site and other facilities.

Data source is primary and secondary. Primary data were obtained through survey and interview which require respondents or key informants to fill the questionnaire. The informants are community members or stakeholders who have close involvement in agro-tourism development project. Secondary data were acquired from the institutions that publish agriculture and tourism data. These institutions are Central Bureau of Statistics for North Kalimantan Province and also the government offices in North Kalimantan Province that handle agriculture and tourism affairs.

Research phase begins with identification of villages that have agro-tourism development potentials and this identification uses sample criteria. Secondary data published by Central Bureau of Statistics for North Kalimantan Province, the Office for Agriculture and Food Tenacity Affairs, and the Office for Tourism Affairs were scrutinized. Several individuals from the relevant local office in each regency, which in this context is the office for tourism affairs, were invited into discussion. The phase of identification produced four village samples and each sample represented each regency. These villages are Panca Agung Village in Bulungan Regency, Setulang Village in Malinau Regency, Kujau Village in Tana Tidung Regency, and Selisun Village in Nunukan Regency.

The next phase is to determine the rank of the samples in order to know which village with the highest potential for agro-tourism development. Method for this determination is weight analysis (scoring) and *Analytical Hierarchy Process* (AHP), which the operation is supported by computer application of *Expert Choice*. The scoring was applied on the data collected from survey and questionnaire. Respondents are mostly community members who have close involvement in agro-tourism project, such as head of village, tourist village manager, and other related stakeholders. Scoring method comprises 10 (ten) variables which were already used in previous literatures (Jubaedah and Fajarianto, 2021; Muchlis and Santoso, 2017; Jafaruddin et al., 2020). These variables are: facility, accessibility, village attraction, village community involvement and empowerment, service and friendliness of the village community, agricultural and plantation resources, natural disaster resilience, other attractions, environmental conservation, and local wisdom values. Each variable has indicators which then were measured with five categories that are used as the anchor to score the variables. These categories are 5 = very high, 4 = high, 3 = adequate, 2 = low and 1 = very low. Each indicator of the variables is presented in detail in the following Table 1.

In this research, respondents are individuals who have deep understandings about tourist village in North Kalimantan Province. Less surprisingly, the employees or staffs at the Office for Tourism Affairs are more dominant than other respondents. The answers of these informants in questionnaire were put on Analytical Hierarchy Process (AHP) for processing. This analytical method directs the respondents to compare two elements or to do *pairwise comparison* across criteria or alternatives. In this context, the criteria are the variables used in the scoring analysis, which include facility, accessibility, village attraction, village community involvement and empowerment, service and friendliness of the village community, agricultural and plantation resources, natural disaster resilience, other attractions, environmental conservation, and local wisdom values. The sample villages were also similar to the villages determined by scoring method, which involve Panca Agung

| Variable | Number of Indicator | Indicator |
|---|---|---|
| Facility | 13 | security post, transportation, parking lot, road sign, information center office, trash bin, toilet, prayer house, lodging house, souvenir stalls, financial institutions, health post, restaurants |
| Accessibility | 6 | road, water source, health service, communication/internet, security service, and settlements |
| Village Attraction | 18 | mountain, natural forest, cool air, natural park, agro-tourism potential, wildlife, waterfall, physical recovery service, natural hot water source, culture and customs, sacred cemetery, religious ritual, historical sites, art culture, customary festival, customs during planting and harvest periods, and culinaries |
| Village Community Involvement and Empowerment | 2 | understandings about agro-tourism and consent for agro-tourism |
| Service and Friendliness of the Village Community | 15 | hotel staff friendliness, hotel comfort, transportation service, easy of information, community friendliness, community behavior and culture, mutual work, deliberation, culture of greeting, information about flora and fauna, information about sacred place, service of sellers/merchants |
| Agricultural and Plantation Resources | 4 | quality and quantity of agricultural and plantation commodities, fishery, processed products and human resources in agriculture |
| Natural Disaster Resilience | 3 | the ability to recognize disaster threat, to be adaptive, and to recover after the disaster |
| Other Attractions | 10 | mountain, camp ground, fishing pond, hunting ground, culinary, surfing, suspension bridge, waterfall, and culture that can be shown at the tourist destination |
| Environmental Conservation | 3 | trash management, waste management, and customs that conserve environment |
| Local Wisdom Values | 4 | art and culture, language, customs, noble values |

Source: Jubaedah and Fajarianto (2021), Muchlis and Santoso (2017) and Jafaruddin et al. (2020)

Table 1: Variables and indicators of agro-tourism villages.

Village in Bulungan Regency, Setulang Village in Malinau Regency, Selisun Village in Nunukan Regency and Kujau Village in Tana Tidung Regency. The score for questionnaire is set on the scale between 1 and 9. More explanations about the rating of this scale and its definition are presented in the following Table 2.

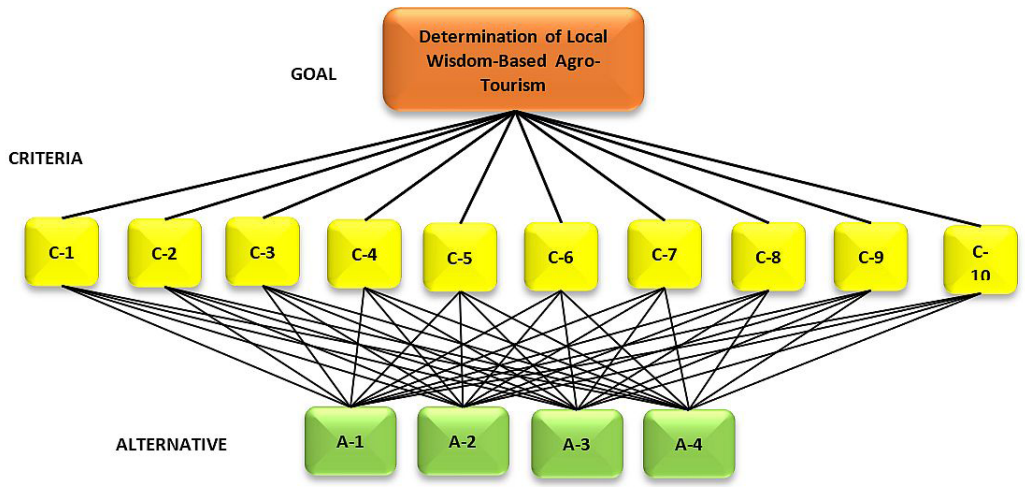
The AHP method involve criteria in determining goal and in this context, the goal is tourist village in North Kalimantan Province with high potentials to be developed as local wisdom-based agro-tourism. As previously said, the criteria are ten variables, namely facility, accessibility, village attraction, village community involvement and empowerment, service and friendliness of the village community, agricultural and plantation resources, natural disaster resilience, other attractions, environmental conservation, and local wisdom values. The alternative villages are Panca Agung Village in Bulungan Regency, Setulang Village in Malinau Regency, Selisun Village in Nunukan Regency and Kujau Village in Tana Tidung Regency. In the AHP procedure, a hierarchy was then made consisting of 10 variables and 4 alternative villages. This hierarchy is depicted in Figure 2, where C-1 = Facility, C-2 = Accessibility, C-3 = Village Attraction , C-4 = Village Community Involvement and Empowerment , C-5 = Service and Friendliness of the Village Community, C-6 = Agricultural and Plantation Resources, C-7 = Natural Disaster Resilience, C-8 = Other Attractions, C-9 = Environmental Conservation, and C-10 = Local Wisdom Values.

A-1 = Panca Agung Village, A-2 = Setulang Village, A-3 = Kujau Village, and A-4 = Selisun Village.

| Importance Intensity | Definition | Explanation |
|---|---|---|
| 1 | One element is as important as other element. | Both elements have same contribution level. |
| 3 | One element is a bit more important than other element. | One element is a bit dominant over other element. |
| 5 | One element is clearly more important than other element. | One element is quite dominant over other element. |
| 7 | One element is extremely more important than other element. | One element is surely dominant over other element. |
| 9 | One element is absolutely more important than other element. | One element is strongly dominant over other and always chosen. |
| 2,4,6,8 | There is a doubt in chosing one between two elements in proximity. | There is a room for negotiating the positions. |

Source: Saaty (1993)

Table 2: Comparative matrix scale.




Source: Developed from several results of empirical

Figure 2: Hierarchy of research.

## Results and discussion

### General description

Several villages in North Kalimantan have the potential to be developed in agro-tourism. The data shows agricultural production as the second largest contributor to the Gross Regional Domestic Product, North Kalimantan. In addition, the tourism sector, although not yet a leading sector, with its natural beauty potential and high agricultural yields has the potential to be developed into an agro-tourism area. The following data shows some of the results of agricultural production in North Kalimantan in Table 3.

Based on the data in Table 3, these commodities have great potentials to be developed as agro-tourism products in North Kalimantan Province. For example, the production level of fruits and vegetables has increased from 89.874 tons in 2019 to 220.922 in 2021. On the other hand, the production level of seasonal fruits and vegetables is averagely around 35.8 thousands tons per year. Furthermore, data on foreign tourist arrivals to North Kalimantan from 2019 to 2021 is presented, in Figure 3.

Figure 3, shows the number of foreign tourist visits, which in 2019 experienced an increase in visits from 358,684 in 2018 to 584,453 visits. In the following two years, visits decreased to 334,021 in 2021. This decrease in visits was due to visiting restrictions due to the outbreak of the Covid-19 pandemic. However, the data shows that the potential for foreign tourists is quite high and this has not been added to by local tourists. Thus from these data the tourism industry, especially agro-tourism has the potential to be developed.

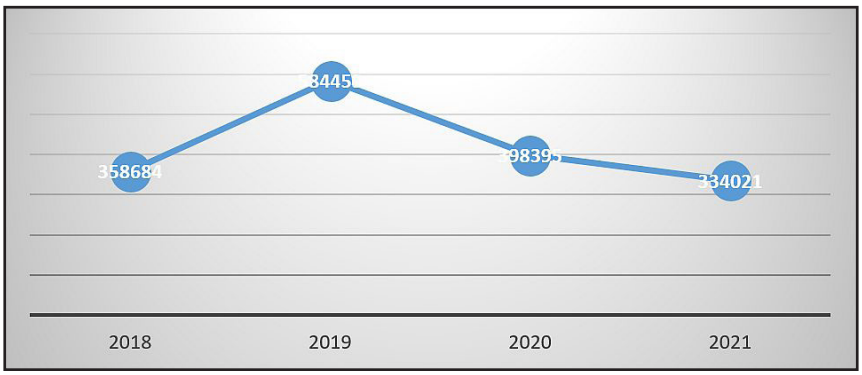
### Weight analysis (scoring)

Secondary data from four tourist villages in four regencies have been mapped to determine their potentials for agro-tourism development. The four villages are Panca Agung Village in Bulungan Regency, Setulang Village in Malinau Regency, Kujau Village in Tana Tidung Regency and Selisun Village in Nunukan Regency. Scoring method was

| No. | Commodity | 2019 | 2020 | 2021 |
|---|---|---|---|---|
| 1 | Annual Fruits and Vegetables | 89.874 | 89.9 | 220.922 |
| 2 | Mango | 3.47 | 5.804 | 8.59 |
| 3 | Durian | 10.017 | 9.577 | 8.429 |
| 4 | Siamese oranges | 6.206 | 4.265 | 7.045 |
| 5 | Banana | 27.095 | 38.363 | 110.463 |
| 6 | Pawpaw | 12.078 | 6.698 | 34.577 |
| 7 | Snakefruit | 1.669 | 3.32 | 5.663 |
| 8 | Jackfruit | 8.204 | 8.255 | 21.75 |
| 9 | rambutans | 13.562 | 5.997 | 13.644 |
| 10 | Paddy | 33.357 | 33.574 | 38.165 |
| 11 | Biopharmaceuticals (ginger, laos, noni etc.) | 1.464 | 1.977 | 2.603 |
| 12 | Vegetables (Chili, Onion, Potato, Tomato etc.) | 18.686 | 16.395 | 22.082 |

Source: Central Bureau of Statistics, North Kalimantan (2022)

Table 3: Some of North Kalimantan's agricultural commodity production (tons).




Source: Central Bureau of Statistics, North Kalimantan (2022)

Figure 3: Number of arrivals of international tourists (visit).

applied on the results of survey and questionnaire by giving emphasis on 10 variables, respectively facility, accessibility, village attraction, village community involvement and empowerment, service and friendliness of the village community, agricultural and plantation resources, natural disaster resilience, other attractions, environmental conservation, and local wisdom values. The results of scoring method on ten variables are shown in the following Table 4.

In accordance with the contents of the Table 4, tourist village with the highest total score is Panca Agung Village, followed by Setulang Village, Selisun Village and finally Kujau Village. Total score of Panca Agung Village is 256 with mean score of 3.28, which signifies that the indicators for agro-tourism development in Panca Agung Village are in the category of above the adequate (> 3). Setulang Village has total score of 240 with mean score of 3.08, which informs that the indicators for agro-tourism development in Setulang Village are also above the adequate (> 3). Meanwhile, Selisun Village and Kujau Village have mean score below 3, which make both villages are in low category. Based on the description above, Panca Agung Village in Bulungan Regency is selected as the priority village for agro-tourism development. The alternative is Setulang Village in Malinau Regency. Further confirmation for these results were done using Analytical Hierarchy Process (AHP).

## Analytical Hierarchy Process (AHP)

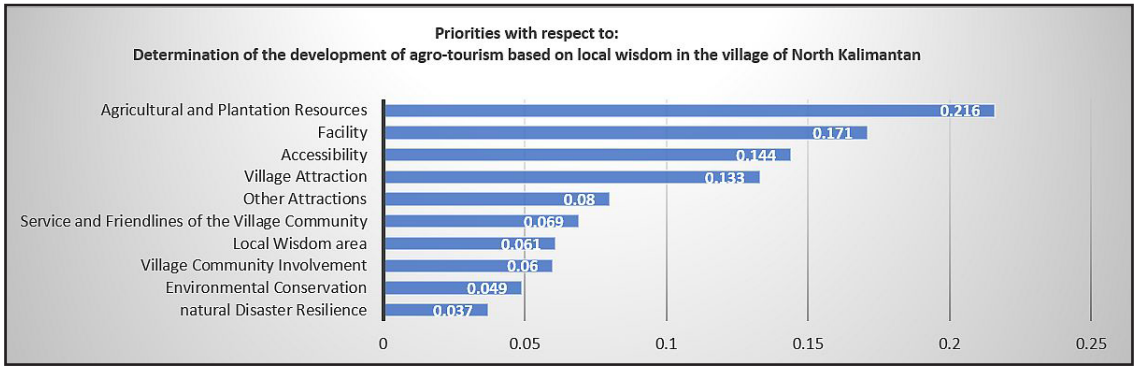
### Pairwise comparison across criteria

In this section, the criteria used to select village for the development of local wisdom-based agro-tourism are compared to each other. There are 10 criteria to compare and the results of this comparison are displayed in Figure 4.

| Variable | Panca Agung Village | | Setulang Village | | Selisun Village | | Kujau Village | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Total Score | Mean | Total Score | Mean | Total Score | Mean | Total Score |
| Facility | 3.46 | 45 | 2.77 | 36 | 2.31 | 30 | 1.92 | 25 |
| Accessibility | 3.50 | 21 | 3.17 | 19 | 2.83 | 17 | 3.83 | 23 |
| Village Attraction | 2.78 | 50 | 2.78 | 50 | 2.72 | 49 | 1.33 | 24 |
| Village Community Involvement and Empowermen | 4.00 | 8 | 3.00 | 6 | 3.00 | 6 | 4.00 | 8 |
| Service and Friendliness of the Village Community | 3.60 | 54 | 3.40 | 51 | 3.33 | 50 | 3.00 | 45 |
| Agricultural and Plantation Resource | 3.50 | 14 | 2.75 | 11 | 2.75 | 11 | 2.50 | 10 |
| Natural Disaster Resilience | 3.00 | 9 | 3.00 | 9 | 3.00 | 9 | 2.00 | 6 |
| Other Attractions | 3.20 | 32 | 3.00 | 30 | 2.90 | 29 | 1.70 | 17 |
| Environmental Conservation | 3.00 | 9 | 4.00 | 12 | 2.00 | 6 | 2.33 | 7 |
| Local Wisdom Values | 3.50 | 14 | 4.00 | 16 | 2.75 | 11 | 3.25 | 13 |
| **TOTAL** | **3.28** | **256** | **3.08** | **240** | **2.79** | **218** | **2.12** | **165** |

Source: Primary data are processed (2022)

Table 4: Scoring assessment on variables of agro-tourism villages.




Note: Inconsistency = 0.06
Source: Primary data are processed (2022)

Figure 4: Pairwise comparison across criteria for importance intensity.

Correspond to Figure 4, the three most important criteria for selecting village for the development of local wisdom-based agro-tourism are that the village must have high potential of agricultural and plantation resources (0.216), the village must have supportive facility (0.171), and the village must have good accessibility (0.144). Other criteria are less important than these three and the lowest criterion is natural disaster resilience (0.037).

According to the statement above, the most important criterion for agro-tourism development is that the village must have high potential of agricultural and plantation resources. This result is in line with the definition of agro-tourism as a combination between natural scenery and agriculture potential. As stated by Sastrayuda (2010), agro-tourism is a tourism activity that take benefits from agriculture resources potentials, especially the natural scenery of agriculture land, the diversity of agriculture production and technology, and the culture of farmer community. Agro-tourism helps the tourists to enhance their knowledge about agriculture, to develop recreative experience on the field, and to build business contact in agriculture, which may include business on food crop, horticulture crop, plantation, fishery and animal husbandry. Interestingly, forestry can also be managed as the commodity for agro-tourism. Seemingly, high potential of agriculture resources is an absolute requirement for agro-tourism development. North Kalimantan Province has quite high potential of agriculture resources and therefore the Province has a privilege over other regions for agro-tourism development (Liputan6.com, 2021). Moreover, agriculture sector is the second biggest contributor to Gross Regional Domestic Product after mine sector in 2020 with contribution level reaching IDR 10,922.84 millions (BPS-Kaltara, 2020).

The next important criterion for agro-tourism development is facility. In this context, facility is defined as structure designated to make the tourists become easier, comfort and safe in visiting the destinations. Facility of tourist destinations is measured by the presence of indicators such as security post, transportation, parking lot, road sign, information center office, trash bin, toilet, prayer house, lodging house, souvenir stalls, financial institutions, health post, and restaurants. Facility is a factor that can make the visitors feel satisfied. Usually, the visitors also feel comfort after finding that the facility in the destinations is complete (Santoso and Nadapdap, 2019). Indeed, facility is a minimum standard in any tourist destinations (Istiqomah and Priyatmono, 2019). Therefore, facility is absolutely needed in agro-tourism development.

Another important criterion for the development of local wisdom-based agro-tourism is accessibility. This criterion gets third rank after agricultural and plantation resources and facility. In this context, accessibility encompasses structure and infrastructure that enable the movement of tourists from their departure point to the destinations and also those that support the movement of tourists inside the destinations. The indicators of accessibility are road, water source, health service, communication/internet, security service, and settlements. More often, the quality of accessibility is measured from the quality of transportation mode that brings someone from one location to another (Aguila and Ragot, 2014). Accessibility in good quality will give satisfaction to the tourists and convince them to make repeated visit (Chin et al., 2018).

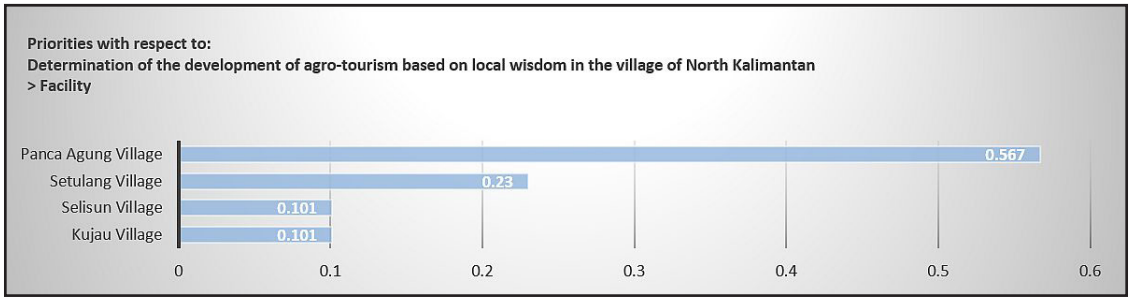
In addition, the results of AHP also revealed that village attraction and other attractions are two criteria, precisely fourth and fifth criteria, which are also important for the development of local wisdom-based agro-tourism. Every alternative village in this research has its own local wisdom. Each village has culture and customs that cannot be found in other place. Both culture and customs represent one indicator that explains the variable of village attraction. Surprisingly, local wisdom values that suppose to be the crucial element in the development of local wisdom-based agro-tourism are only getting seventh rank. The lowest rank is occupied by criterion of natural disaster resilience.

**Pairwise comparison across alternatives (villages)**

Each alternative village was compared to each other using the criteria. To begin with, the four alternative villages are compared by criterion of “facility”. The results of this comparison are shown in Figure 5.

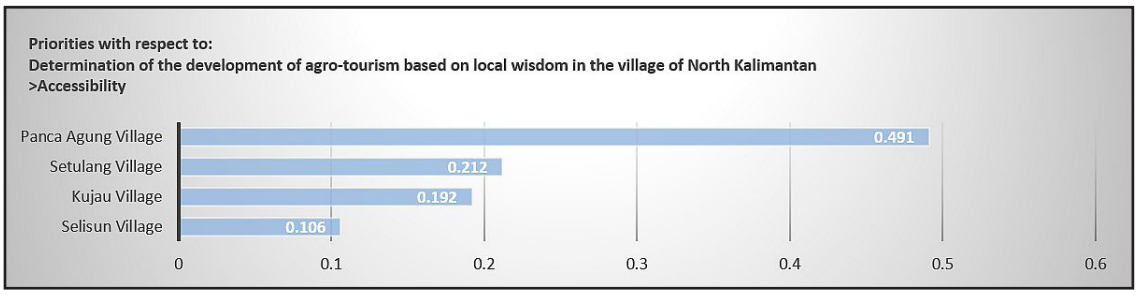
In conformity with Figure 5, the alternative village with the highest potential for agro-tourism development based on criterion of “facility” is Panca Agung Village (0.567), followed by Setulang Village (0.230), Selisun Village (0.101), and finally Kujau Village (0.101).

The results of pairwise comparison across alternative villages by criterion of “accessibility” are given in Figure 6.




Note: Inconsistency = 0.07
Source: Primary data are processed (2022)

Figure 5: Pairwise comparison across alternatives by criterion of "facility".




Note: Inconsistency = 0.04
Source: Primary data are processed (2022)

Figure 6: Pairwise comparison across alternatives by criterion of "accessibility".

Based on the contents of Figure 6, the alternative village with the highest potential for agro-tourism development based on criterion of "accessibility" is Panca Agung Village (0.491), followed by Setulang Village (0.212), Selisun Village (0.192), and finally Kujau Village (0.106).

Furthermore, the results of pairwise comparison across alternative villages by criterion of "village attraction" are depicted in Figure 7.

Referring to the contents of Figure 7, the alternative village with the highest potential for agro-tourism development based on criterion of "village attraction" is Panca Agung Village (0.417), followed by Setulang Village (0.316), Selisun Village (0.140), and finally Kujau Village (0.126).

Criterion of "village community involvement and empowerment" is used in pairwise comparison across alternative villages and the results are put on Figure 8.

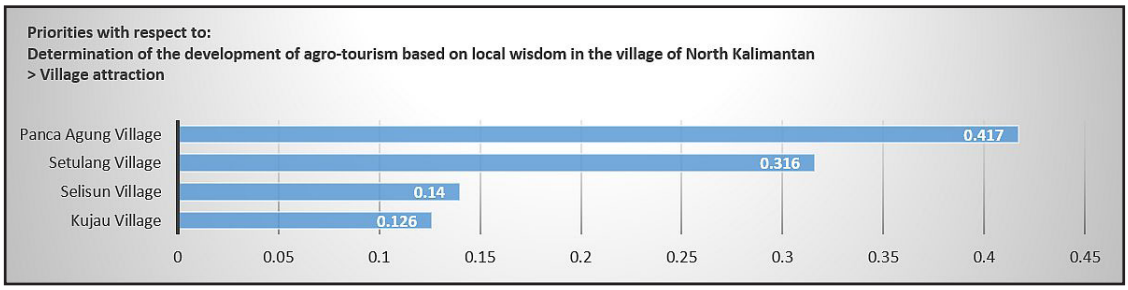
In regard to the contents in Figure 8, the alternative village with the highest potential for agro-tourism development based on criterion of "village community involvement and empowerment" is Panca Agung Village (0.435), followed by Setulang Village (0.233), Selisun Village (0.228), and finally Kujau Village (0.103).

Criterion of "service and friendliness of the village community" is used in pairwise comparison across alternative villages and the results are set on Figure 9.

Pursuant to the contents of Figure 9, the alternative village with the highest potential for agro-tourism development based on criterion of "service and friendliness of the village community" is Panca Agung Village (0.489), followed by Setulang Village (0.265), Selisun Village (0.131), and finally Kujau Village (0.115).

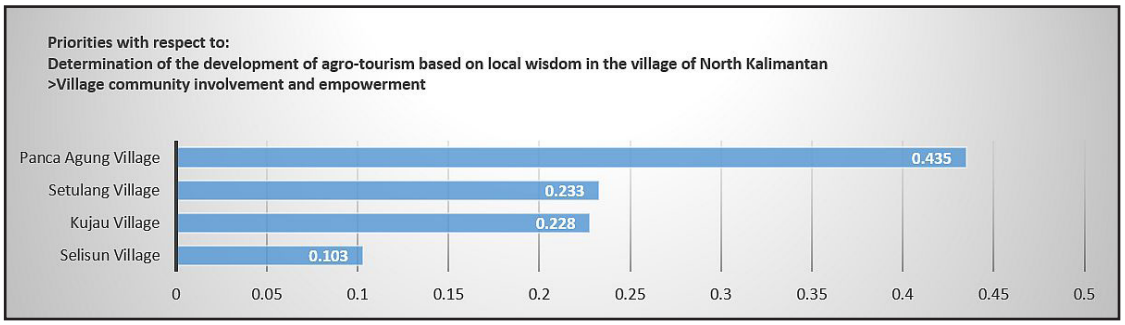
The results of pairwise comparison across alternative villages by criterion of "agricultural and plantation resources" are displayed in Figure 10.

Following the contents of Figure 10, the alternative village with the highest potential for agro-tourism development based on criterion of "agricultural and plantation resources" is Panca Agung Village (0.568), followed by Setulang Village (0.195), Selisun Village (0.128), and finally Kujau Village (0.109).



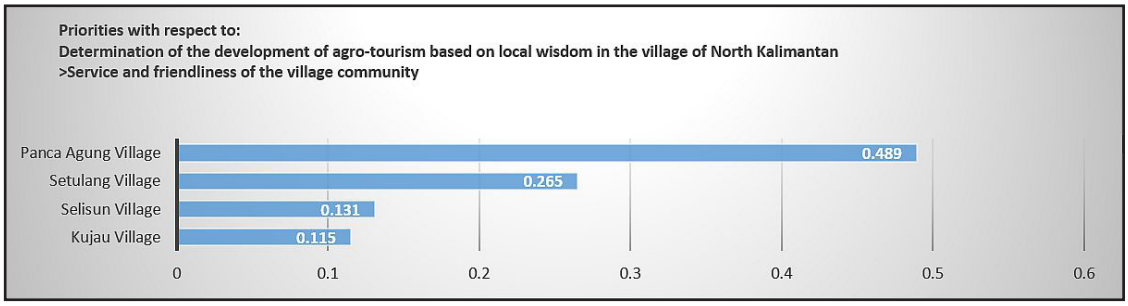

Note: Inconsistency = 0.07
Source: Primary data are processed (2022)

Figure 7: Pairwise comparison across alternatives by criterion of "village attraction".



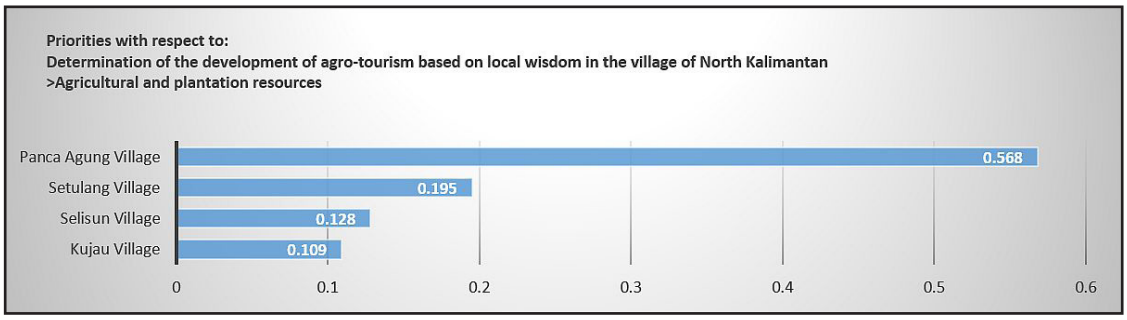

Note: Inconsistency = 0.02
Source: Primary data are processed (2022)

Figure 8: Pairwise comparison across alternatives by criterion of "village community involvement and empowerment".




Note: Inconsistency = 0.05
Source: Primary data are processed (2022)

Figure 9: Pairwise comparison across alternatives by criterion of "service and friendliness of the village community".




Note: Inconsistency = 0.02
Source: Primary data are processed (2022)

Figure 10: Pairwise comparison across alternatives by criterion of "agricultural and plantation resources".

Criterion of "natural disaster resilience" is used in pairwise comparison across alternative villages and the results are shown in Figure 11.

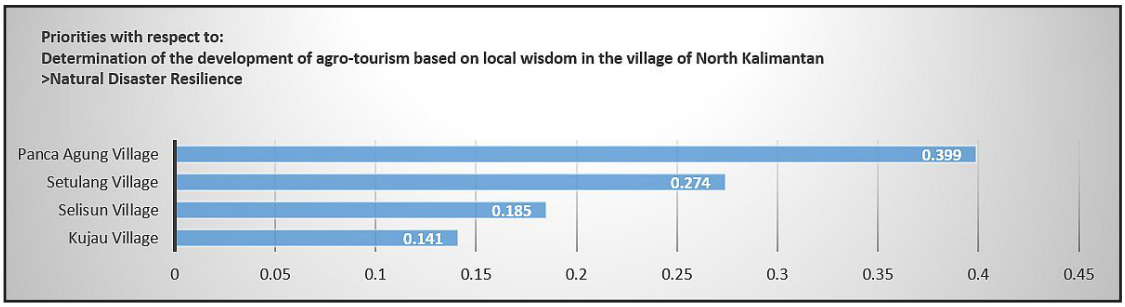
In association with the contents of Figure 11, the alternative village with the highest potential for agro-tourism development based on criterion of "natural disaster resilience" is Panca Agung Village (0.399), followed by Setulang Village (0.274), Selisun Village (0.185), and finally Kujau Village (0.141).

The results of pairwise comparison across alternative villages by criterion of "other attractions" are given in Figure 12.

By the contents of Figure 12, the alternative village with the highest potential for agro-tourism development based on criterion of "other attractions" is Panca Agung Village (0.472), followed by Setulang Village (0.289), Selisun Village (0.138), and finally Kujau Village (0.102).

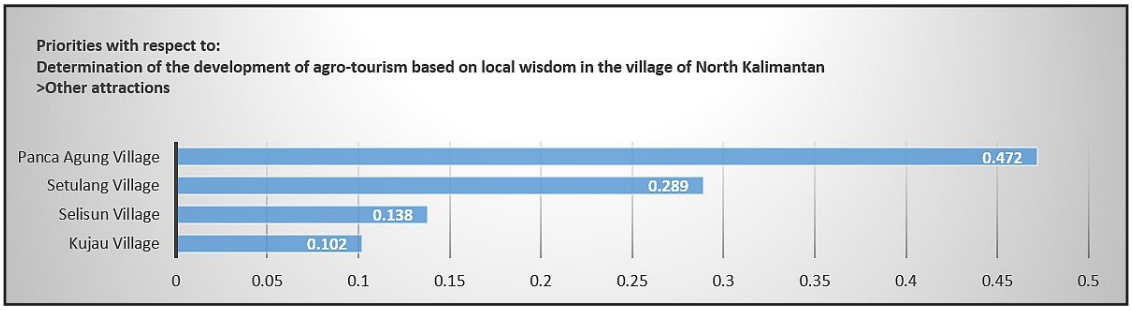
Criterion of "environmental conservation" is used in pairwise comparison across alternative villages and the results are depicted in Figure 13.

The results of pairwise comparison across alternative villages by criterion of "local wisdom values" are presented in Figure 14.



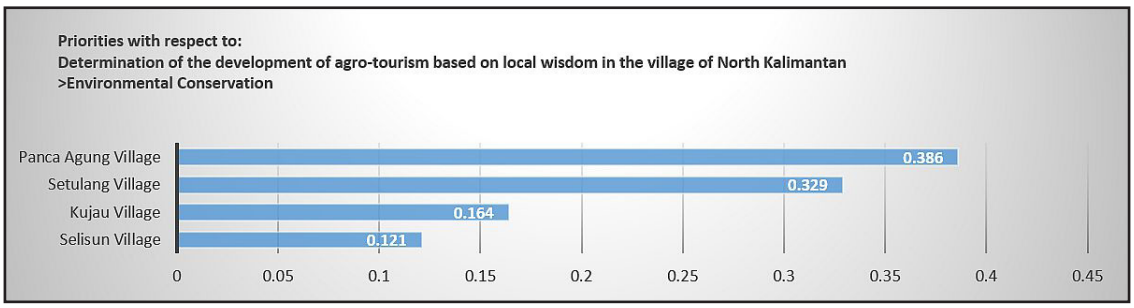

Note: Inconsistency = 0.02
Source: Primary data are processed (2022)

Figure 11: Pairwise comparison across alternatives by criterion of "natural disaster resilience".



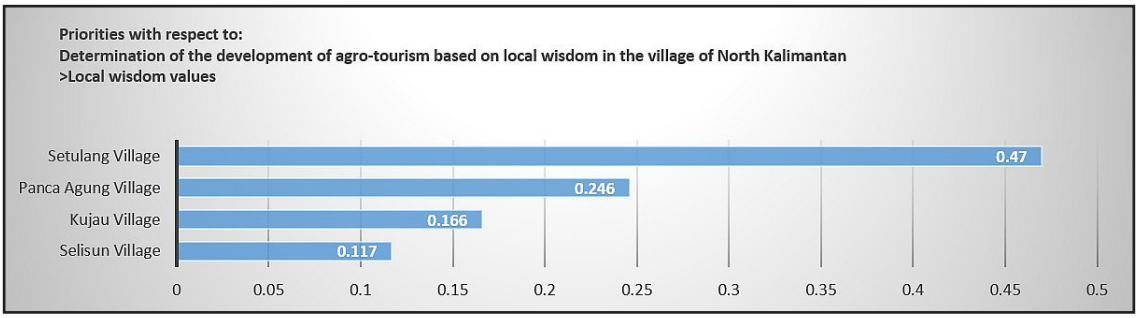

Note: Inconsistency = 0.02
Source: Primary data are processed (2022)

Figure 12: Pairwise comparison across alternatives by criterion of "other attractions".




Note: Inconsistency = 0.02
Source: Primary data are processed (2022)

Figure 13: Pairwise comparison across alternatives by criterion of "environmental conservation".




Note: Inconsistency = 0.03
Source: Primary data are processed (2022)

Figure 14: Pairwise comparison across alternatives by criterion of "local wisdom values".

According to the contents of Figure 14, the alternative village with the highest potential for agro-tourism development based on criterion of "local wisdom values" is Setulang Village (0.470), followed by Panca Agung Village (0.246), Kujau Village (0.166) and finally Selisun Village (0.117).

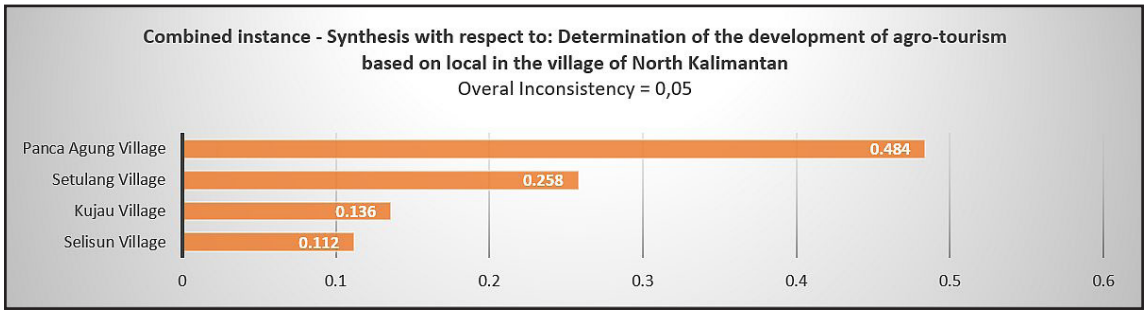
**Priority village for local wisdom-based agro-tourism**

Villages that become alternative for agro-tourism development have been compared one to another. This comparison is expected to be helpful in selecting village to be the priority of agro-tourism development. Comprehensive assessment needs to be done at least to confirm the best alternative in compliance with opinions of informants. The results of comparison for the priority village is put on Figure 15.

The pairwise comparison was conducted over alternative villages for determining the priority village for the development of local wisdom-based agro-tourism. The highest point is gotten by Panca Agung Village in Bulungan Regency which makes this village become the priority. Second alternative is Setulang Village in Malinau Regency. Third and fourth positions are occupied by Kujau Village in Tana Tidung Regency and Selisun Village in Nunukan Regency. The results from both scoring method and AHP method have been taken into account. Seemingly, the results of both methods similarly show that the priority village for the development of local wisdom-based agro-tourism is Panca Agung Village.

Selecting one village to become priority for the development of local wisdom-based agro-tourism is indeed the goal of the current research. The priority is fallen to Panca Agung Village. As one of villages that make up the District of Tanjung Palas Utara, Bulungan Regency, North Kalimantan Province, the land width of Panca Agung Village is 2500 ha. Historically, Panca Agung Village was established in 1983 through transmigration program. The 2021 data reported that the population of Panca Agung Village is 2300 individuals with 766 family heads. Javanese tribe is quite dominant among the village dwellers. Therefore, most of the dwellers are the wanderer or the participants of transmigration program who leave their life in Java and move to Kalimantan. The leading potency of Panca Agung Village is agriculture and so far, the management of agriculture land in this village is handled by Village Enterprise (BUMDES). For the topography, the altitude of Panca Agung Village is 34 meters with 65 % mountain valleys and 35% low land. The dominant land use is for agriculture. To farm out this wide agriculture land, farmers, and also plantation workers, have use advanced and modern farm equipments and technology. Special land in the village is managed and developed to be millenial agriculture land. So far, the agriculture commodity in Panca Agung Village is emphasized on rice, fruits and vegetables, whereas the plantation commodity is dominated by coconut.

In general, Panca Agung Village has complete facility either in village or regency levels. This facility includes air port, sea port, bus station, electric network, water network, security post, transportation, parking lot, road sign, information center office, trash bin, toilet (bath room), prayer house (mosque), lodging house, souvenir stalls, financial institutions (banks), health post (community health center), and restaurants. Accessibility to the village has been relatively good including the access for water source, health service, security service and settlements. Meanwhile, accessibility to tourist destination needs to be improved to ease the visitor in reaching




Source: Primary data are processed (2022)

Figure 15: Pairwise comparison across alternative villages for determination of priority village.

their desired spots. The government can make this happen by launching a supportive program such as the construction or the improvement of the access road to tourist destination.

Village attraction of Panca Agung Village is quite promising. The combination between mountain valleys and agriculture land provides beaufitul scenery for the visitors. Beside this scenery, other elements that make up the attraction in Panca Agung Village are natural forest, cool air, extensive width of agriculture and plantation lands, traditional medicine, art culture, and culinaries. Interestingly, several tourist destinations have been integrated in one area, which is Panca Agung Village, and this makes the village become the popular destination. The integrated destinations include natural tourism (*Batu Tumpuk*), rafting tourism, public square tourism, fishing pond tourism, religious tourism, motor vehicle (ATV) arena tourism, cultural tourism and culinary tourism.

Panca Agung Village has extensive agricultural land supported by modern equipment and the dominant community profession as farmers and garden workers. Villages have special land as village assets that can be developed as millennial agricultural land. Agricultural products are in the form of rice, fruits, vegetables while plantation products are in the form of oil palm.

People in Panca Agung Village are respecting the noble values of mutual work, tolerance, altruism and religiosity. All these values are considered as the constituent values of local wisdom. Villagers and also village officers have determined to enforce the behavior that conserve the environment. Possibly, because the dominant occupation in the village is being farmer and plantation worker, then most of village dwellers already know about the importance of environmental conservation and also agro-tourism. Taking this situation into consideration, therefore, Panca Agung Village is highly potential to be developed as local wisdom-based agro-tourism. The reason behind this is that Panca Agung Village not only has beautiful natural scenery and high potential of agriculture resources but also has human resources which are already familar with agriculture due to their profession as farmer and plantation worker.

## Conclusion

The objective of this research is to identify the potentials of villages in North Kalimantan Province for the development of local wisdom-based agro-tourism and also to construct resource map in order to find the proper village to be developed as local wisdom-based agro-tourism. Several results of research were obtained. One result showed that the nominee village for the development of local wisdom-based agro-tourism must fulfill three main criteria (more important over other criteria), respectively agricultural and plantation resources, complete facility and good accessibility. In addition, village attraction and other attractions are other criteria that are considered supportive to agro-tourism development.

Other result revealed that Panca Agung Village in Bulungan Regency of North Kalimantan Province has defeated other villages (Setulang Village, Selisun Village, Kinjau Village) because this village has been selected for the development of local wisdom-based agro-tourism. Panca Agung Village not only has beautiful natural scenery and high potential of agriculture resources but also has human resources which dominantly work as farmer and plantation worker who definitely understand the importance and benefit of agro-tourism. The people in Panca Agung Village respect the noble values of mutual work, tolerance, altruism and religiosity. All these values are the constituent values of local wisdom. The government can support and facilitate

the development of agro-tourism by launching programs that construct and improve the access road to tourist destination which in turn will make the tourist feel comfort and satisfied in their journey to the destination.

More specifically, the current research is the material for the next research that will construct the model of development and management of agro-tourism village. There is an expectation that the current research will contribute the development and management of local wisdom-based agro-tourism villages in North Kalimantan Province. Also, for the future, the development of agro-tourism villages is expected to contribute the sustainable development at local, regional, national and international levels.

## Acknowledgements

This research is supported by Directorate General of Higher Education, Research and Technology, that is responsible to the Ministry of Culture, Research and Technology of the Republic of Indonesia.

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Agris on-line Papers in Economics and Informatics

Volume XV Number 2, 2023



Agris on-line Papers in Economics and Informatics

The international reviewed scientific journal issued by the Faculty of Economics and Management of the Czech University of Life Sciences Prague.

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**ISSN 1804-1930**