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Comparative Analysis of ARIMA and Artificial Neural Network Techniques for Forecasting Non-Stationary Agricultural Output Time Series

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Abstract

With the vast popularity of the deep learning models in the engineering and mathematical fields, Artificial Neural Networks (ANN) have recently attracted significant research applications in agriculture, economics, informatics and finance. In this paper, we use a deep learning method to capture and predict the unknown complex nonlinear characteristics of agricultural output based on autoregressive artificial neural network, using Nigeria as a case study. Using the proposed model, shocks in agricultural output is analyzed and modeled using data obtained for a period of forty years (1980-2019), and compared with analyses obtained from the autoregressive integrated moving average model (ARIMA). This result is significant because it justifies the superiority of the hybrid ANN model over the traditional Box-Jenkins methodology for forecasting non-stationary time series. The empirical results show that the proposed autoregressive ANN model achieves an improved forecasting accuracy over the traditional Box-Jenkins ARIMA method. It is further proposed that various types of artificial neural networks would be useful in forecasting and solving relevant tasks and problems widely defined in global agricultural production.

Keywords

Artificial neural network, ARIMA, agricultural output, Nigeria, forecasting.

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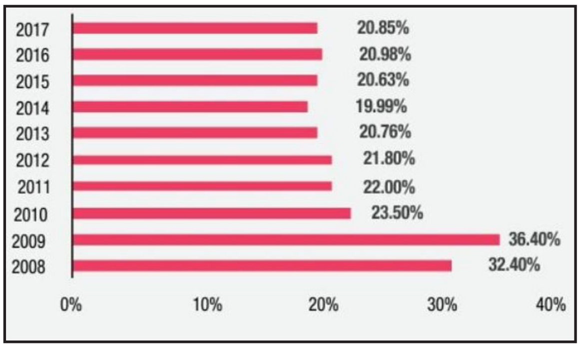
Introduction

Agricultural output has been said to be affected by various factors including land availability and fertility, temperature, rainfall, population, active labour force participation, exchange rate, inflation rate, oil prices and much more. Most importantly, in Nigeria, an oil-dependent country, agricultural output tends to be majorly affected by the oil market (Awe et al., 2018). This study deals with finding a suitable model for forecasting Agricultural Output, using Nigeria as a case study. Nigeria is an enormous agricultural nation which is endowed with large human and natural resources which comprising of 68 million hectares of arable land, fresh water resources covering about 12.6 million hectares, 960 km of coastline and an ecological diversity which enables the country to produce a wide variety of crops, livestock, forestry and fishery products (Ewetan et al., 2017). Agricultural output helps in revealing the productivity of the agricultural sector of the economy.

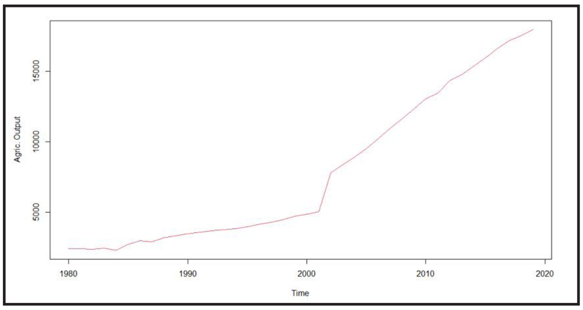
From historical perspectives, agricultural output in Nigeria has been volatile and erratic with average productivity on a downward slope (Akinkumi, 2017). With available statistics from the Central Bank of Nigeria (CBN), the agricultural sector's share of GDP rose from 28% in 1985 to 32% in 1988, went down to 31% in 1989, went up to 37% in 1990 but decreased significantly to 24% in 1992, it then rose again to 37% in 1994. It was 32% in 1996 and increased to 40% in 1998, decreased to 27% in 2000, went up to 37% and went downward to 31% in 2002 and 2006 respectively. The percentage contribution of the agricultural sector to GDP decreased persistently from 0.37 in 2009 to 0.22 in 2012 and to 0.20 in 2014 (Falola et al., 2008). It has continued to increase considerably since 2008 (see Figure 1). However, Nigeria's real GDP growth rate has been lower than those of many other African countries in recent times, including smaller countries in the Northern and Eastern parts of Africa (Awe and Gil-Alana, 2019). Hence, a study on agricultural output is necessary because agriculture is the backbone of the Nigerian economy, after crude oil exploration (Matthew and Mordecai, 2016).



Source: Nigerian Bureau of Statistics (NBS)

Figure 1: Contribution of Agricultural Output to Nigeria's GDP from 2008-2017.

The poor performance of the agricultural sector in Nigeria has been hinged on the oil glut and its consequences on several occasions, resulting in low agricultural output and productivity due to negligence of the agricultural sector. (CBN, 2014; Christiaensen et al, 2007). Agriculture is broadly divided into four sectors in Nigeria – crop production, fishing, livestock and forestry. Crop production remains the largest segment and it accounts for about 87.6% of the sector's total output (Anderu and Omotayo, 2020). This is followed by livestock, fishing and forestry at 8.1%, 3.2% and 1.1% respectively (Igbokwe, 2005). A chart depicting the trajectory of agricultural output from 1980-2019 in Nigeria is shown in Figure 2.



Source: Nigerian Bureau of Statistics (NBS)

Figure 2: Trajectory of Agricultural Output in Nigeria from 1980-2019.

Between 1960 and the early 1970s, agriculture was the primary source of revenue for the Nigerian economy, with revenue from other sources considered a bonus. The growth rate of agricultural output in Nigeria increased from an average of about 3% in the 1990s to about 7 % in mid 2000s and has continued to rise majorly due to the fall in oil price which made the succeding governments to concentrate on improving agricultural output (Igbokwe 2005).

The government of Nigeria has enacted various policies and embarked on many developmental programmes with the goal of increasing agricultural output in order to overhaul the agricultural sector and diversify the Nigerian economy (Awe et al., 2018). With the much that have been expended on these policies and programmes, there is an urgent need to steadily measure and forecast the corresponding progress of agricultural output in Nigeria using modern deep learning tools (Rakhmatuiln et al., 2021). Several time series methodologies have been applied to analyze agricultural data in recent times but have been seen to be incapable of capturing non-linear dynamics like the modern methods (see for instance, Mensi et al., 2017; Hloušková et al., 2018; Awe et al., 2018; Kharin, 2018 and Ayinde et al., 2015). The results and predictions obtained from the use of these modern tools would be useful for policy makers act on.

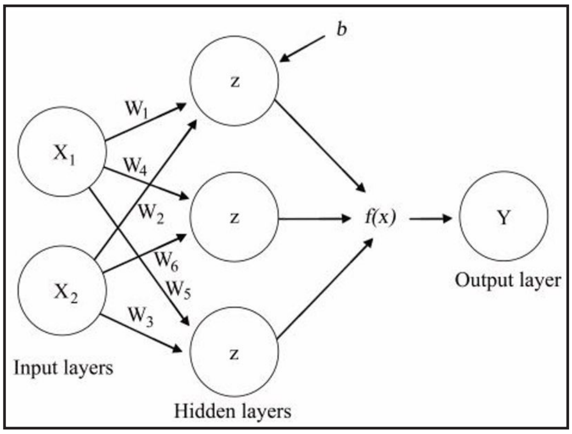
Therefore, this paper examines the forecasting of agricultural output in Nigeria using a modern approach. More so, the use of artificial neural network technique for analyzing and forecasting agricultural output is scanty in literature. The remaining sections of this paper is organized as follows: following this non-exhaustive introductory aspect, the methodology of artificial neural network is discussed in section two. The third section is on empirical analysis and results, while the fourth section dwells on the discussion of results, and finally, the last section is on conclusion and recommendations.

Materials and methods

Artificial neural networks

Artificial neural networks (ANNs) have gained tremendous popularity and use as a promising alternative technique for forecasting climate and agricultural time series because of their several distinguishing features (Abhishek et al., 2012). Similar to the biological structure of neurons, artificial neural networks define the neuron as a central processing unit, which performs a mathematical operation that generates an output from a set of inputs (Rodrigues et al., 2020). Artificial neural networks are one of the most important elements of machine learning and artificial intelligence. They are inspired by the human brain structure and function as if they are based on interconnected nodes in which simple processing operations take place. The spectrum of neural networks application is very wide, and it also includes agriculture (Kujawa and Niedbała, 2021).

Artificial neural networks have been increasingly used by food producers at every stage of agricultural production and in efficient agricultural management (Li and Chao, 2020). Examples of their applications include: forecasting of food production in agriculture on the basis of a wide range of independent variables, classification of diseases and pests, intelligent weed control, and classification of the quality of harvested crops (Niedbała et al., 2020). Artificial intelligence methods support decision-making systems in agriculture, help optimize storage and transport processes, and make it possible to predict the costs incurred depending on the chosen direction of management. An ANN is based on a collection of connected units or nodes called artificial neurons, which loosely model the neurons in a biological brain. An artificial neuron receives a signal then processes it to yield an output which is computed by some non-linear function which is the sum of its inputs. The output of a neuron is a function of the weighted sum of the inputs plus the bias (Rodrigues et al., 2020). The scheme of the artificial neural network used in this study is shown in Figure 3. A hybrid neural network model for agricultural output time series was adopted in this study with the aid of the R package *forecast*, through the *nnetar* function, which generates a feed-forward neural network with a single hidden layer and lagged inputs for forecasting univariate output time series (agricultural output).



Source: Rodrigues et al. (2020)

Figure 3: A feed-forward artificial neural network scheme.

Results and Discussions

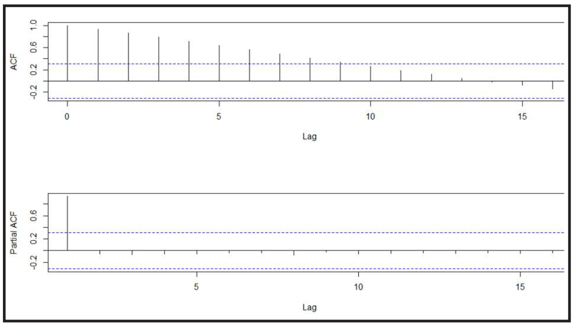
Data

The data used in this study are annual Agricultural Output of Nigeria from 1980-2019 obtained from the database of the World Development Index of the World Bank website (https://data.worldbank.org). The line plot of this data is shown in Figure 1.

Stationarity test

It is vital to test if the time series of agricultural output is stationary. To test for stationary of the data, we use the Augmented Dickey-Fuller (ADF) test. ADF test is a statistical test for finding out if a time series contains a unit root. The null hypothesis for the ADF test is that a time series has a unit root (that is, time series is not stationary). The choice of value of d depends on the number of time a non-stationary time series must be differenced to attain stationarity.

Figure 3 presents the correlograms of autocorrelation functions at some lags for agricultural output of Nigeria over the years. It can be seen from the figure that the data series are not stationary.



Source: Author

Figure 4: Corelogram of Nigerian agricultural output.

A formal test based on ADF test is employed to investigate if the data is stationary. The null hypothesis for this test states that the data series are not stationary while the alternative hypothesis states that the data series are stationary. At 5% level of significance, it can be seen that the data is not stationary because the ADF test fails to reject the null hypothesis (p-value = 0.6944). In addition, each correlogram shows that each data series does not exhibit long – range dependence. As a result, fractional integration of the data series to achieve stationarity may not produce an optimal model as the autocorrelation function of Nigerian agricultural output is seen to experience a fast decay. The outcome of this is that recent methods such as autoregressive fractionally integrated moving average (ARFIMA) and its seasonal version (SARFIMA) may produce sporadic results when applied to analyze the data. This is because the use of ARFIMA and SARFIMA requires a long – range dependence series of data (Awe et al., 2021; Awe and Gil-Alana, 2019), hence it is reasonable to explore the performance of a modern method like ANN.

ARIMA model

The ARIMA methodology of Box & Jenkins was adopted in this study with a view to identifying the optimal model for Nigerian agricultural output and comparing its forecasting performance with that of the proposed autoregressive artificial neural network model described above.

The ARIMA (p, d, q) model on a time series Y_t is defined as (1)

$$\Delta^d Y_t = \emptyset_1 \Delta^d Y_{t-1} + \emptyset_2 \Delta^d Y_{t-2} + \cdots + \emptyset_p \Delta^d Y_{t-p} + \epsilon_t + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + \cdots + \theta_q \epsilon_{t-q} \quad (1)$$

where p, d and q are orders of autoregressive, integrated and moving average parts respectively, ϵ_t is the residual of the estimated Y_t, which is assumed uncorrelated. Δ is the backward shift operator, $\emptyset_1$, $\emptyset_2$,…, $\emptyset_q$ are the parameters of the autoregressive part of the model, $\theta_1,\theta_2,\ldots,\theta_q$ are parameters of the moving average part of the ARIMA model (Awe et al., 2020). The choice of optimal values of p and q are based on the ARIMA (p, d, q) model with the least Akaike information criterion and root mean square of error. The parameters of the ARIMA model are estimated by minimizing sum of the square of ϵ_t using maximum likelihood estimation (see Table 1).

ARIMA Model	AIC
ARIMA(2,2,2)	584.5697
ARIMA (0,2,0)	594.9623
ARIMA (1,2,0)	586.755
ARIMA (0,2,1)	577.3763
ARIMA (1,2,1)	579.6402
ARIMA (0,2,2)	579.6185
ARIMA (1,2,2)	582.0142

Source: Author

Table 1: ARIMA model selection

From the Table 1, it shows that ARIMA (0,2,1) performs best because it has the lowest Akaike information criteria of 577.3763.

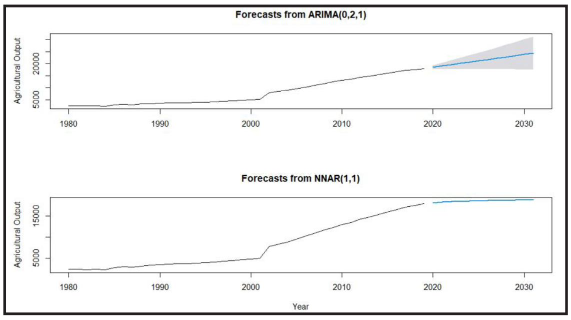
Point forecasts

Shocks in agricultural output is analyzed and modeled with ARIMA using data obtained for a period of forty years (1980-2019), and compared with analyses obtained from the hybrid autoregressive artificial neural network model (AANN). The empirical results show that the proposed deep learning model achieves an improved forecasting accuracy over the traditional Box-Jenkins ARIMA method. Point forecasts from ARIMA and AANN algorithms are shown in Table 2. Notice that predictions from the artificial neural network model are lower than those from the ARIMA model. The unit of measurement of agricultural output is in Billion Naira. Figure 4 depicts a diagrammatic representation of the forecasts from the two techniques. They both depict a steady upward slope.

Year	ARIMA	AANN
2020	18490.55	18140.15
2021	19022.52	18283.31
2022	19554.49	18395.30
2023	20086.46	18482.35
2024	20618.43	18549.69
2025	21150.40	18601.59
2026	21682.37	18641.45
2027	22214.34	18672.01
2028	22746.31	18695.40
2029	23278.28	18713.27
2030	23810.25	18726.91

Source: Author

Table 2: Eleven year point forecasts from ARIMA (0, 2, 1) and AANN (1, 1) models



Source: Author

Figure 5: Point forecasts from ARIMA (0,2,1) and AANN(1,1).

Model evaluation metrics

The Root Mean Squared Error (RMSE) and Mean Percentage Error (MPE) were used in evaluating model performance in this study. The **root mean square error (RMSE)** (also often referred to as the root mean square deviation, RMSD) is a frequently used measure of the difference between values predicted by a model and the values actually being observed. These individual differences are also called residuals, and the RMSE serves to aggregate them into a single measure of predictive power. The RMSE of a model prediction with respect to the estimated variable X_{model} is defined as the square root of the mean squared error (2):

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2}{n}} \quad (2)$$

where X_{obs} is observed values and X_{model} is modelled values at time/place i with sample size n.

It is one of the most commonly used measures in literature for evaluating the quality of predictions. The **mean percentage error (MPE)**, which is the computed average of percentage errors by which forecasts of a model differ from actual values of the quantity being forecasted is also used to corroborate model evaluation in this study. To properly validate the predictive accuracy of the models from the training data, a k-fold cross-validation was adopted in this study. In k-fold cross-validation, model validation is done by dividing the data into k subsets of approximately equal sizes, the model is thereby trained k times (Bergmeir and Benitez, 2012). In each of the k times of model training, one of the subsets is randomly set aside which in turn is used to evaluate the model's performance (Bergmeir et al., 2018). In spite of being computationally intensive and time consuming, this method ensures a more accurate prediction. In this study, a 10-fold cross-validation (k=10), which has been used in several related studies, was adopted. Results of model evaluation, showing the average RMSE and MPE are in Table 3.

Model	RMSE	MPE
ARIMA	437.97	1.21
AANN	416.70	-0.82

Source: Author

Table 3: Model comparison via RMSE and MPE.

Table 3 shows that the autoregressive artificial neural network (AANN) proposed performs better than the traditional ARIMA model because it exhibits the lowest RMSE and MPE respectively.

This work is relevant because it does not only use ANN and ARIMA for prediction of agricultural output but also confirms and justifies the suitability of ANN for prediction of non-stationary time series over the traditional Box-Jenkins methodology, especially for the Nigerian data. The autoregressive neural network proposed generates a feed-forward neural network with a single hidden layer and lagged inputs. Further more, this result is significant because it also addresses the concerns of Faraway and Chatfield (1998) who querried the forecasting ability of the neural network model for predicting non-stationary seasonal monthly time series. This study has shown that ANN are not as poor as portrayed by the authors for modeling such data. More advanced variants of this model would be explored for scientific computing and forecasting of agricultural output in our future studies.

Conclusion

In this paper, we have deduced some salient results on the forecasting of agricultural output using autoregressive integrated moving average and autoregressive artificial neural network models. Comparison between these two methods showed that the autoregressive artificial neural network performs better for forecasting agricultural output data. Hence, deep learning methods are recommended for use in Agricultural forecasting because of their rich computational suitablility especially for non-linear time series data. Other deep learning/artificial neural network methods that would be explored in our future studies include the Long Short-Term Memory (LSTM) which is a type of recursive neural network that learns a mapping from input to output over time as reviewed recently in Rakhmatuiln et al. (2021).

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Could Exist a Causality Between the Most Traded Commodities and Futures Commodity Prices in the Agricultural Market?

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Abstract

Nowadays, many financial and academic practitioners explore the area of high-frequency forecasting in new dimensions. Research on agricultural commodities is an important issue for food policy and security. This paper is focused on the causality between the spot prices and futures prices of the main traded agricultural commodities. Thus, the Granger causality was used to identify the relationship between spot and futures prices of commodities. Our results show the Granger causality between cash prices and futures prices of wheat and cocoa. However, there is also causality in the opposite direction in the case of wheat. Causality could be related, among other things, to a specific market position of the commodity, food policy, historical aspects, the sensitivity of the market, speculation activity, tax policy, and particular interconnection of the market with the energy commodities market. In the price process of cash and futures wheat prices, inventories and storage play an important role.

Keywords

Agricultural commodity, Granger causality, commodity futures, cash price, agricultural commodity interdependence, food policy.

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Introduction

Nowadays, commodities are characterized as the most traded financial contracts around the world. Significant fluctuations in the main commodity prices occurred from 2006 to 2009, followed by a downtrend in the commodity markets due to economic crises (Huchet-Bourdon, 2011). There is a significance of price fluctuation in the capital and financial markets. There is a need to consider seasonality, storability, external shocks, and breaks in the agricultural commodity market. With all these variables, we have to deal.

The motivation to detect the causal relationship between spot and future prices comes from the need for financial practitioners and hedge funds to fix the price. Nowadays, uncertainty introduces the look with high importance. The theoretical background assumes that the cash-futures prices come from a strict relationship spot-forward. Contrary, the commodity market is not perfect. The imperfection consists of a lack of market information, investor sentiment, market friction, or new reactions. There should be an empirical investigation of this causal relationship in the last decade.

Many financial researchers and practitioners deal with volatility analysis among US, german and japan indices, see Reider (2009), Zhang et al. (2015), Poon (2005). One time we worked with price volatility, and research focused on the main agricultural commodities' price variability and dynamics. The pioneering research deals with asset price uncertainty; see Markowitz (1952). According to Zhang et al. (2015), there are problems and difficulties with visibility and patterns or any breaks within simulated data. The asset price dynamics changed 15 years ago due to the consideration of high-frequency data (Aït-Sahalia and Jacod, 2014). The price fluctuations are influenced by news or speculation activity among hedge funds. There are many applications of why volatility forecasting is important. First of all, there is an interest in risk management. Secondly, according to Hull (2003), portfolio management has a significant impact consisting of assets, commodities, or derivatives. The need for long-term research activity in this field is based on volatile periods of commodity prices changing over time (Fama, 1965).

The article's main purpose is to evaluate if spillovers exist between the commodity market and the futures commodity market. However, as the current literature shows, there is a difference in the findings of individual authors. However, it is often discussed whether speculative activity in the future market can increase agricultural commodity prices. It still seems a largely controversial theme; there is a massive increase in trading in agricultural commodity derivatives, which has been related to the activities of many institutional money managers (Zuppiroli, 2015). However, Zuppiroli (2015) shows that speculations on commodity markets didn't affect the interaction of demand and supply in the food market. In conflict with Zuppiroli (2015) are the findings of Yang et al. (2005) and Hernandez and Torero (2010). Yang et al. (2005) indicate that increased futures trading volume caused an increase in the price volatility of commodities. This information supports the destabilizing effect of futures trading on agricultural commodity markets. Yang et al. (2005) explain why historically are most virulent markets with agricultural commodities. Moreover, Hernandez and Torero (2010) argue that spot prices are generally discovered in futures markets and that changes in futures prices lead to changes in spot prices more often than in reverse. Hernandez and Torero (2010) also claim that information flow from futures to spot markets has intensified in the past 15 years, probably due to the increase in the relative importance of electronic trading of futures contracts.

Different findings in contrast with Hernandez and Torero (2010) and Yang et al. (2005) determined Alquist and Gervais (2011) and Brunetti a Büyükşahin (2009). Alquist and Gervais (2011) show that changes in financial firms' positions do not predict oil-price changes, but that oil-price changes predict changes in positions. Findings also indicate that financial speculations did not cause price increases during 2007/2008. Further, the analysis of Alquist and Gervais (2011) suggests that there is no empirical evidence to suggest a strong relationship between speculators' positions and price changes. In addition, Brunetti and Büyükşahin (2009) indicate that speculation activity is not destabilizing because the analysis shows that it is not causing any price changes, but its effect is risk reduction. However, Brunetti and Büyükşahin (2009) argue that speculation does not seem to destabilize futures markets. They find that speculative trading activity has a beneficial effect on markets. Similar findings are presented by Pindyck (2001), who argued that previously published research detected that there might be expected that some portion of commodity price variation is not based on fundamentals but is instead the result of speculative trading or herd behavior. But in the analysis, Pindyck (2001) questioned this conclusion because it is possible to incorporate speculative behavior in the error terms of the model.

Opposite results compared with Brunetti and Büyükşahin (2009) and Pindyck (2001) detected by Ali and Gupta (2011) and Manogna and Mishra (2020). Ali and Gupta (2011) found a long-term relationship between futures and spot prices in agricultural commodities like maize, chickpea, black lentil, pepper, castor seed, soybean, and sugar. Then, the findings of Ali and Gupta (2011) show that futures markets have a stronger ability to predict subsequent spot prices for chickpea, castor seed, soybean, and sugar than maize, black lentil, and pepper, where bi-directional relationships exist in the short run. Similarly, Manogna and Mishra (2020) determined that price discovery exists in six analyzed futures commodity markets (soybean seed, coriander, turmeric, castor seed, guar seed, and chana). The Granger causality tests show that futures markets can predict spot prices more easily. And then, there exist mutual spillover effects on futures and spot markets by using the EGARCH volatility test. According to Manogna and Mishra (2020), the futures market is more efficient in the price discovery of agricultural commodities in India.

The same with Manogna and Mishra (2020) and Ali and Gupta (2011) are the results of Nath and Lingaredd (2008). Nath and Lingaredd (2008) indicate the volatility and prices of pulses were higher during the period of futures trading than before its introduction on markets and after the ban of futures contracts. Then opposite to Nath and Lingaredd (2008) are the findings of Stoll and Whaley (2015), who showed that commodity index investing is not speculation. Second, changes in commodity index investment do not cause futures prices to change; and third, the failure of the wheat futures price to converge to the cash price at the contract's expiration has not undermined the futures contracts' effectiveness as a risk management tool. As Stoll and Whaley (2015) and Sashi (2007) determined, in wheat, turmeric, sugar, cotton, raw jute, and soybean oil, the nature of spot price volatility has remained the same with the onset of futures trading. However, in wheat and raw jute, there has been a weak destabilizing effect from futures to the spot with the onset of futures trading.

In addition to Sashi (2007), a certain degree of interconnectedness of markets is also evident in Kang et al. (2017), who analyzed the dynamics of return and volatility spillover indices. Kang et al. (2017) found that the correlation between commodity futures market returns increased significantly during crises. One of the basic findings is the occurrence of two-way spillovers of returns and volatility across commodity futures markets. They also found more pronounced trends in their levels in the post-crisis period. These findings can be essential for investment decisions and trading strategies. Adämmer and Bohl (2018) also emphasize the interconnectedness of the markets. They determined the impact of the futures market on spot prices and pointed out that more significant trading activity in the futures market did not have a more significant impact on spot prices. Similar findings can be seen in Bouri et al. (2021), pointing to the fact that the connectedness of volatility varies over time and is affected by uncertainty and the macroeconomic situation (e.g., interest rates, level of real GDP).

While Dimpfl et al. (2017) confirmed that the futures market contributes less than 10% to the formation of the spot price, Dimpfl et al. (2017) emphasize that in the long run, speculation in futures markets adversely affects the commodity market. Likewise, the results of Xu (2018) and Xu (2019) did not support a causal structure between the individual variables but demonstrated a long-run equilibrium relationship. In contrast, Samak et al. (2021), Tiwari et al. (2020), and Pradhan et al. (2021) demonstrate the connection between spot and futures markets of agricultural commodities. According to Samak et al. (2021), information flows and investor sentiment from the futures market to the spot price market. However, Tiwari et al. (2020) refer to industrial inputs as the originator of volatility transmission.

Materials and methods

This paper investigates the data consisting of 2,455 trading days for each commodity. The analysis for the daily time series is run. The timeframe of research is based on the years 2012–2020. represents the future commodity price and spot cash closing prices of different commodities – Wheat, Corn, Soybeans, Cocoa, Coffee, and Sugar. All the data are obtained from the database Stooq and Investing. The EViews software for the analysis is used. For the statistical analysis, the logarithmic returns are calculated therefore:

$$r_t = \left(ln\ \frac{P_t}{P_{t-1}}\right) \tag{1}$$

where P_t is the closing price of the commodity and P_{t-1} is one lagged (prior day).

The Augmented Dickey-Fuller test and Phillip-Peron test are employed to examine the presence of the unit root within data. The use of the Dickey-Fuller test is positively evaluated, for example, by Haug and Basher (2011), who states that it has the highest and most stable force for typical final sample sizes due to the likely data generation processes encountered by practitioners. On the other hand, for example, Choi (1992) shows that, especially for the aggregate data, the Phillip-Perron tests appear to be more powerful than the augmented Dickey-Fuller test. Due to a different view of the strength of unit root tests, we use both tests, whose results are presented in Table 1. In the case of the presence of non-stationarity of the observed data, the logarithmic returns are made. It leads the transition from one period to the next (Tillman, 1973). If the data exhibits non-stationary, thus the regression analysis does not reflect the real spillover effect. Table 1 displays the unit root analysis. In both cases of the test, the null hypothesis is rejected. The null hypothesis is the presence of unit root at level 0.01of confidence. The results of the Augmented Dickey-Fuller unit root test and the Phillips-Perron test in Table 1 also demonstrate that both tests could identically evaluate the used time series stationarity. The results show that time series (logarithmic returns) are stationary at the level.

According to Appendix 1, descriptive statistics is employed to analyze the main characteristics of time series, both spot price, and futures commodity prices. Except for the sugar futures price, all commodities exhibit heavier tails. Thus the time series do not have symmetric distribution. The casual relationship is used for the spillover analysis of logarithmic returns (Granger, 1969). The Granger methodology investigates if the changes in one time series casual the change in another. There is an assumption that the past values

Commodity	Type of unit root test	Cash price of commodities (returns)	Price of commodity futures (returns)
Wheat	ADF	-52.5808* (0)	-47.7303* (0)
	PP	-52.8231* (0)	-47.7428* (0)
Corn	ADF	-29.0256* (0)	-53.6819* (0)
	PP	-141.2100* (0)	-54.0621* (0)
Soybeans	ADF	-26.4103* (0)	-46.5939* (0)
	PP	-161.8327* (0)	-46.5982* (0)
Cocoa	ADF	-51.2335* (0)	-49.0617* (0)
	PP	-51.2039* (0)	-49.0569* (0
Coffee	ADF	-51.7969* (0)	-49.7318* (0)
	PP	-51.8948* (0)	-49.6960* (0)
Sugar	ADF	-17.9662* (0)	-2.6376*** (0)
	PP	-50.5757* (0)	-2.5845*** (0)

Note: *, **, *** means significance at 1 %, 5 %, and 10 % levels. ADF symbolizes the Augmented Dickey-Fuller unit root test, and PP presents the Phillips-Perron unit root test. (0) means stationary at the level, and (1) means stationary at the first difference.

Source: Authors' calculation (based on data available from Stooq and Investing)

Table 1: Results of Augmented Dickey-Fuller and Phillips-Perron unit root test statistic.

of the time series *X* can predict the future values of *Y* with consideration of all relevant information. Vice versa, it can be valid if values of *Y* Granger-cause of the importance of *X*. This concept is introduced by two OLS regression equitations (Gujarati, 2009):

$$X_t = \alpha_0 + \sum_{i=1}^{m} \mu_i X_{t-1} + \sum_{j=1}^{m} \delta_j Y_{t-j} + u_{1t} \quad (2)$$

$$Y_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i Y_{t-1} + \sum_{j=1}^{m} \beta_j X_{t-j} + u_{2t} \quad (3)$$

where X (futures prices of commodities) and Y (cash prices of commodities) represent the stationary variables, and parameter m is lag length for both X and Y. The u_{1t} and u_{2t} are uncorellated error terms. Therefore we run the Granger analysis test represented with hypothesis H_0:

$$H_0: \beta_1 = \beta_2 = .. = 0 \quad (4)$$

It means that X's values do not Granger-cause Y's values. We can construct the alternative hypothesis:

$$H_1: \beta_j \neq 0 \quad (5)$$

In the case of rejection, the null hypothesis, it is evident that $\beta_j \neq 0$ for j. In summary, this fact approves the Granger causality evidence.

Before calculating the empirical estimations, it is presented the development of the main important factors that affect commodity markets. The graphs in Appendix 2 show that wheat prices were most influenced in 2014, 2016, 2017, and 2018. Prices of corn, sugar, and soybeans were most affected in 2020. The prices of coffee were most volatile, mainly in 2014, 2019, and 2020. The cocoa prices oscillated throughout the analyzed period, but most in 2017, 2019, and 2020. However, a significant event in the commodity market in May 2012 was the rise in soybean, wheat, and maize prices due to the drought that hit the US, with a more modest increase in prices for coffee and sugar. A good harvest in the southern hemisphere contributed to the stabilization of prices in 2012. In 2013, the decline in food commodity prices related to the forecast of a new harvest (e.g., wheat) appeared to be important, while in energy crops (soybeans, maize), prices rose in July 2013 due to favorable weather reports. However, the price of sugar fluctuated near a minimum of more than three years; the same was true for coffee. The outlook at the end of 2013 was the expectation of a slight increase in prices for corn, wheat, and coffee, while the price of soybeans was to fall. These were related to lower demand from developing countries, lower incentives to hold commodities as hedges against inflation, and expectations of a slowdown in monetary easing in developed countries (CNB, 2021).

The beginning of 2014 was marked by a continuing trend of shifting growing demand from developed countries. In February 2014, the price of wheat, corn, coffee, and soybeans began to rise due to fears of damage to this year's crop in the USA due to severe frosts and bad weather in Brazil. On the other hand, the more than a three-month decline in sugar prices came to a halt. Agricultural tensions in Ukraine also began to show political tensions. The factor that will dampen rising prices was expected to be the expected strengthening of the US dollar and the tightening of US monetary policy, which should lead to an outflow of investment from commodity markets. This outflow occurred in April 2014 and the transfer of investment to the stock markets. In the second half of 2014, the impact of high wheat yields in the Black Sea region became apparent, and, compared to 2013, growing conditions for maize and soybeans in the USA improved due to favorable weather. In general, expectations of a good global harvest have led to a fall in agricultural commodity prices, as has the intensity of the political conflict in Ukraine and concerns about the harvest. The mild winter in Europe and the cold summer in the US led the USDA to forecast a rich harvest, which pushed grain prices to four-year lows. However, rainy weather in Western Europe disrupted the fall in prices. However, grain prices in the USA were affected by uncertainty about the future production of alcohol from grain and corn. The price of soybeans was influenced by growing competition from palm and rapeseed oil. Coffee and sugar prices also rose (drought in Brazil and growth in ethanol production there). Especially at the end of the year, agricultural commodity prices were negatively affected by rainy weather in the USA, Russia, and Ukraine, which slowed down the harvest of cereals and soybeans. There were also fears of cold weather in the US and restrictions on exports from Russia. The price of corn was significantly affected by growing production and demand for ethanol, and the price of soybeans was affected by high exports from the USA (CNB, 2021).

At the beginning of 2015, fears of production outages and high stocks of some commodities in the USA subsided. The weather in South America began to improve, which was reflected in agricultural commodity prices. The price of soybeans started to fall, mainly due to good weather in Brazil and forecasts of record USDA global production. The price was also depressed by the larger sown areas of North America, the Middle East, and North Africa; it offset the decline in planted regions of Russia. The price of wheat has risen temporarily due to low temperatures in the US and fears of crop damage. Other factors included the strengthening exchange rate of the US dollar, expectations of high global yields, and lower demand for biofuels (low oil prices). In mid-2015, sugar prices rose due to the strengthening of the Brazilian currency and expected higher exports from India. Cocoa prices have increased due to a reduction in the Ghana harvest estimate. In the second half of the year, the price of agricultural commodities was affected by the weather and higher demand; especially due to the humid weather, corn and soybeans began to rise. The price of soybeans was also affected by the devaluation of the Chinese renminbi. At the end of 2015, the price of soybeans reached a more than eight-year low. The reason was high production in Brazil and a record harvest in the USA. Sugar prices also rose sharply due to dry weather and lower yields in India, China, and the EU. The price of corn has been pushed down by estimates of higher harvests and falling fuel prices (CNB, 2021).

Significant events in the markets for agricultural commodities in 2016 can be described as the decline in sugar and cocoa prices at the beginning of the year due to the estimate of a good harvest; a similar trend was also evident for grains. The negative effects on commodity prices began to show in April 2016. The rise in sugar prices was linked to the strengthening of the Brazilian real and the decline in exports from Thailand due to dry weather, while rains in Brazil slowed the sugar cane harvest. The strengthening of the Brazilian currency has also impacted coffee prices. In the case of grains, the drought in Brazil appeared to be problematic, with a negative impact on the maize crop, and rains in Argentina negatively affected the soybean crop. The drought in the USA also affected the harvest of these commodities. Since August 2016, the USA's weather improvement has been reflected in the expectation of a rich harvest of soybeans and corn. There has also been an increase in the sown area of grains. Larger wheat harvests in Russia, Kazakhstan, and Ukraine were also reflected in the decline in grain prices. At the same time, the negative impact was evident on the price of coffee. There was a strike of carriers in Colombia and the threat of the frost crop in Brazil. Sugar prices reflected lower production in Brazil and expectations of lower production in India, which led to the price reaching a four-year high (CNB, 2021).

In the first half of 2017, grain prices were affected by expectations of lower yields, also due to drought in the main growing areas. In addition, lower wheat production was expected in India and Kazakhstan, and higher demand for maize in China and Mexico. In the case of sugar prices, prices increased due to an estimate of lower production in India (dry weather). The persistent oversupply caused a significant increase in the price of cocoa. Soybean prices were affected by the rich harvest in the USA and Brazil. At the end of April, the price of wheat began to rise due to frosts in growing areas of North America (frosts on the US Central Plains). During the year, the prices of cocoa, sugar, and coffee continued to fall sharply. The price of sugar and coffee began to show a weakening of the Brazilian reality in connection with political instability in the country. In the case of sugar, an important factor was that most of the harvest would be used for sugar production and less for ethanol. The price of soybeans fell due to an estimate of a good harvest. In the second half of 2017, the price of grain was affected by unfavorable weather in some areas (drought in Australia and Argentina and floods in Southeast Asia). Still, at the end of the year, the high global stocks of these commodities had a stabilizing price. The price of sugar started to rise in August 2017 due to the strengthening Brazilian real and the reduction of the local ethanol tax (CNB, 2021).

In 2018, agricultural commodity prices tended to stagnate as a result due to high stocks and the global harvest. However, some fluctuations have been observed in cocoa prices, which are highly volatile over the period. It was due to the weather in the main growing areas (Ghana and Côte d'Ivoire). The weather affects the quality of cocoa, and tree infections leading to pruning are also a problem. USD fluctuations and support programs also have some implications. Wheat and corn prices in 2018 were affected by strong demand and a slight decline in production, while crop growth was expected for soybeans due to a good harvest in Argentina.

In most cases, the first half of 2019 was associated with a decline in agricultural commodity prices, reflecting the existence of high global supply prospects of a rich harvest. In the second half of 2019, grain, sugar, and coffee prices began to rise, citing dry weather concerns in Canada, Australia, and Russia and floods in some areas of the United States that threatened the supply and quality of commodities. In the end, coffee, cocoa, and sugar prices also started to rise more significantly. In 2020, price developments varied considerably, with agricultural commodity prices being affected by Covid-19 measures with markets becoming highly speculative due to supply constraints, high demand, and supply uncertainty. Depending on changes in agricultural commodity prices, the speculative activity of financial investors and, thus, the volatility of yields on the futures market may also have taken place (CNB, 2021).

Results and discussion

First, the correlation coefficients between spot prices and futures prices of selected commodities were calculated. As the results in Table 2 show, none of the presented correlation coefficients were not statistically significant. It indicates that there is no linear relationship between the analyzed variables. According to these findings, it is evident that the co-movements of variables need to be sufficiently strong.

Wheat	-0.0207
Corn	0.0136
Soybeans	0.0288
Cocoa	0.0320
Coffee	0.0004
Sugar	0.007645

Note: *, **, *** means significance at 1 %, 5 %, and 10 % level.

Source: Authors' calculation (based on data available from Stooq and Investing)

Table 2: Correlation coefficients between the price of commodity futures and the cash price of commodities.

Then, it was necessary to identify the optimal lag length. The Akaike information criterion, the Schwarz Criterion, and the Hannan–Quinn information criterion is commonly used to determine the optimal delay. As findings in Table 3 show, it seems most appropriate to use an optimal lag length of one day based on the Akaike information criterion, the Schwarz Criterion, and the Hannan–Quinn information criterion.

In Table 4, there are test statistics of Granger causality. The causality effect is detected between the cash price of wheat and the futures price at the significance level of 0.05. There is also evident causality in the opposite direction going from the futures prices of wheat to spot prices of wheat at the significance level of 0.01. In other words, the Granger causality exists between a wheat commodity's cash price and futures price. The second case where causality between spot prices and futures prices is found is with cocoa, at the significance level of 0.01. In other cases, the causality relationship was not proved.

Commodity	Lag	LogL	Sequential modified LR test statistic (at 5 % level)	Final prediction error	Akaike information creiterion	Sxchwarz information criterion	Hannan-Quinn information criterion
Wheat	0	-9433.618	N/A	12.4979	8.2013	8.2063*	8.2031
	1	-9418.192	30.8120*	12.3744*	8.1913*	8.2063	8.1968*
Corn	0	-12461.19	N/A	151.0601	10.6934	10.6983	10.6952
	1	-12156.98	607.6475*	116.7568*	10.4358*	10.4506*	10.4412*
Soybeans	0	-10697.19	N/A	77.9685	10.0320	10.0373	10.0340
	1	-10412.37	568.8425*	59.9190*	9.7687*	9.7846*	9.7745*
Cocoa	0	-8977.807	N/A	9.2583	7.9012	7.9063*	7.9031
	1	-8965.858	23.8647*	9.1938*	7.8942*	7.9094	7.8998*
Coffee	0	-9710.427	N/A	16.8030	8.4973	8.5023*	8.4991
	1	-9700.841	19.1466*	16.7210*	8.4924*	8.5074	8.4979*
Sugar	0	-27074.63	N/A	63844318	23.6477	23.6527	23.6495
	1	-21416.90	11300.63*	457808.4*	18.7099*	18.7249*	18.7154*

Note: * indicates lag order selected by the criterion.
Source: Authors' calculation (based on data from Stooq and Investing).

Table 3: Determination of optimal lag length.

Null Hypothesis	F-Statistic	Probability	Causality
Futures price of wheat =/=> Cash price of wheat	7.2132*	0.0073	+
Cash price of wheat =/=> Futures price of wheat	4.3110**	0.0380	+
Futures price of corn =/=> Cash price of corn	0.0660	0.7973	-
Cash price of corn =/=> Futures price of corn	0.2553	0.6134	-
Futures price of soybeans =/=> Cash price of soybeans	0.3873	0.5337	-
Cash price of soybeans =/=> Futures price of soybeans	0.4135	0.5203	-
Futures price of cocoa =/=> Cash price of cocoa	2.5442	0.1108	-
Cash price of cocoa =/=> Futures price of cocoa	6.7221*	0.0096	+
Futures price of coffee =/=> Cash price of coffee	0.2179	0.6406	-
Cash price of coffee =/=> Futures price of coffee	0.5510	0.4580	-
Futures price of sugar =/=> Cash price of sugar	0.2326	0.6296	-
Cash price of sugar =/=> Futures price of sugar	0.1023	0.7491	-

Note: *, **, *** denotes significance at 1 %, 5 %, and 10 % level. Symbol + means the existence of a causal relationship between analyzed variables, and symbol denotes no causal relationship between selected factors.
Source: Authors' calculation (based on data from Stooq and Investing).

Table 4: Results of Granger Causality Test for prices of commodity futures and cash price of commodities.

There is evidence of non-causality among these commodities in predicting power spot and futures commodity prices. However, the wheat commodity futures prices are applicable for research on spot prices. Our results are similar to Sashi (2007), who determined a weak destabilizing effect from futures to the spot prices in the case of wheat, while for the other commodities analyzed. The possibility of a causal relationship between spot prices and futures prices is also identified by Kang et al. (2017), Adämmer and Bohl (2018), and Manogna and Mishra (2020). On the other hand, the absence of a causal relationship between spot prices and futures prices for some of the analyzed commodities is consistent with the findings of Dimpfl et al. (2017), Xu (2018), Xu (2019), and Zuppiroli (2015).

There could be some reasons for the causality between wheat's spot prices and futures prices. The role could be historical because wheat belongs to the most traded agricultural commodities. Wheat is connected with the beginnings of trading on futures markets because it was the first commodity used as the underlying asset for futures contracts. The fact that wheat belongs to the most traded agricultural commodities could reflect that increasing speculations on financial markets can be transmitted to markets with real assets and effected this market. The wheat market appears to be more sensitive than other agricultural commodities markets, as indicated, for example, in 2009 by the fact that the price of wheat reached its peak earlier than the prices of other commodities. Greater sensitivity could be related to the interconnectedness of the energy commodities market, as part of the wheat produced is sugar and partly ethanol. It means that there could exist a spillover effect due to these facts. The other reason for significant causality may be in the field of important convergence between the cash market price and wheat futures price. The wheat commodity has a difficult role in the world. For instance, it has a complicated market structure because of the wheat grown. In the futures wheat market, 20 local contracts are listed worldwide. According to the CME Group, there are many fluctuations and disconnects between cash and futures prices. It can be reasoned in the field of the power of U.S wheat stocks. The same concept for wheat price discovery can come from storage and different expiration contracts in the futures market.

One of the most reasons for a causal effect among wheat spot and derivative markets could also be in food security, respectively, food policy. That's because wheat is the most important commodity used for human nutrition. The concept of food security is defined as a state in which all people always have access, both physically and financially, to a safe and nutritionally rich diet. Such nutrition aims to satisfy nutritional needs and dietary preferences (as defined by the FAO, 2015). The world community has had a significant impact over the past decade on providing nutrition for the population. However, more than 800 million people worldwide suffer from hunger and face problems caused by malnutrition (FAO, 2015). The Food and Agricultural Organization (FAO, 2015) has identified four pillars of food safety access, availability, efficiency, and stability. Food availability is measured by the overall food supply, while access to food is based on household income. However, these conditions are necessary, but more is needed for food stability. For example, research on several factors that affect food prices has been conducted by Haile et al. (2014). Food price stability can be involved in several ways:

- Fluctuations in the harvest of agricultural commodities (market effects and storage costs).
- Changes in real income with an impact on access to food.
- The impact of natural disasters or pandemics.
- For each such factor, changes in food prices signal a change in the stability of food security. Conversely, high prices may indicate the problem of rising prices in general. The specifics of these areas in the wheat market may be the reason for the causality between spot and futures prices of wheat.

The fact that national governments are responsible for ensuring a certain degree of food security and living conditions for citizens could have some impact (Bellemare, 2015). Food policy is a politically sensitive issue in the context of the growing trend of urbanization of the world's population. Based on research (Béné et al., 2015), there are recommendations for working with increased commodity price volatility through specific food policy objectives. The sensitivity of rising food prices to political results, for example, in elections, has been demonstrated. Examples are known where the increase in food prices has led to societal protests in Haiti (in 2008) and Algiers (in 2011); for example, in 2007/2008 as well, rising food prices led to social protests in Bangladesh (Bellemare, 2015). Once food prices become a sensitive policy issue, there will be a rapid response from international organizations, such as the OECD, to limit the extreme rise in price volatility. However, a significant share of these responses to rising food prices had a partial effect (Martin and Anderson, 2012). One of the main reasons for the failure of these joint actions is the growing integration of local agricultural markets into global structures. It is a situation where the traditional agricultural market is fully integrated into various financial markets. It makes it difficult to identify the sources of increased volatility. The conventional concept of supply and demand in the agricultural commodity market has less of a defining feature for price fluctuations. Important factors in the agricultural market that play a role are energy commodity prices, interest rates, monetary policies of central banks, speculation and investment, trade restrictions, or lack of information (Martin and Anderson, 2012). In the case of wheat, price volatility could also be reflected in the causality because wheat commodity volatility was a crucial problem at the time. There are periods with high price fluctuation and evidence of the leverage effect (Cermak, 2017). With the increasing wheat cash price, there is a tendency to change the commodity price volatility in the same direction.

The second commodity that shows Granger

causality between spot prices and futures prices is cocoa. The reason for demonstrating Granger causality between spot prices and cocoa futures prices could be that cocoa is a potential commodity that can be used for industrial processing. Tulashie et al. (2022) found that the chemical characteristics in oil extraction from cocoa nibs were below the recommended standards acceptable for industrial applications. Additionally, the oil was found to be highly stable despite thermal extraction. The potential for using cocoa in the industry could influence speculation on the development of cocoa prices to a greater extent. A large concentration of cocoa bean production in a certain area could appear as an important factor. According to Faostat (2022), 68% of cocoa beans are produced in Africa. It means that market supply is significantly influenced by factors affecting African production, for example, the age of cocoa trees, climatic conditions, level of technology, etc. (Wessela and Quist-Wessel, 2015). It is related to the fact that cocoa is a crucial raw material for further processing, especially for the production of chocolate. Price fluctuation is, therefore, significantly influenced by the demand for final cocoa products. External factors, such as weather or price shocks, are the main reasons for the growth in the use of futures contracts (International cocoa organization, 2022).

Granger causality was reflected for cocoa in the high dependence of the producer on the given commodity and the related importance for the national economy (source of income, jobs). It applies, for example, to Indonesia, the 3rd largest cocoa producer in the world (Adelina, Hasyim, and Wibowo, 2020). In addition, according to Rubbaniy et al. (2022), cocoa can be considered a "safe haven" for short-term investors in both futures and spot markets, especially during the Covid-19 pandemic. Conversely, this relationship does not apply to investors using a long-term horizon. Another factor could be the possibility of export taxes on cocoa, as these taxes could affect the integration of domestic and international markets, which may be a source of greater market uncertainty (Duron et al., 2022).

On the market with other analyzed agricultural commodities, there didn't have to be a causal relationship between spot prices and futures prices of analyzed agricultural commodities since commodity price changes may not be affected by financial market turbulence. There is no speculation on the financial markets for some agricultural commodities to the same extent as for wheat. Another reason may be that other agricultural commodity markets are not as sensitive as the wheat market and are not linked to the energy commodity market as wheat. There are differences between the information absorbed by the financial market and the real asset markets. It could be reflected even more strongly in these commodities. The location of commodity cultivation is also an important criterion, i.e., how a given commodity is widespread worldwide. It could also be linked to the tendency of farmers to secure. Another important factor may be the degree to which food policy is addressed. There may be distortions in the markets for the other agricultural commodities analyzed, for example, because of various support programs.

Conclusion

The objective of this paper was to examine if the causal relationship between spot prices and futures prices in main traded commodities exists. The Granger causality was used for data daily (wheat, corn, sugar, coffee, cocoa, and soybeans) in 2012 – 2020. Our results show that the Granger causality exists among cash prices and futures prices of wheat and that there is also causality in the opposite direction. There can be several reasons for this finding. These reasons may include the following. First, there is an issue with food policy or security as its subarea. All the examined commodity prices, including wheat commodities, do not have a crucial effect on food nutrition like wheat. According to the findings, the possible explanation can be related to the importance of the commodity wheat, like a worldwide good traded at major commodity exchanges and in the field of specific convergence and market structure.

We then detected Granger causality between spot prices and cocoa futures prices. It could be reflected in the position of the commodity on the market and in industry, barriers to international departure through taxes and customs duties, or macroeconomic factors. In the case of other commodities, no causal link was found between spot prices and fur prices. These results may have been due to less sensitivity of the markets, less level of hedging, the effect of speculation in the markets, the level of concentration of cultivation of commodities, and interconnectedness of the financial market with the market of real assets.

These results are important and useful

for agricultural policymakers, investors, and financial practitioners. From a practical point of view, these findings can be used to create and simulate scenarios of various portfolios where the inclusion of agricultural commodities is considered. In terms of price volatility among the monitored commodities, the results are helpful regarding the causal influence of price movements.

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Appendix

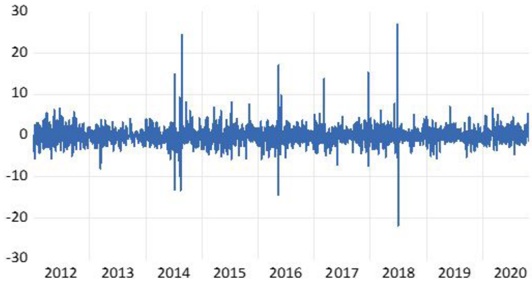
Variable	Price of wheat futures	Cash price of wheat	Price of corn futures	Cash price of corn	Price of soybeans futures	Cash price of soybeans
Mean	-0.0093	0.0058	-0.0245	0.0029	-0.0055	-0.0114
Median	-0.0519	0.0000	0.0000	0.0000	0.0186	0.0000
Maximum	6.6272	23.9149	25.0288	227.9300	5.4957	232.2664
Minimum	-6.7077	-24.5738	-26.8620	-230.3398	-12.5420	-228.6311
Std. Dev.	1.6190	2.1830	1.7796	6.9023	1.2258	7.0934
Skewness	0.2896	0.5878	-1.2435	-0.5034	-0.7544	0.7385
Kurtosis	4.0844	26.1158	56.8393	1042.649	10.0284	1014.446
(continued)						
Variable	**Price of cocoa futures**	**Cash price of cocoa**	**Price of coffee futures**	**Cash price of coffee**	**Price of sugar futures**	**Cash price of sugar**
Mean	0.0092	-0.0002	-0.0249	-0.0347	-1284.457	-0.0201
Median	0.0236	0.0000	-0.0275	0.0000	-1219.888	-0.0700
Maximum	19.2511	12.2363	11.7892	22.3992	-697.5694	811.3441
Minimum	-19.7491	-13.4124	-7.6331	-44.0641	-2323.845	-818.7789
Std. Dev.	1.7893	1.6998	2.0584	1.9901	328.5009	24.3291
Skewness	0.0769	-0.2562	0.2709	-4.8060	-0.7137	-0.4176
Kurtosis	16.2977	13.1275	4.5716	126.1574	2.8858	1100.897

Source: Authors' calculation (based on data available from Stooq and Investing)

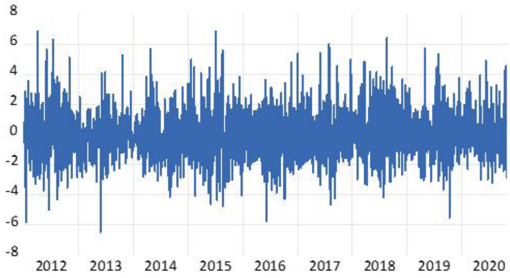
Appendix no. 1 Descriptive statistics of future prices and cash prices of analyzed commodities.

Wheat

Cash price of wheat

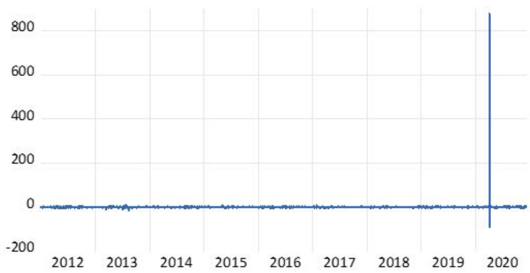


Price of wheat futures

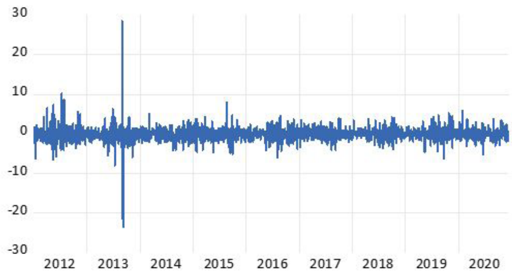


Corn

Cash price of corn

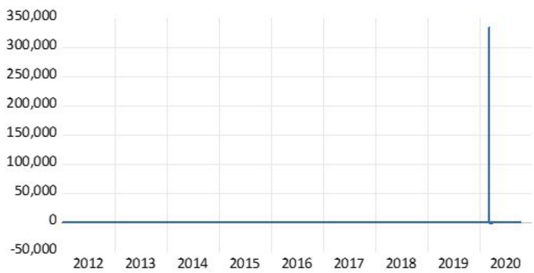


Price of corn futures

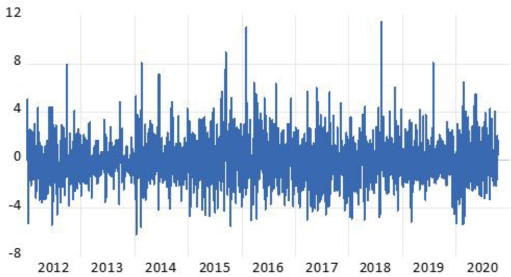


Sugar

Cash price of sugar

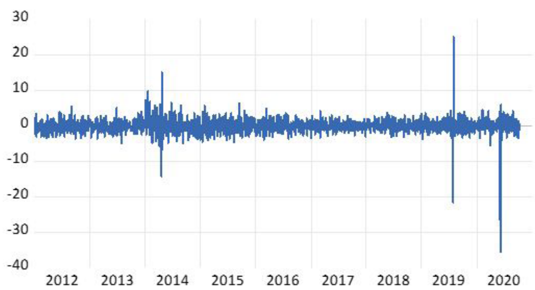


Price of sugar futures

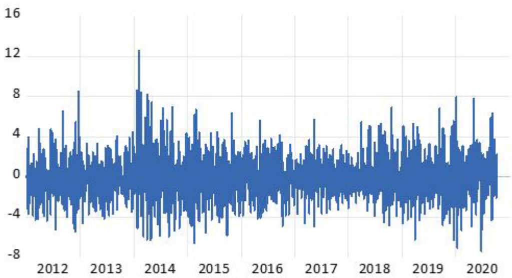


Coffee

Cash price of Coffee



Price of coffee futures

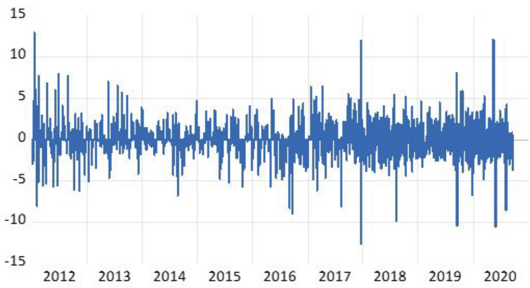


Source: Authors' calculation (based on data available from Stooq and Investing)

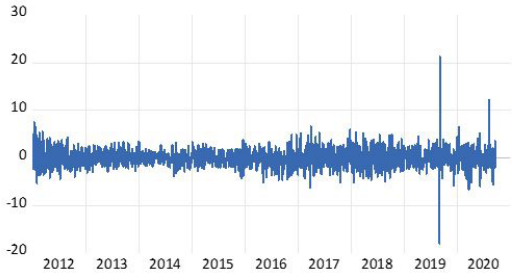
Appendix no. 2: Development of future prices and cash prices of analyzed commodities (change in %) (To be continued).

Cocoa

Cash price of cocoa

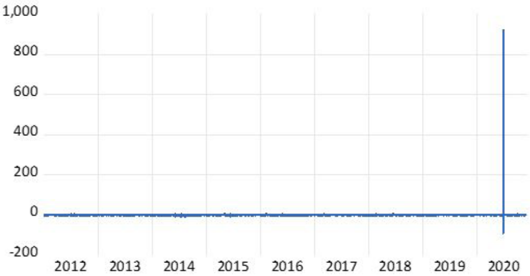


Price of cocoa futures

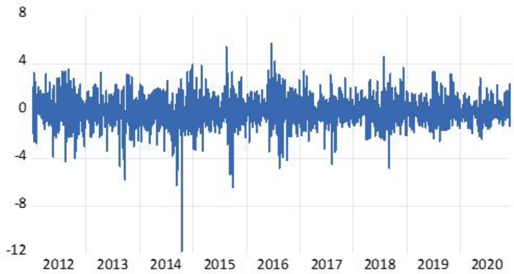


Soybeans

Cash price of soybeans



Price of soybeans futures



Source: Authors' calculation (based on data available from Stooq and Investing)

Appendix no. 2: Development of future prices and cash prices of analyzed commodities (change in %) (Continuation).

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Milchbot: App to Support the Process of Feeding and Caring for Dairy Cows in Peru

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Abstract

At present, Peru's agricultural sector has a shortfall of professionals, so livestock producers cannot be provided with relevant and reliable information to ensure good nutrition and care for dairy cows, which affects productivity. Milchbot is a chatbot that answers queries about the feeding and care of dairy cows based on reliable documentation. To do so, a chatbot model was designed to cover the topics of feeding, care, news and frequently asked questions for the planning, feeding and care processes about dairy cows. The model consists of a friendly interface, a dialog engine and a search engine that allows you to find and provide information from a document storage. This model was implemented employing Watson Assistant and Discovery. Milchbot was used and evaluated by 6 livestock producers and 7 zootechnicians. The results of the usability and satisfaction surveys show a high rating for both livestock producers and zootechnicians, and it should be noted that zootechnicians gave very high ratings on satisfaction.

Keywords

Chatbot, dairy cows, agricultural sector, Watson

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Introduction

In Peru, the population of dairy cows in 2019 was 905,818, being Cajamarca (17.7%), Puno (11.4%) and Cusco (9.1%) the regions with the largest populations (MINAGRI, 2017), which generated more than 2 million tons of milk per year, with a turnover of 2,771 million dollars and jobs to more than 452,217 producers (MINAGRI, 2019), and with an annual growth rate of 1.9% between 2007 and 2016.

The livestock production process begins with planning, in which the choice of the dairy cow breed and the stages of production are determined; the characteristics of the infrastructure, feed and the quantities that are required for production are defined; and the production parameters that are expected to be produced are established. Then comes the care of the animals in which the production environment is prepared, the physical condition of the cows is reviewed, a sanitary control and handling are carried out to ensure that the exact number of animals is available for production in the barn; at the same time, food and distribution equipment are prepared to feed dairy cows. Last, the milk production process is carried out, to subsequently store and distribute the production to the intermediary companies between the farmer and the final consumer (MINAGRI, 2017). This process can be affected by different factors, such as the experience of the producer, technical assistance, the use of technologies, staff training and sanitary management. The consequences of all these factors are reflected in the mortality rate, milk productivity, production costs among others, being the mortality rate of 9.87%, in 2016, in Puno, one of the regions of Peru (Nacional, Altiplano, 2017).

Livestock activity for small and medium-sized producers, in general, is inefficient, due to information gaps about the correct care and feeding of animals, little access to technology, inadequate infrastructure, poorly trained personnel, among others (MINAGRI, 2017). In addition to this problem, the deficit of professionals in this sector, which only, in 2017, 3.5% of the total of 927,426 university students chose to study Veterinary and Zootechnical Medicine, of which 0.4% are zootechnics, which is insufficient to cover the needs of information, production, care and health in the sector (INEI, 2018). An alternative to provide adequate, accessible and timely information are chatbots (Symeonaki, 2020). This technology has been used to support processes such as human resources, in which 80% accuracy was obtained in the answers to queries about this process (Majumder et al., 2021).

Chatbots in the livestock sector answer queries about optimal conditions and water care for animals and give information on how to procure a good production outcome (Udin et al., 2020). For the poultry sector, there is a chatbot and a forum to answer queries about poultry feeding and care (Shapa, et al., 2020). For the agriculture sector, there is a chatbot based on IoT sensors that provide information to the farmer about the care of plants (Ekanayake et al., 2020), the improvement of the agricultural production process and the optimization of the resources used for production (Wiangsamut, 2019). In addition, Vijayalaksh, et al. (2019) developed a chatbot to provide relevant information, replicate a conversation, and identify queries with grammatical errors. From the reviewed studies, there is evidence that chatbots have been developed for the agricultural and livestock sector that attend the queries of producers for the care of plants and animals, however, a chatbot focused on the feeding and care of dairy cows has not been identified.

This study proposes the development of a chatbot capable of providing information required by the livestock producer, and reliable documentation that allows the improvement of the production processes of feeding and care of dairy cows, so they will be able to have a virtual specialist in real time 24 hours a day, 7 days a week, and, they will also be able to contact with that specialist.

Materials and methods

Chatbots applied in the agricultural sector

Chatbot is a computer program that uses Artificial Intelligence (AI) and natural language in text and/or audio to interact with humans, determine user intent, and answer queries and requests (IBM, 2018).

Its components are the following: (a) Interface, which manages the inputs and outputs of the devices that make the queries to the chatbot, allowing the communication between the user and the chatbot to be through messages or audio, and is carried out through mobile or desktop devices (Rooein, et al., 2020); (b) Controller, which receives the user's message and processes it using natural language, and then classifies it into different intentions that it has been taught to identify (Vijayalaksh, et al., 2019); (c) Dialog manager, divided into two domains, one generic to generate dialogues that resemble a natural conversation, and another specific, to answer specific queries to the user (Shapa, et al., 2021); and (d) User Controller, which sends the answer to the user, which can be a text, images, videos, etc. (Ekanayake et al., 2020).

An inventory of 10 chatbots for the production processes of the agricultural sector are presented in Table 1.

N°	Chatbot	Description	Author
1	Agribot - Sawant	A portable virtual assistant that uses analytics and data mining to help farmers in India with various farming techniques, decide on the most suitable crops, and stay informed about any factors that may affect crop productivity and profits. Unidentified inquiries are redirected to call centers.	Sawant et al., (2019)
2	Plant quality	Gives information about the temperature and the state of the plants, as well as the humidity of the air and the soil, through the chatbot and IoT devices for the improvement of the quality of the plants.	Gunawan et al., (2019)
3	Orchid care	Enables communication between plants and humans, through a chatbot that interacts with plants grown on an automated farm based on IoT and Fuzzy Logic. Tests show the accuracy of the conversation between a user and the information presented of an orchid to be 71%.	Wiangsamut et al., (2019)
4	Agribot - Arora	Provides Indian farmers solutions to various agriculture-related problems and supports decision-making. In addition to this, it helps detect crop diseases through a convolutional network.	Arora et. al., (2020)

Source: Authors processing

Table 1: Chatbots in the agricultural sector. (To be continued).

N°	Chatbot	Description	Author
5	E-Agro	Consists of a chat room and a Chat-Bot to discuss the predominant issues related to agriculture with peers and experience. It also helps farmers make timely decisions about agriculture by contemplating a standard set of questions, intentions and answers from farmers, experts and other stakeholders.	Ekanayake et al., (2020)
6	Integrated crop management	A Virtual Assistant that provides information for the integrated management of crops, and contemplates a set of questions, intentions and answers from agricultural producers of Otuzco, in Peru, experts and other sources. Tests show a reduction in the cost of access to information by up to 90% and reduction of time of 15 minutes per 8-hour day.	Mendo et al., (2020)
7	Water quality monitoring	Tracks the water quality for the aquaculture sector in real time through IoT devices, a cloud system and a chatbot assistant.	Udin et al. (2020)
8	Plants care	Messaging assistant for efficient, secure and easy-to-use interaction for smart agriculture through the integration of conversational user interfaces with IoT devices.	Symeonaki and Arvanitis (2020)
9	Poultry farmers support	A decision support system based on mobile devices through a mobile application integrated with a chatbot assistant to solve various problems related to poultry farming and to simplify decision-making in Tanzania, via interactions in natural language.	Shapa et al. (2021)
10	Adithri	Provides information to the farmer about government policies, weather information, fertilizers, among others, for different types of crops.	Gayathri and Kumar (2021)

Source: Authors processing

Table 1: Chatbots in the agricultural sector. (Continuation).

Milchbot model

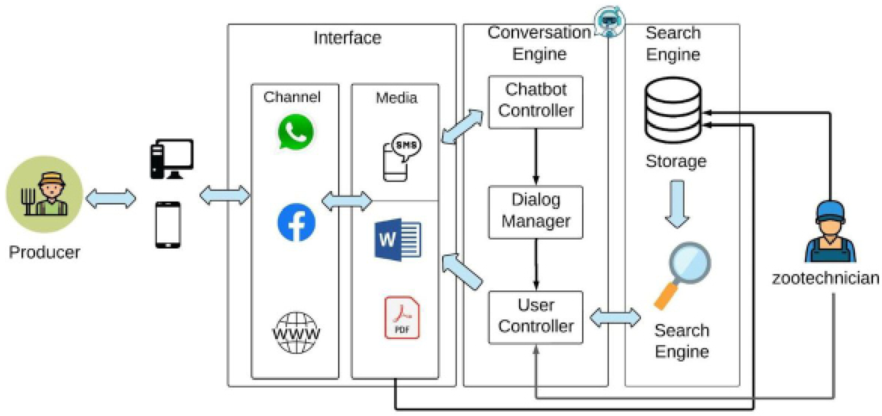
The Milchbot model (acronym for “Milch” and “Bot”) is a model of a chatbot that provides information required by the livestock producer about the feeding and care of dairy cows.

As shown in Figure 1, the model has three components: interface, which contains the channels and formats with which the chatbot and the user communicate; the conversation engine, composed of the chatbot controller that allows the identification of intention and entities within the user's message; and the dialog manager, which classifies such intent and directs it to a specific node and to the user controller that handles the output of the response to the user; and, finally, the search engine that contains the connection to the intelligent search service and the storage to be able to consume documents and categorize information to send it to the user, if necessary.

The Milchbot model (Figure 1) has two user profiles: the livestock producer, who makes queries to the chatbot about the feeding and care of dairy cows using a device, which allows access to the interface; and the zootechnician, who is responsible for managing the information used by the chatbot to provide answers, keeping the document repository updated and, if necessary, engaging in a direct conversation with the farmer, who accesses the application interface through a device (mobile, desktop or any device that allows access to a web browser), making use of WhatsApp, Facebook Messenger and a web page. The livestock producer initiates the interaction with the chatbot through .pdf or .docx documents, and then the chatbot processes the data, identifying the intention and the response to the intention. In case the producer does not find an answer, the chatbot will proceed to make use of the search engine to find an answer (.txt) and documentation (.pdf, .docx) from a repository of documentation on the processes of feeding and caring for dairy cows. It should be noted that the web application allows the farmer to share their documents with the repository.

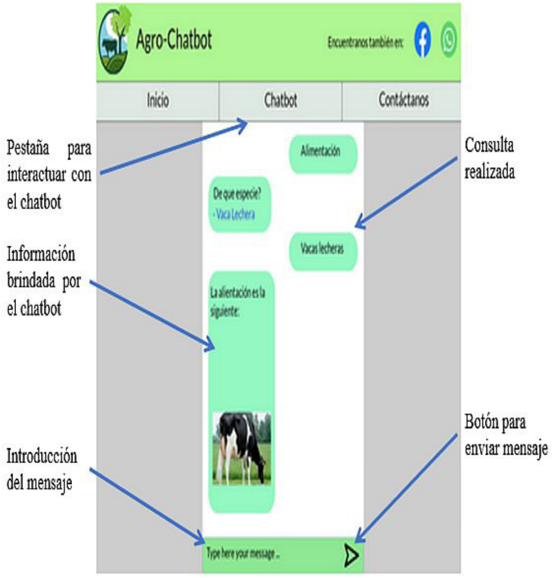
Interface

This component shows in a friendly way the flow of the conversation with the chatbot (text message or a file in Word or PDF format) through channels (WhatsApp and Facebook Messenger for mobile device; and WhatsApp Web, Facebook and Agro-Chatbot web for desktop/laptop), where the message box, a send button, and an image of the chatbot are displayed, as shown in Figure 2. In addition to this, the interface allows the storage of unstructured documents (.docx and .pdf) and categorization into food, care, news and documentation.



Source: Author

Figure 1: Milchbot model.



Source: Author

Figure 2: Chatbot Mockup .

Conversation engine

This component receives the message from the user in order to process it and generate a response. The "chatbot controller" is the first to receive the message from the user, with which, through the previously trained algorithm of natural language understanding, understands and identifies an intention. Then, the generated intention is analyzed and assigned by the "Dialog Manager" component to the corresponding node, which is handled by a flow of unified nodes within a decision tree scheme, resulting in the location of the final node related to the identified intention and entity. At last, the "User Controller" component is responsible for locating the response that can be a text, option, image, audio, video, pause, search, etc., and finishes by sending this message to the "Interface." In case the type of response is a search, the chatbot will generate a request to the "Search Engine" in order to consume the intelligent information search engine and send it to the user.

Search engine

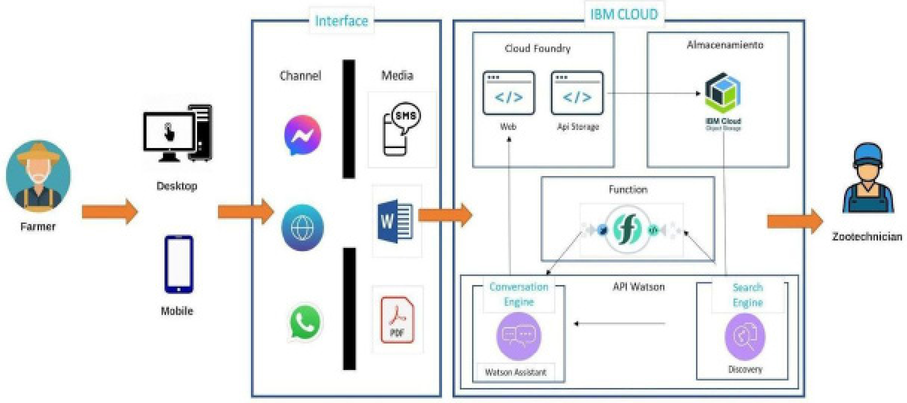
This component receives the request from the "User Controller" and proceeds to perform an intelligent search of the required information from a document repository. This is achieved based on the application of natural language understanding that provides different metadata from the fragments of text that have been found in the previously registered documents, and that relate to the message of the request. After performing the search and extracting the required information, the chatbot proceeds to send the response and a link of the documentation to the "User Controller," to respond to the user.

Milchbot

The following is a description of the Milchbot application that implements the Milchbot model to support dairy cow care information to the dairy producer.

Architecture

The architecture solves the functionality related to the Milchbot model. The components are created using IBM Cloud provider services. As can be seen in Figure 3, the technologies involved are Object Storage, for document storage; Watson Assistant, as a chatbot development platform; Discovery, as an intelligent search engine to perform a powerful response integration for the chatbot; a Function, as a service to take advantage of multiple Discovery features; and finally, Cloud Foundry,



Source: Author

Figure 3: Milchbot's logical architecture.

which is the platform as a service that was used for the deployment of the web and storage service. This architecture allows the model to comply with the flow proposed in the Milchbot.

Modules

Interface module

The interfaces were prepared for the web, Facebook and WhatsApp channels (Figure 4), for a dialogue. In addition, the interface contains the presentation of Milchbot, a tutorial to manage the chatbot, a file manager so that users can share documents, and information about food, care and news. The website channel was developed using the Node js a language with the express framework and the vue.js framework and for its integration with the chatbot the script provided by IBM Cloud was used. On the other hand, the integration of the chatbot with Facebook was done using the Watson Assistant platform, and its integration with WhatsApp was done using Twilio.

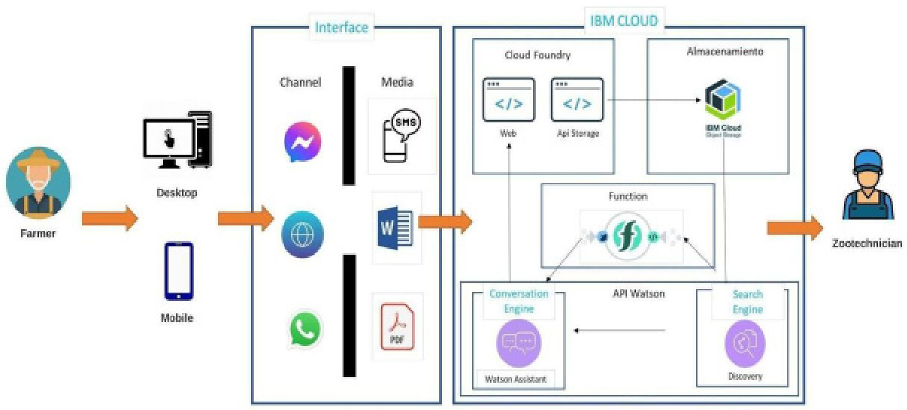
Conversation engine module

The Watson Assistant chatbot development platform was used to design the decision tree that the chatbot follows to manage the conversation flow covering the topics of documentation, feeding, care, news, and frequently asked questions (Figure 5).

The chatbot was trained considering 112 examples of seven intentions (Table 2) and six entities (Table 3). The intentions together with the entities allow the chatbot to improve understanding and obtain better responses.

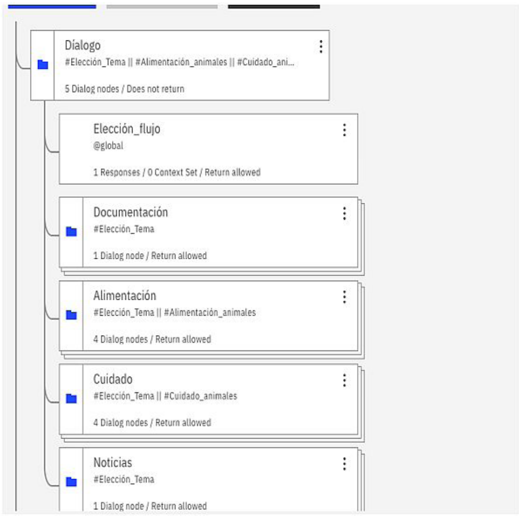
Search engine module

For the engine, Discovery was used, which allows connection to a document repository and trains the service to extract relevant information for the user. In addition, a serverless connection was used to integrate the chatbot with the intelligent search engine using the Discovery SDK. To manage file input from the web and have a repository to feed Discovery, the Api Storage was programmed using Node js.



Source: Author

Figure 4: Milchbot interfaces per channel: A) Facebook; B) Website; C) WhatsApp.



Source: Author

Figure 5: Watson chatbot decision tree.

Intents	Description	N.º Examples
Animal feed	Generate direct inquiry for animal feeding	8
Human contact	Request a human agent	35
Animal care	Generate direct inquiry for animal care	8
Choice of topic	Theme options: Food, Care, Documentation and News	19
Frequently Asked Questions (FAQ)	Set of frequently asked questions that can be asked to the chatbot (stages, regions, etc.)	4
Dialogue greeting	Greetings to the Bot	18
End of dialogue	End of conversation	20

Source: Author

Figure 5: Watson chatbot decision tree.

Entities	Type	Values
Animals	Synonyms	Chicken, Dairy cow, Dual-purpose cow
Continue to	Synonyms	Yes, No
Global	Synonyms	Subject, Cow
Country	Synonyms	Peru, Colombia, Argentina, Venezuela, etc.
Frequently Asked Questions (FAQ)	Synonyms	Stage, Regions
Topic	Synonyms	News, Documentation, Care, Food, Region, Age

Source: Author

Table 3: Entities used in the chatbot.

Results and discussion

Milchbot usability and satisfaction

Participants

Six producers with two to 19 years of experience, and seven animal technicians with two to three years of experience, all from 13 different farms (Table 4) located in Lurín, in the province of Lima, participated. The cattle in each of the farms are in open spaces, in general, with no grass, fed with five to seven kilos per day on average with dry matter such as forage and supplements (for instance, antioxidants), with 70 liters of water per day on average. In addition, on average each farm has 30 cows for milk production, which produces approximately 40 liters of milk per cow per day. The producers plan their production according to their experiences, considering the breed, the animal's life stage and the available infrastructure, then generating feeding and care plans, which are later executed and supervised.

ID	Participant	Sex	Experience
P1	Livestock Producer	Male	19 years
P2	Livestock Producer	Male	17 years
P3	Livestock Producer	Male	5 years
P4	Livestock Producer	Male	2 years
P5	Livestock Producer	Male	14 years
P6	Livestock Producer	Male	3 years
Z1	Zootechnician	Female	2 years
Z2	Zootechnician	Female	2 years
Z3	Zootechnician	Female	2 years
Z4	Zootechnician	Female	2 years
Z5	Zootechnician	Female	2 years
Z6	Zootechnician	Female	2 years
Z7	Zootechnician	Female	3 years

Source: Author

Table 4: Profiles of participating livestock producers and animal producers.

Evaluation instrument

To evaluate the usability and satisfaction (Villena, 2016) of Milchbot, an instrument of 10 questions was used (Table 5): five questions about usability, three about satisfaction and two others, based on the User Experience Questionnaire (UEQ) and applied through Google Forms to the participants.

Category	Id	Question
Usability	Q01	How well did the chatbot answer your queries about feeding and/or care about dairy cows?
	Q02	Do you consider that the process improves the time it takes to answer your questions?
	Q03	Did the information provided seem relevant?
	Q04	Do you consider that the information provided could benefit micro, small and medium-sized producers?
	Q05	How effective was the chatbot for direct responses?
Satisfaction	Q06	How friendly do you rate the chatbot?
	Q07	Do you agree with the type of language used for the chatbot?
	Q08	How fluent was the conversation?
	Q09	Did you have any problems using any of the 3 channels via an Android device?
	Q10	Which channel do you think you would use most often?

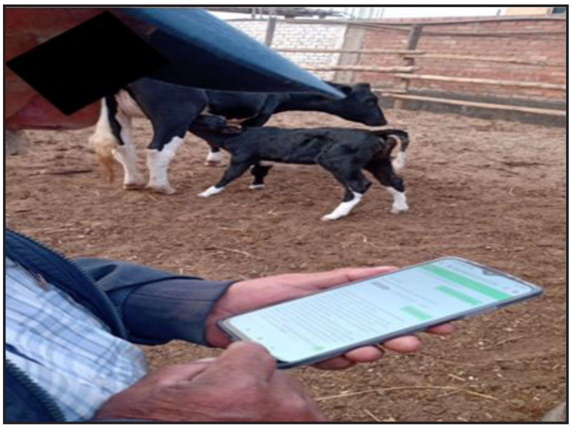
Source: Author

Table 5: Usability and satisfaction questionnaire.

The answers to the questions were measured through the Likert scale (5: Very High, 4: High, 3: Moderate, 2: Little and 1: Not at all) as pointed out in several studies such as "An Attitudinal Scale in Relation to the Scientific-Social Research Process" (Zulia, 2005). Questions Q09 and Q10 have response alternatives of Yes/No and Facebook/WhatsApp/webpage, respectively. In addition, an open-ended question on recommendations and opportunities for improvement was included.

Experiment

Each participant was introduced to the software, at the following link: https://web-agrochatbot-empathic-ardvark-kt.mybluemix.net. In approximately 60 minutes, the participants were presented with the software's benefits, functionsand facilities through videoconference; then they performed a sequence of tasks (initiating a dialog, document entry, document request, dairy cow care and feeding questions, and frequently asked questions) using the three Milchbot channels (Figure 6); next, they freely interacted with the software. At the end of the tasks, the usability and satisfaction survey in Table 5 was applied.



Source: Author

Figure 6: Livestock producer interacting with the chatbot.

Results

The results of the usability satisfaction questionnaire for livestock producers (Table 6) show an average score of 4.06, high in terms of usability and satisfaction for Milchbot. In usability, it was rated very high for correct information (Q01), and high for the other questions, i.e., it improves consultation times (Q02), offers relevant information (Q03), presents benefits to farmers (Q04), and is effective in generating direct answers (Q05). In satisfaction, a high score was obtained in respect to friendliness (Q06), use of appropriate language (Q07) and fluency of conversation (Q08). On the other hand, only one livestock producer expressed delay in communication due to the poor internet signal present on the farm (Q09), in addition, the channel with the highest preference is WhatsApp for being the most used by livestock producers (Q10).

The results of the usability satisfaction questionnaire for zootechnicians (Table 7) show a high score of 4.06 for usability and a very high score of 4.23 for satisfaction. In usability, a very high score was obtained for correct information (Q01), and a high score for the rest of the questions, improving consultation time (Q02), giving relevant information (Q03), providing benefits to livestock producers (Q04) and being efficient in supplying direct answers (Q05). In the satisfaction aspect, a very high score was obtained for friendliness (Q06) and fluency in conversation (Q07), and a high score was obtained on the use of appropriate language (Q08). In addition, none of the respondents presented a problem in the use of the chatbot through the three channels (Q09), and the channel with the highest preference is WhatsApp, as it is the application most used by zootechnicians (Q10).

In response to the open-ended question "What recommendations or opportunities for improvement would you give for the chatbot?" livestock producers stated four recommendations and opportunities for improvement (Table 8).

Category	Questions	P1	P2	P3	P4	P5	P6	Average	Average
Usability	Q01	5	4	5	3	4	5	4.3	4.06
	Q02	5	4	5	3	4	4	4.2	
	Q03	4	4	4	3	4	3	3.6	
	Q04	5	4	5	3	4	4	4.2	
	Q05	4	3	4	4	4	5	4	
Satisfaction	Q06	4	4	4	4	5	4	4.2	4.06
	Q07	4	4	3	5	4	4	4	
	Q08	5	3	4	4	4	4	4	
	Q09	No	No	No	No	Yes	No	No	
	Q10	Wp[1]	Ws[3]	Fb[2]	Wp[1]	Wp[1]	Wp[1]	Wp[1]	

Note: [1] WhatsApp; [2] Facebook; [3] Website

Source: Author

Table 6: Results of the usability and satisfaction questionnaire for livestock producers.

Category	Questions	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Average	Average
Usability	Q01	4	5	5	5	4	4	4	4.3	4.06
	Q02	3	4	5	5	4	4	3	4	
	Q03	4	4	4	5	4	3	3	3.9	
	Q04	3	4	5	5	4	4	3	4	
	Q05	4	5	4	5	3	4	4	4.1	
Satisfaction	Q06	4	5	4	5	4	4	4	4.3	4.23
	Q07	5	5	5	5	3	4	3	4.1	
	Q08	4	5	5	5	4	3	4	4.3	
	Q09	No	No	No	No	No	No	No	No	
	Q10	Wp[1]	Ws[3]	Fb[2]	Wp[1]	Wp[1]	Wp[1]	Wp[1]	Wp[1]	

Note: [1] WhatsApp; [2] Facebook; [3] Website

Source: Author

Table 7: Results of the usability and satisfaction questionnaire for zootechnicians.

ID	Recommendations and improvement opportunities
R01	Information on prices of products, inputs and others related to livestock farming.
R02	Focus on the management of other breeds and animals.
R03	Enhance images for better user guidance.
R04	Extending to healthcare issues such as treatments and medications.

Source: Author

Table 7: Results of the usability and satisfaction questionnaire for zootechnicians.

Conclusion

A chatbot model was designed to provide information about the planning, feeding and care processes of dairy cows, as well as to provide news, and to display frequently asked questions. The model consists of a friendly natural language interface, a dialog engine and a search engine that allows finding information from a document container, and was implemented using Watson Assistant and Discovery, giving Milchbot as a result. Unlike other chatbots for the agricultural sector, Milchbot is specialized and unique to dairy cows, and integrates a search engine that facilitates access to documentation.

The results of the usability and satisfaction surveys applied to six livestock producers and seven zootechnicians who used Milchbot show high usability and satisfaction for both livestock producers and zootechnicians, yet satisfaction was rated very high for zootechnicians. However, these results are limited to the perception of the respondents.

As future work, we intend to add other functionalities to Milchbot that will allow the monitoring of each individual cow, so that it can be integrated to trace the development of each cow and its products.

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Hub4Everybody - New Collaborative Environment for Sharing

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Abstract

Hub4Everybody is a one-of-a-kind solution for publishing, sharing and cooperative management of geographical datasets, such as professional data and measuring, results of research projects or student papers, educational materials, emotional maps, visualization of in-field research and other maps, tables, or databases. You can easily upload or update your data as well as adjust the parameters of sharing among different audiences. Hub4Everybody is an alternative tool combining online office software with an editorial system for spatial data. It is also an Open-Source alternative to already existing commercial solutions, while offering additional extending options. Hub4Everybody offers all usual functions of geoportals (working with a map, linking of external data and services) but on top of that it offers a possibility to link desktop and mobile solutions for geographical data processing, data visualisation in form of storyboard and communication components via social networks. The solution is scalable and fully adaptable to the end-user needs. You can store your data directly on Hub4Everybody cloud or in your own infrastructure. All technologies used for Hub4Everybody are open source, which enables you to communicate with all kinds of users all over the world while no costs are necessary. The paper describes not only the current system, but also the history of development and potential utilization. An intensive testing and development using a series of INSPIRE Hackathons are an important part of development.

Keywords

Digital innovation hubs, social space, regional development, web mapping, spatial information, hackathon.

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Introduction

What is Web Mapping? What is the current status of Web Mapping technologies? How can Web Mapping be linked with Digital Innovation Hubs? How the development of rural regions could be supported by Web Mapping? And mainly how can it all be done easily? These are the questions which we will try to answer in this paper.

The history of Web Mapping is already relatively long. Usually, the United States Vice-President Al Gore's 1998 speech about the necessity of geographical information being accessible globally and available to many users is being considered as the first idea about large scale Web

Mapping (Veenendaal et al., 2017; Gore, 1999).

There are a lot of definitions of what Web Mapping is. We can mention for example following two:

- Web mapping is a technique of utilizing maps that are obtained by an information system for spatial and geographical data (Techopedia: What Does Web Mapping Mean?).
- Web mapping is a process of designing, implementing, generating, and delivering maps on the World Wide Web (Neumann, 2008).

Spatial Data Infrastructure (SDI), another term introduced by Al Gore, is connected closely with Web Mapping. SDI is usually defined as technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data, services, and other digital resources. It includes maps, data, geospatial services, and tools (Georgiadou et al., 2006; Hendriks et al., 2012). In Europe, building of SDI is closely connected with the Infrastructure for Spatial Information in Europe (INSPIRE) directive, which has focus to release the potential of spatial data managed by governments at all levels (Local, Regional, National, European) and to guarantee reuse data by all actors including business and citizens mainly for the purposes of Community environmental policies and policies or activities which may have an impact on the environment. The INSPIRE Directive, came into force on 15 May 2007, with expected full implementation in every EU Member State required by 2021 (Craglia and Annoni, 2007; Cetl et al., 2019). Similar initiatives exist also in the US, where there is National SDI coordinated by the Federal Geographic Data Committee (FGDC) (Maguire and Longley, 2005) and common SDI between Australia and New Zealand managed by Australian and New Zealand Land Information Council (ANZLIC) (Rajabifard and Williamson, 2001). On a global level, the effort is coordinated by The Group on Earth Observations (GEO) with the goal to build the Global Earth Observation System of Systems (GEOSS) (Giuliani et al., 2017). Spatial Data and Spatial Data Infrastructure play a more and more important role also in rural and regional development (Halbich and Vostrovsky, 2011; Kliment et al., 2015; Pavlík et al., 2015).

Crowdsourcing is the new step in broader citizens participation on collection of spatial data. Crowdsourcing together with Volunteered Geographic Information (VGI)are currently part of a broader concept – Citizens Science (Charvát and Kepka, 2021). Crowdsourcing is a model where a group of organizations or individuals can contribute to a common goal. It could be used for collecting finance, but also for data collecting. It often relates to citizen science, as the involvement of the public in scientific research (Irwin, 1995; Gura, 2013). We can also speak about Earth Observation or Citizens' Observatories (Newman et al., 2012; Robinson et al., 2018). Volunteered Geographic Information (VGI) is a very similar approach (Elwood, 2008).

Digital Innovation Hubs (DIHs) are mainly used to support local and regional SME in testing new tools and developing new solutions. "Digital Innovation Hubs are one-stop-shops that help companies become more competitive with regard to their business/production processes, products or services using digital technologies, by providing access to technical expertise and experimentation, so that companies can "test before invest" (Kalpaka et al., 2020). Digital Innovation Hubs have to guarantee access of local businesses and public authorities to the newest digital technologies and provide training in digital skills. It needs to support specialization of the regions, in line with their regional Smart Specialization Strategies as a set of priority areas for public investment, corresponding to regional competitive advantages (Miörner et al., 2019; Jarolimek et al., 2009; Kánská et al., 2021). To support regional policies and regional businesses is one of the key priorities on PoliRural projects, where an important part was to develop and test utilization of DIHs in regional context (Ulman et al., 2020).

Various web map platforms, with potential to support DIHs are available on the scene with a wide range of features, target user groups and maturity level.

Provision of web GIS functionality and content can be provided by the large set of open sourced or open license-based solutions like examples mentioned in Table 1.

	Product title	URL
1	Geonode	https://geonode.org
2	Georchestra	https://www.georchestra.org
3	Lizmap	https://www.lizmap.com
4	Mapbender	http://mapmint.com
5	MapLibre	https://maplibre.org
6	Mapmint	https://oskari.org
7	Mapstore	https://mapbender.org
8	Oskari	https://mapstore.readthedocs.io

Source: Authors processing

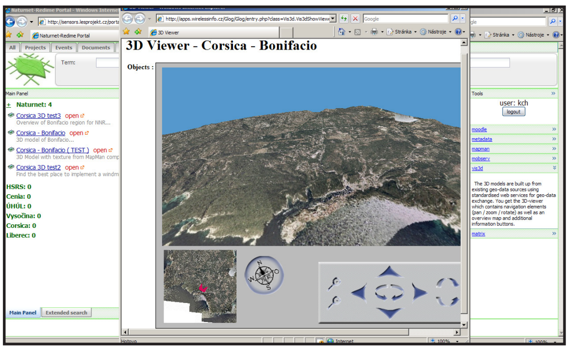
Table 1: Examples of web map platforms.

The goal of this paper is to describe implementation of DIHs and their practical testing and improvements. It was done not only as part of PoliRural projects, but in cooperation with other projects SmartAgriHub, EO4Agri and SIEUSOIL. Based on practical experiences, we have created a new design of such DIH - Hub4Everybody, which can now be easily modified and used in different contexts.

Materials and methods

Current solution

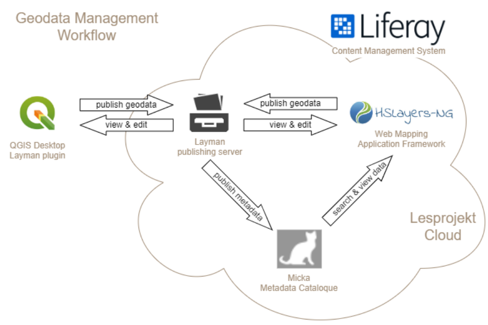
The initial ideas leading to the current Hub4Everybody first concept and first prototyping was the concept of Uniform Resource Management (URM). Uniform Resource Management provides a framework in which communities can share information and knowledge through their description, which is easily understandable within the community, e.g., scientific community, living lab, etc. This URM concept is one of the research results introduced by NaturNet-Redime project and today deeply elaborated by Collaboration at Rural (C@R) project and support sharing of knowledge inside of community using metadata and catalogue standards for their description and discovery (Figure 1).



Source: Charvát et al. (2008)

Figure 1, NaturNet-Redime URM.

This model has been extended throughout the years and new components were added or were modified (Charvat et al., 2009; Charvat et al, 2011; Charvat et al., 2014) and it has led to currently used solutions, based on Liferay CMS (Figure 2).



Source: Charvát et al.

Figure 2: Initial Architecture of Hub with Liferay CMS.

Liferay

The frontend layout of the DIH portal was based on the wireframe for better UX usage and is implemented into the Liferay portal framework. Responsive design based on the Bootstrap framework is used for optimal viewing and navigation across a wide range of devices, including traditional PC, tablet and surface, smartphones, and all other mobile devices. Also, semantic code for better SEO and application of the SEO principles.

Liferay Portal provides a robust platform to build a website on quickly and serve it to all clients - desktop, mobile, or anything in between. It provides all the standard applications which are needed. It also provides an easy-to-use development framework for new applications or customization.

Liferay's collaboration suite resonates with apps and features that foster excellent communication. Its Message Boards app gives users a platform for discussions, questions and answers, and comments. Blogs publish user's ideas using rich content, so readers can understand them clearly and respond to them. Collaboration is enhanced in all these applications through mentioning other users–tagging them by name to get their attention or give them kudos.

CMS - page editor - Liferay Portal's Web Content Management (WCM) system allows non-technical users to publish content to the web without having advanced knowledge of web technology or programming of any sort. Liferay WCM empowers users to publish their own content with a simple point and click interface and it helps them keep the site fresh.

With Liferay Portal's WCM, users have the ability to create, edit, stage, approve, and publish content with easy-to-learn yet powerful tools. Liferay's WCM streamlines the content creation process for end users. It's much faster to use Liferay's WCM than it would be to create all the content for your site in HTML. WCM is integrated with Liferay's services so advanced template developers can use them to query for data stored elsewhere in Liferay.

- **WYSIWYG Editor:** A complete HTML editor that allows users to modify fonts, add colour, insert images, and much more.
- **Structure Editor:** Easily add and remove fields users want available to content creators and then dynamically move them around. This editor includes an entire suite of form controls you can drag and drop onto your structure.
- **Template Editor:** Import template script files or create their own template that informs the system how to display the content within the fields determined by the structure.
- **Web Content Display:** An application that lets users place web content on a page in a website.
- **Asset Publisher:** An application which can aggregate different types of content together in one view. This app is covered in more detail in the Publishing Assets section.
- **Scheduler:** Lets users schedule when content is reviewed, displayed and removed. This feature is covered in more detail in the Scheduling Web Content Publication section.
- **Workflow Integration:** Run users' content through an approval or review process. This feature is covered in more detail in the Using Workflow section.

Collaboration - Liferay Portal ships with a robust suite of collaboration applications that can be used to build communities of users for the website. These applications provide all the features that would be expected of standalone applications outside a portal setting. The difference with Liferay's collaboration apps, however, is that they all share a common look and feel, security model, and architecture.

Available apps on Liferay and all the components of Liferay's Collaboration suite:

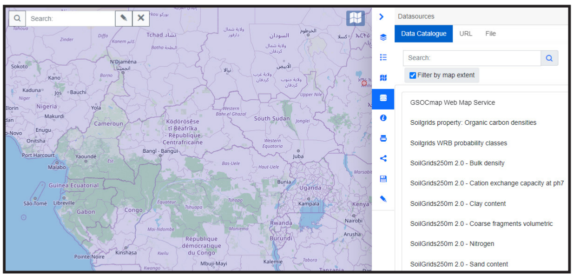
- Blogs
- Message Boards
- Wikis
- Announcements
- Mail
- Knowledge Bases
- Bookmarks

Media manager - Liferay Portal's Documents and Media library provides a mechanism for storing files online using the same type of structure that is used to store files locally. It serves as a virtual shared drive and can mount and browse external repositories. Its companion app, the Media Gallery, displays selected content from the Documents and Media library. It can display image, audio, and video files. Other features in the Documents and Media library include customizable document types and metadata sets, automatic document preview generation, and support for mounting multiple external repositories.

Web Map Application

The web mapping component (Figure 3) uses the open-source mapping framework HSLayers-NG, see https://ng.hslayers.org/. This tool is built upon the basis of OpenLayers and enables significant customization and functional additions depending on the requirements of the system. At the same time, there is a functional integration to the Wagtail CMS in the form of a map widget, which allows easy creation of maps within all HTML pages of the content management system, including the detailed configuration of map layers and tools if required.

Important role of the web map is to publish geo-data in the form of single layers or complex thematic maps. Most common vector and raster data formats are supported (GeoJSON, Esri Shapefile, KML, GPX, GeoTiff, JPEG, PNG).



Source: Charvát et al.

Figure 3: Web mapping component.

Desktop GIS Client

All the geo-data publishing tasks that can be carried out in the web application are available also via a desktop client. That is represented by a plugin for the most popular open-source GIS platform QGIS. The plugin is called "Layman" and is available through the native QGIS repository. Similar to the HSLayers web map, spatial data layers can be published as services and thematic maps composed of layers can be created using the Layman plugin.

Data Publishing Server

Both HSLayers and QGIS Layman plugin act as client applications which means they don't do the actual data publishing but are using some other service for that. And that is the role of Layman (https://github.com/LayerManager/layman), the publishing server that automatically converts geo-data into web services in OGC WMS and WFS standards. It provides an extensive REST API so any other possible client can be connected.

Metadata Catalogue

Any geo-data management system cannot work without metadata. Micka is the detailed metadata catalogue with INSPIRE standard support. All geodata published by our tools is automatically metadata-recorded. The metadata can be searched back through the HSLayers web client or the QGIS desktop tool.

Existing Hubs installation

Within the projects, HUBs were installed with the aim to:

- Provide a social space for a community of practices
- Promote pilots work and support access to their analysis
- Promote existing best practices
- Support hackathons and promote results of challenges
- Offer new tools and technologies for testing
- Provide access to digital technologies and competencies
- Provide access to infrastructure and tests digital innovations ("test before invest")
- Support effective data management
- Provide development playground for map-based projects
- Offer training and skills development
- Help in networking and connecting users and suppliers of digital innovations

PoliRural Hub (hub.polirural.eu)

PoliRural DIH aims to offer a solution for the global promotion of pilots and regions. This DIH integrated technology, datasets, and libraries in one infrastructure with a complex user-oriented portal in the Web environment. The DIH can connect end-users with developers or researchers to improve the impact of the demo applications or case studies by short-chain feedback from end-users. End users can join larger communities around the DIH to get advice, cooperation potential and access to modern technologies utilization. Important part of the Hub is the pilot section, where pilot work was presented (Figure 4).

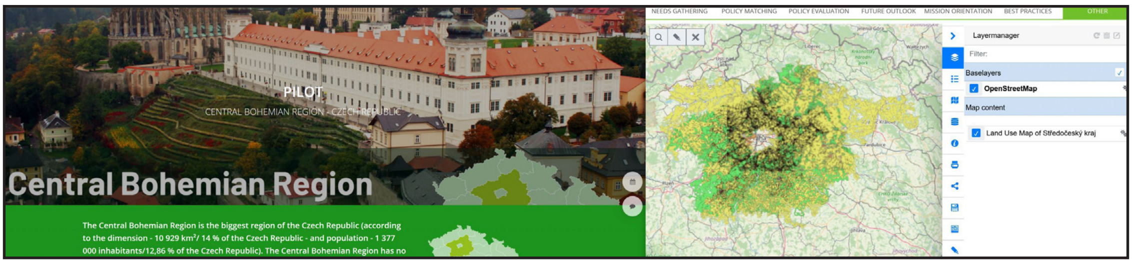
AgriHub CZ (agrihub.cz)

The purpose of AgriHub CZ is to design and develop a smart technological innovation centre for agriculture. The hub is designed to create links between people, companies and other entities with knowledge and technology that will help in the implementation of innovative projects and ideas. AgriHub was initially founded in cooperation with 2 companies - WirelessInfo and Lesprojekt - služby s.r.o. - with the intention of supporting and developing smart agriculture. It is currently being developed in cooperation with the Agricultural Association of the Czech Republic and the Crop Research Institute. In a later stage Plan4all association and Czech Centre for Science and Society contributed to development.

During the Agrihub INSPIRE Hackathon series, AgriHub is widely used as an information guide to individual challenges, presenting results and announcing winners. The presented information and the obtained results from individual challenges are used for the following years of the hackathon.

AgriHub SK (agrihub.sk)

The main goal of the Slovak Agricultural Innovation Hub "AgriHub SK" is to support innovations based on data and technologies that



Source: Charvát et al.

Figure 4: PoliRural Hub presentation of Central Bohemia Pilot.

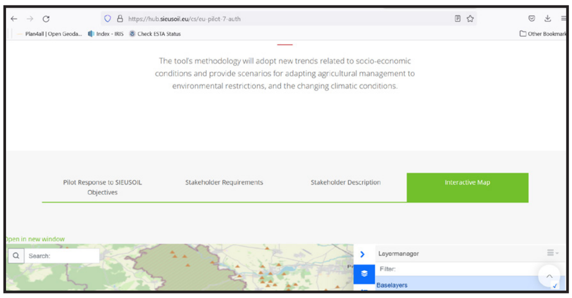
will enable the ecological and efficient development of the agro-sector and thus strengthen its societal benefits. AgriHub SK will be an open platform aimed at supporting cooperation between farmers, researchers, developers, or officials themselves. The portfolio of target groups is therefore open to representatives of the public, private, non-profit, and academic sectors, not excluding the professional and lay public. AgriHub SK will provide space for better definition of problem areas with regard to the transfer of innovations, experiences and knowledge of good practice through the identification of project opportunities and the search for opportunities to support their implementation.

SmartAfriHub (www.smartafrihub.com)

SmartAfriHub is a Digital Innovation Hub that connects people to digital information and services in Africa. DIH integrates African agriculture and climate community members, and beyond, to the knowledge bases e.g., Blog, Forum, Science Shop, WIKI. DIH provides different types of Open Source Software and demo applications, where farmers, developers and researchers can cooperate, test different API for new solutions and also provide common experiments upon geospatial information and agriculture. Currently, there is an existing community around SmartAfriHubs and the extension and development are supported by INSPIRE Hackathons (Charvát et al., 2021).

SIEUSOIL Hub (hub.sieusoil.eu)

SIEUSOIL aims to develop sustainable and holistic soil management practices based on a harmonised land information system suitable for diverse climate and operation conditions along different EU and China locations. A research platform consisting of advanced crop and soil sensing tools, modelling and data fusion, digital soil mapping and farm management information systems will be developed to maximise land productivity and socio-economic benefits, while minimising the environmental impacts. Moreover, there is a strong focus on support of regions and publishing of their results (Figure 5).



Source: Charvát et al.

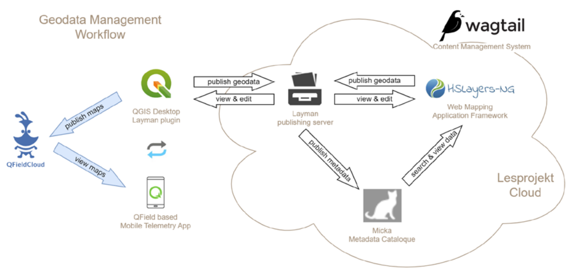
Figure 5: SIEUSOIL Rostenice Pilot.

Main problems and limitations

The previous experiences demonstrate that the main difficulties for broader utilisation of the current Hub is the Liferay CMS framework. It is too complex and too difficult to understand, and it brings challenges for non-expert users. Non-expert users had problems generating content and also combining spatial and non-spatial data. This was the reason why we started to look for new solutions, which will enable easier content publishing, and which will be more user-friendly for non-experts. Another topic, which we found important, was a better support for mobile users and usage of data in terrain. This was the reason why we started to develop a new generation of CMS. This fact was mainly visible on PoliRural and SIEUSOIL hubs in preparation of pilot presentation and also on SmartAfriHub, where complexity was a big limitation.

Hub4Everybody

Hub4Everybody is based on previous experiences and is presented to the user as a single and complex solution and workflow for managing geo-data. But it is built upon interlinked multiple separate components. The basic architecture of the whole system is depicted in the schema (Figure 6).



Source: Charvát et al.

Figure 6: Hub4Everybody general architecture.

The main improvements are linked with usage of Wagtail CMS and Implementation of Mobile Support. Both were done as part of Agrihub INSPIRE Hackathon (Plan4all website: Agrihub INSPIRE Hackathon 2022).

Content Management System (CMS)

The Editorial system represents a basic unifying element for geodata processing. This component allows for the creation of web portal content and also represents a natural junction for other parts of the system. Hub4Everybody uses Wagtail CMS (https://wagtail.org) Platform, extended by CodeRed Extensions (https://www.coderedcorp.com/cms/). It is one of the leading open-source CMS used by small as well as large organisations (Google, NASA, British NHS). Wagtail is based on the Django system and the main programming language is Python. It enables very easy extension of the functionalities in the forms of widgets, web page templates, or extending of authorization and other system parameters. It is, therefore, possible to integrate it with other systems used within the organisation (e.g., geoportal of a city), if such demand occurs. There is a huge community of developers behind the system, where more complements and extensions can be developed.

The default set of features has been extended to offer a larger set of web page elements including an interactive map application (see Figure 7).

A web portal built by the content management presents the gateway for the user and unifies the rest of the system on the level of user identity. That means the user has one account to access all the components no matter if it is on a web platform or desktop application. Single Sign-On is ensured this way.

Mobile support

HSLayers web application naturally supports mobile devices and is convenient to use. But that is not enough in today's mobile world. That is why the mobile apps based on QField (https://qfield.org/) have been recently adopted into our solution pipeline. It is an exaggeration to say that QField is a mobile QGIS, which also allows you to view published maps on your mobile phone and offers tools for data collection in the field. And all this can be extended according to users' requirements. The possibility to easily publish maps via the QGIS Layman plugin also to the QField Cloud (https://qfield.cloud/) is the newest feature available. The next phase of development envisages incorporation of the QField Cloud directly into the hub which assumes the hosting of the cloud in the same infrastructure. That will allow better integration on the level of user identity as QField Cloud does not support any other authentication mechanism than its native one.

Used infrastructure

Hub4everybody is a part of internal cloud solution run on own managed and dedicated servers in a location of Prague, Czech Republic and as such is under full control of Lesprojekt - služby company. It is built on OpenStack software, based on Linux operating systems and other open-source technologies. OpenStack enables optimal usage of hardware resources joining standalone servers in a seamless cloud under a single management. It provides a vast number of services including virtualisation, block device sharing, distributed computing, support to various docking technologies, etc. A very strong network stack allows for low level network isolation including VLAN support, NAT and integrated firewall. Fine grained user management enables logical segmentation of OpenStack instances into standalone independent instances as if they were running on separate physical servers. Administrator has a very good overview of current use of hardware resources due to strong reporting capabilities and a web dashboard. Backup is done at least weekly, for critical infrastructure even more frequently. Own backup infrastructure is managed by Lesprojekt - služby company. New virtual servers are rapidly deployed within minutes

Source: Charvát et al.

Figure 7: Example of a web page created by Hub4Everybody CMS including a map.

as requested by our users. Various operating systems are prepared as snapshots for instant use.

Results and discussion

INSPIRE Hackathon as instrument for developing and testing new solutions

Due to the fact that this technology is used by more projects, we are synchronising development using the concept of INSPIRE Hackathons 2016 (Charvat et al., 2018), (Charvát et al., 2021), (Charvát et al., 2021). Also, this year we used Agrihub INSPIRE Hackathon as the instrument to improve and test our solution. There were four challenges directly focused on support for Hub4Everybody:

- **A new social space for geographic information sharing and education**
- **Building a social space for Africa**
- **Agro Environmental Services**
- **Integrating QFild with the Innovation Hub (described in previous chapters)**

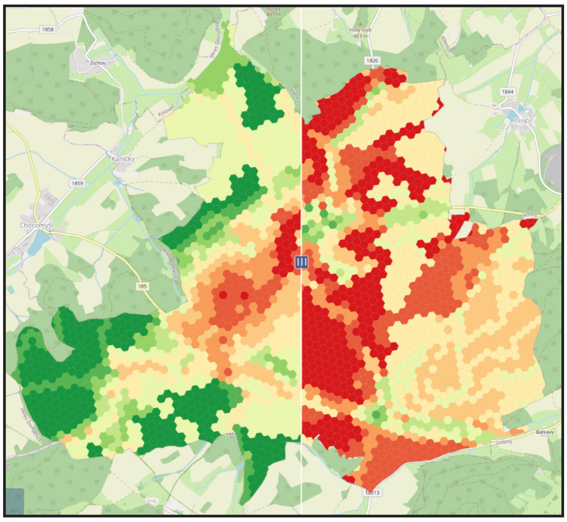
This helps us improve the functionality.

Experiences from Hackathons and experiments

Integration of Regional and local attractiveness with Hub

The Hub4Everybody was used during Agrihub INSPIRE Hackathon 2022 (April - June 2022) as the tool for visualising the assessment of regional attractiveness (Čerba et al., 2021; Čerba et al., 2022). The presenting of attractiveness (on the micro level of municipalities) was a part of the Challenge #9 A new social space for geographic information sharing and education. This challenge introduced a new kind of portal primarily for geographic data that allows easy participation of citizens, students and others and supports easy content creation.

Figure 8 shows the use of the slider in Hub4Everybody to compare two types of attractiveness of the area of the municipality Chudenice (small town in south-west Bohemia, Czechia). Both data layers have the same visualisation approach - red colour means low attractiveness, while the most attractive places are dark green. The left side of the map window presents the attractiveness from the perspective of nature protection (urbanised areas or communications are red). The right part visualises the attractiveness for local people (above all agricultural areas are not attractive because they do not contain neither infrastructure nor place for relaxing).

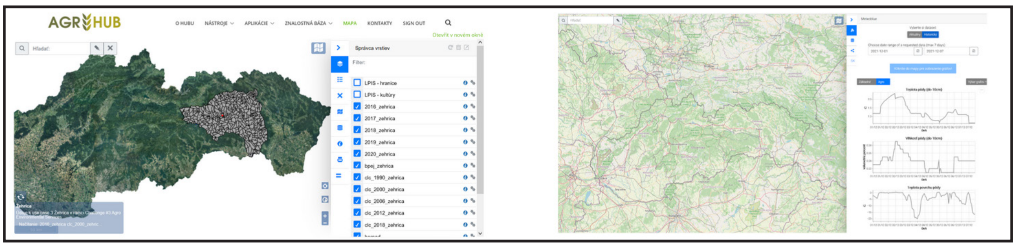


Source: Charvát et al.

Figure 8: Chudenice - comparing two types of attractiveness.

Agro Environmental services

Main ambition of the Agro Environmental Services Innovation Experiment (IE) was to provide support for agri-food GeoICT community building process, networking, stimulating innovations and knowledge transfer in Slovakia. This IE has started to explore potential of the Hub4Everybody platform already during the Agrihub INSPIRE Hackathon 2021 with the main focus to share the outcomes of the challenges addressing topics of the data access and utilisation, water canal structural changes as well as Dynamic changes of landscape identification. In addition, the potential of the third party API extension was successfully deployed in connection to the meteoblue Open API (https://www.agrihub.sk/en/ie-3) (Figure 9).



Source: Charvát et al.

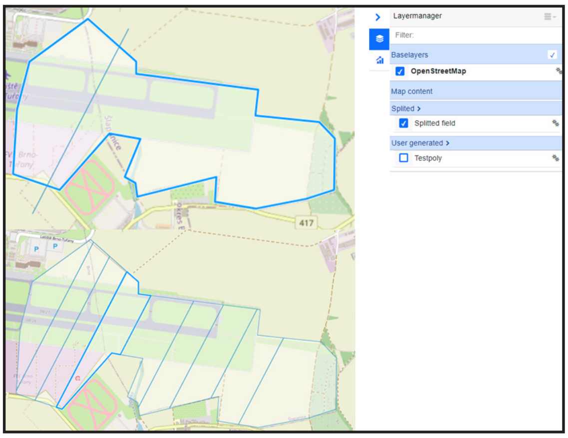
Figure 9: AgriHub.SK Visualisation of the use cases outcomes and integration of meteoblue data during the Agrihub INSPIRE Hackathon 2021.

Source: Charvát et al.

Figure 10: Example of publishing complex QGIS project with pilot farms to the webmap UI.

Based on this experience, further implementations were supported during the following Agrihub INSPIRE Hackathon 2022 with the main focus on support for farmers, utilising the potential of desktop linkage to the QGIS as well as advanced web processing served via web GIS client application (Figure 10).

In connection with the solution of farmers' needs, a tool has been developed that will serve farmers for the quick division of land blocks into smaller units. Next Figure 11 presents the proposed solution.



Source: Charvát et al.

Figure 11: Outcome of custom developed webgis application offering farmers to calculate and visualise specific field areas based on current legal and practical requirements.

SmartAfriHub

During the Hackathon, we were able to organise a couple of overall meetings, 1 large webinar dedicated to Hub4Everybody technology, with an audience of registered 120 participants geographically covering countries throughout the whole Europe, Africa, South America as well as Asia.

Above that, we have organised two specific training sessions on using the SmartAfriHub portal, where we showed step-by-step how the new content can be created and uploaded on-line. Both training sessions were recorded and uploaded on the YouTube channel of Plan4all, as was the Hub4Everybody webinar.

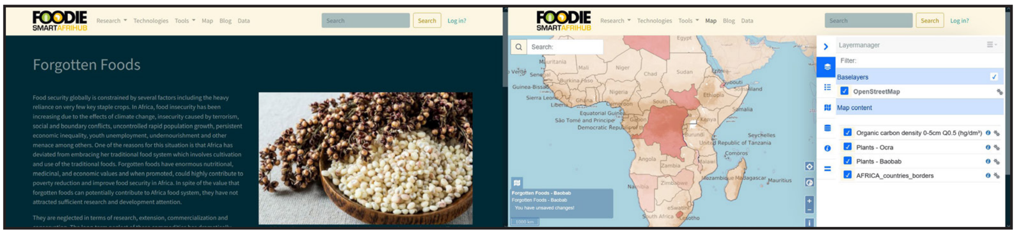
- **https://youtu.be/_t5mtReGjN4**
- **https://youtu.be/3oHpxXFsYeU**
- **https://youtu.be/G1VFv6MKkEE**

A discussion with stakeholders in Africa was led on what are the needs for attracting people to use the new Hub and also to contribute with new content. It was discussed that we need to show the possibilities to build information content in attractive form. It is necessary to demonstrate interesting content possibilities of presentation of different problems. On the basis of discussion, a FARA document: Africa Manifesto and Plan of Action (Forum for Agricultural Research in Africa websites) was selected as an example. A demo presentation of two forgotten crops of Africa - Ocra and Baobab was prepared (later we plan to prepare a presentation of all crops).

At the first stage, interactive maps of countries, in which these crops are growing, were prepared, and published on the Hub (Figure 12).

Testing of new solutions on Environmental Atlas of Liberec

In the beginning, the Atlas of the Liberec Region website was only a supplement to the printed book with AR elements Environmental - Atlas of Liberec (Figure 13). But it soon began to serve as a platform for communicating our maps and educational games for young people. The atlas is also a background for the 3-day annual Map Around Us educational event.



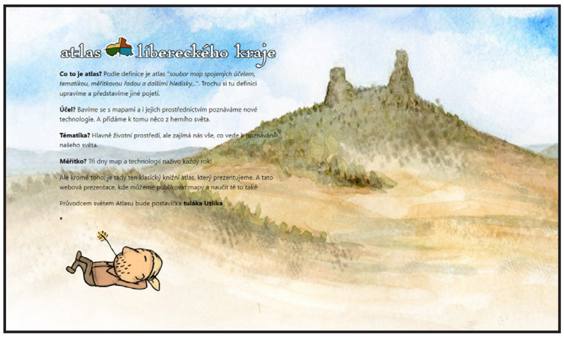
Source: Plan4all website: Agrihub INSPIRE Hackathon 2022: Final reports, Challenge 12

FFigure 12: Forgotten Food of Africa demo.

Source: Charvát et al.

Figure 13: Atlas of the Liberec Region publication.

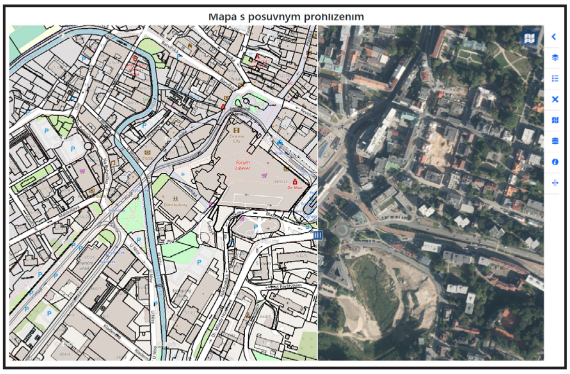
Because the originally used CMS Liferay has ceased to suit, we are currently transferring the entire atlas website (https://atlas.kraj-lbc.cz/) under the new Wagtail CMS (Figure 14, temporarily at https://atlas2.kraj-lbc.cz/) system, which is the basis of the Hub4Everybody.



Source: Charvát et al.

Figure 14: New title page of the Atlas of the Liberec Region.

Local content developers expect the development of new functionalities (Figure 15), especially with the support of interactive story maps or extension of the functionality for independent user mapping. In this regard, the authors of the atlas are experimenting with the use of the Layman system to convert maps created in the open QGIS program.



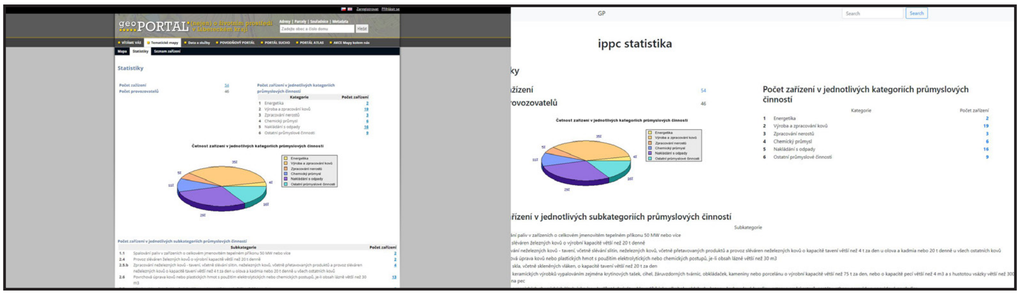
Source: Charvát et al.

Figure 15: New possibilities of the web towards the creation of story maps - slider.

Possibilities to migrate existing data from hubs and portals

The possibility to provide migration of content from existing Hubs and Web Pages into new solution based on Wagtail was also important for successful transfer from previous version to new solution. Due to the idea for future integration of existing web pages and Hubs, we have tested migration of new technologies from two platforms WordPress and Liferay. For Wagtail, the Wagtail WordPress Import module (https://github.com/torchbox/wagtail-wordpress-import) is being developed, allowing content to be converted from WordPress CMS with varying degrees of success. For small amount of content items (pages, blog entries, ...) manual conversion seems to be the fastest and easiest. There is currently no possibility to directly import content from Liferay to Wagtail. So, we focused on developing our own approach. User database transfer should be feasible using the following procedure:

- export from Liferay (either via API or SQL dump from database)
- rewrite of exported data
- import of data using Wagtail's built-in mechanisms



Source: Charvát et al.

Figure 16: Migration of content from Liferay to Wagtail.

Conclusion

Hub4Everybody is based on Agile continuous development and improvement of solution for publishing of spatial and non-spatial data and building attractive content, which can be used in different solutions. Hub4Everybody can be used by whoever wants to publish and present their data, while there is no need to invest into professional GIS or into developers programming and updating their own solutions. Hub4Everybody is designed for SMEs, high schools and universities, research organisations as well as public authorities, NGOs, and many others. We are delivering the results of our development – a unique and adaptable solution based on open sources, which can easily be used in any kind of organisations (from national institutions, over different type of schools and universities, up to SMEs or public authorities), that needs to manage and publish geographical data.

Hub4Everybody comprises of following elements:

- *geoportal*
- *social communication*
- *storyboard*
- *communication with desktop as well as mobile solutions*
- *tool for creating and editing of maps*
- *data management*
- *support of legislative measures, incl. the INSPIRE directive*
- *supporting GEO/GEOSS*

Currently we are transferring previous Hubs and Web pages into this new environment, but also preparing the first implementation for our customer, where this solution will be used for Environmental Atlas.

Acknowledgments

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- Agrihub CZ@SK – AgriHub made in CzechoSlovakia (Sub-Grant agreement no: 2282300354-EXPAND-6)
- EO4Agri – Bringing together the Knowledge for Better Agriculture Monitoring (Grant agreement ID: 821940)
- SIEUSOIL - Sino-EU Soil Observatory for Intelligent Land Use Management (Grant agreement ID: 818346)

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The Digital Economy in the Context of Digital Transformation and Their Impact on the Electronification of Accounting Processes in the Slovak Republic

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Abstract

As a result of the explosive growth of scientific knowledge and the rapid development of ICT, the world economy is undergoing crucial global changes, which are the most significant since the industrial revolution. Digitization represents the most important element of the fourth industrial revolution, enabling the connection of technology and people. The digital economy is related to the rapid onset and penetration of information and communication technologies into all areas of human activity, which also requires new perspectives on the factors affecting the development and success of the economy. We digitize information and data, digitize the processes and systems that make up the functioning of the company, and digitally transform the company and its strategy. The main task of article is to determine the digital economy in the context of digital transformation and their impact on the electronification of accounting processes in the Slovak Republic. The article defines the progress and level of development of Europe's digital competitiveness in individual EU member states using the Digital Economy and Society Index (DESI). The position of Slovakia and the EU is compared for the period from 2018 to 2022. Slovakia needs to create conditions for the gradual digital transformation of all sectors of the economy. Digitization is also coming to the accounting. The article also describes how the approved amendment to the Act on Accounting as of January 1, 2022 creates space for streamlining the processing and archiving of accounting records. The current change in the amendment to the Act on Accounting thus offers completely new opportunities for working with corporate accounting in relation to internal processes in the company, but also in relation to financial administration or tax authorities. All entities, this also applies to agricultural entities keeping the double entry accounting, are obliged to follow the Act No. 431/2002 Coll. on Accounting as amended.

Keywords

Digitization, digital economy, digital transformation, electronification of processes, accounting, agriculture, agricultural accounting entities.

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Introduction

We are increasingly confronted with the opinions that we are living in a period of global information society development. The industry is increasingly information based and dependent on the network connectivity with the internet playing the pivotal role (Šimek et al., 2017). Currently we are facing the period of so called fourth industrial revolution, which is determined as well as a digital revolution. It is combined with the society where the technological progress changes significantly the way we live, work and mutually communicate (Čierny, 2017).

Digitalization presents the driving power of the fourth industrial revolution and the largest transformation of country economies and societies where its pace and power are changing the status. It enables the connection of technologies and human beings (Schwab, 2016). Technological innovation and high-quality economic development are inevitable requirements of sustainable development, and the digital economy has gradually become a new engine to enhance technological innovation and the high-quality development of economy (Ding et al., 2022; Imran et al., 2022).

The digital economy represents a novel economic form based on digital technology, with digital data and digital platforms as its two basic features. Digital data make enterprise business traceable, controllable, and traceable (Jorgenson et al., 2007). In the context of the development of the digital economy, digitalization is conducive to enterprise development (Peng et al., 2009; Suchman, 1995). Digital economy can be characterized as all economic processes, transactions, interactions, and activities base on the digital technologies. Several studies are focused on the fact that technologies are able to change the world quickly, not only in economic but as well as social area. The digitalization of economy brings a huge number of benefits and represents an increase in efficiency, as digital technologies stimulate innovation, create new job opportunities and affect economic growth (Unold, 2003; Gestrin and Staudt, 2018).

The business environment is influenced by modern technologies that enable to automate production processes, to introduce robotization, which partially or completely replace human work or enable the implementation of intelligent solutions that collect data and evaluate them. In the case of business entities, we talk about the implementation of digital technologies in company processes (production, technological, process or operational) as well as digital transformation (Slovak Business Agency, 2019). The digital transformation is defined as the change of work procedures, roles and products or services because of the adoption and implementation of digital technologies by a business or its operating environment (Bloomberg, 2018). The digital transformation is a deep change and accelerates the business activities, process, competences, models in order to fully utilize changes and opportunities in digital technologies and their impact on the company (Bican and Brem, 2020).

Digitization represents the most important element of the fourth industrial revolution and touches any information handled by an individual. The expansion of digital capacities leads to the fact that slowly every aspect of our lives is captured in digital form and shared through digital networks. The result is a global exchange of information in real time between many devices connected to a digital network (Slovak Business Agency, 2019). Data is a fundamental aspect of digitization and the use of data is essential for improving production processes. The need to integrate data and information regarding the processes of creating value chains in the areas of individual IT systems within individual companies as well as across companies in processes relates to this (IA MPSVR SR, 2017).

Digital transformation is a highly current, an important and often discussed topic, which is currently receiving a lot of attention. Due to the impact of the Covid-19 coronavirus, companies were suddenly forced to digitally transform, digitize their products and operate online. The crisis during the COVID-19 pandemic has shown that an adequate level of digital skills is essential for the whole society, as it enables citizens to access services and information (Bednarčíková, 2020; Kouřilová et al., 2021). The potential of digitalization, digital transformation and digital technologies is important for environmental, economic and social sustainability in businesses and can be applied in various industries (Bednarčíková and Repiská, 2021). In addition to office work, digitization also affects agriculture. The consequence of digitization is precision in agriculture. This term can be simply explained as precision agriculture.

The scientific and technical progress associated with the use of information technologies affects all areas of social and economic life, including the automation of business processes. Manually provided transactions in business accounting entities are being gradually replaced by automated systems. The COVID-19 pandemic has accelerated the automation of business processes, including accounting, because the accountants' work has shifted into online environment and the communication with clients, or with financial authorities has to adapt to this change (Blahušiaková, 2022). The transformation of society into a digital society was also manifested in the territory of the Slovak Republic (Lovciová, 2022).

In 2020, a new strategy was planned for Slovakia - Strategy for the Digital Transformation of Slovakia 2030. This strategy is a framework supra-departmental government strategy that defines the policy and specific priorities of Slovakia in the context of the already ongoing digital transformation of the economy and society under the influence of innovative technologies and global trends of the digital age. The strategy puts primary emphasis on current innovative technologies such as Artificial Intelligence, the Internet of Things, 5G technology, big data and analytical data processing, blockchain and High-Performance Computing which will become a new engine of economic growth and strengthening of competitiveness (MIRRI SR, 2019).

The technologies described above, like all technologies, are being improved and find new applications. By combining them, applications are created that are more capable than the mere sum of the capabilities of their parts, synergistic effects and emergent phenomena are created. Legal, accounting and auditing services, as well as services to industry, are typical knowledge-based services. Many of the routine activities occurring in them can be affected by the onset of these new technologies, we can assume a growing share of artificial intelligence, which is already used by e.g. expert systems (Dvořáková et al., 2020). One of the strategic plans for how the government of the Slovak Republic can contribute to the start of rapid and sustainable economic growth after the effects of the COVID-19 pandemic in Slovakia is the Recovery and Resilience Plan of the Slovak Republic. The role of the Green Economy within the Slovak Recovery and Resilience Plan is to support environmental sustainability, while the transformation of society into a digital society and "digitization" itself is considered a significant green innovation in a sustainable business environment with a positive impact on environmental protection. Digitization is considered a key area, because its successful implementation in society has a significant impact on Slovak legislation in the field of accounting. Its impact is manifested in changes to existing legislation and in the adoption of new Slovak legislation into which provisions regulating digitization in various production or administrative processes are composed and incorporated (Lovciová, 2022). Agriculture with its production and non-production tasks has a lot of specifics. Therefore it is essential to adapt the accounting and recognition of agricultural production to these specifics and risks arising from agricultural activities.

Act no. 456/2021 Coll., amending Act No. 431/2002 Coll. on Accounting, as amended, effective from January 1, 2022 has the crucial impact on the digitization in the accounting. The act responds to developments in society and the rising trend of digitization of any processes in an accounting entity recorded in its bookkeeping. Based on the reactions of the current rising trend of digitization, the Act on Accounting has supplemented and clarified the conditions that an accounting entity is obliged to comply with when processing electronic accounting records. Specifically, the wording of the provisions of the Act on Accounting was changed in the provisions of § 31 Accounting record, § 32 Provability of accounting record, § 33 Transfer of accounting record (Transformation of accounting record from 1 January 2022) and the provision regarding the archiving of documentation, i.e. §35 Archiving and protection of accounting documentation (Blahušiaková, 2022; Lovciová, 2022).

Materials and methods

As a result of the explosive growth of scientific knowledge and the rapid development of ICT, the world economy is undergoing excessive global changes. At the global and regional level, the topic of digitization, digital transformation, cyber security, etc. is increasingly coming to the fore. The expansion of digital capabilities means that almost every aspect of our lives is captured digitally and shared through digital networks. The result is a global exchange of information in real time between many devices connected to a digital network. The digital economy is also related to the rapid onset and penetration of information and communication technologies into all areas of human activity. It also requires new perspectives on the factors influencing the development and success of the economy.

The main task of article is to determine the digital economy in the context of digital transformation and their impact on the electronification of accounting processes in the Slovak Republic. The article defines the progress and level of development of Europe's digital competitiveness in individual EU member states using the Digital Economy and Society Index (DESI). This index helps the EU member states identify areas that require priority investments and measures. The article also describes how the approved amendment to the Act on Accounting as of January 1, 2022 creates space for streamlining the processing and archiving of accounting records.

It does not provide specific technical solutions applicable to the accounting practice, but it defines the principles of circulation of documents up to their archiving, including the verifiability of accounting records and their transformation from paper to the electronic form. The amendment to the Act on Accounting also introduces the cancellation of the signature record of the person responsible for the accounting case as a mandatory element of accounting documents, provided that electronic data exchange or the internal control system of accounting records is used, as well as the cancellation of the signature record of the person responsible for its bookkeeping. In addition to the mentioned signature records, it is no longer necessary to indicate the determination of the accounts on which the accounting case was recorded in the double-entry bookkeeping system on the accounting documents after the amendment to the Act on Accounting came into force. The abolition of these hitherto mandatory requirements of accounting documents no longer hinders the development of modern trends in the field of electronic accounting.

Information from professional literature and available electronic resources consisting of various magazines and scientific publications from the databases Web of Science, Scopus, Researchgate and other data from the websites of the European Commission and the World Economic Forum were used as the source for the processing of the article. The basic methodical approach of processing is presented by standard methods of scientific work such as selection, analysis, comparison, deduction and synthesis in a theoretical as well as in a practical level.

DESI Index (The Digital Economy and Society Index)

The DESI index is a composite index that summarizes Europe's digital performance indicators and monitors developments in the digital competitiveness of the EU member states. It includes all member countries of the European Union, and in 2020 data is still available for Great Britain, even though it has left the EU.

DESI consisted of five basic dimensions until 2020:

- Connectivity.
- Human capital.
- Use of internet.
- Integration of digital technology.
- Digital public services.

The resulting DESI value for a country is calculated as follows:

DESI = *Connectivity* * 0,25* + *Human capital* * 0,25* + *Use of internet* * 0,15 + + *Integration of digital technology* * 0,20* + + *Digital public services* * 0,15*

(* the value of the scales determined by experts)

In 2018, there was a slight change in the methodology of the DESI index. By using the MIN-MAX method, the data were recalculated in order to use a rating scale from 0 to 100 (0 - the lowest score, 100 - the highest score). Furthermore, from the point of view of comparability, it was necessary to normalize the data and apply the current system of weights for individual dimensions in the case of both indexes. A semi-log model was used to determine the growth rate for comparison of methodology changes with current data. This model belongs to the growth models and is used by default to calculate the growth rate of various variables.

A more interesting view of the ranking of countries is provided by dividing countries into groups. Group analysis according to pre-selected variables sorts the statistical units into groups in such a way that there is the greatest possible similarity within the groups and the greatest possible difference between the groups. The groups were defined as follows:

- rapidly developing countries,
- average developing countries,
- catching up countries,
- lagging countries.

Ward's clustering method was also used to confirm the classification of countries into groups. The principle of this method is the minimization of the heterogeneity of clusters according to the criterion of the minimum increment of the intragroup sum of squares of deviations of objects from the centroid of the cluster. In each step, for all pairs of deviations, the increment of the sum of squares of the deviations resulting from their merging is calculated. Then those clusters corresponding to the minimum value of this increment are joined. Ward's method tends to remove small clusters, that is, it forms clusters of approximately the same size (Kaufman and Rousseeuw, 2005). The most frequently used approach is the heuristic approach, which represents the determination of the number of clusters based on the subjective opinion of the solver. In 2021 and 2022, the structure of the index dimensions changed (Figure 1).

The resulting value from 2021 is recalculated as follows:

DESI = *Human_capital* *0.25 + *Connectivity* * 0.25 + *Integration_of_Digital_Technology* * 0.25 + *Digital_Public_Services* * 0.25

Source: European commission, own processing

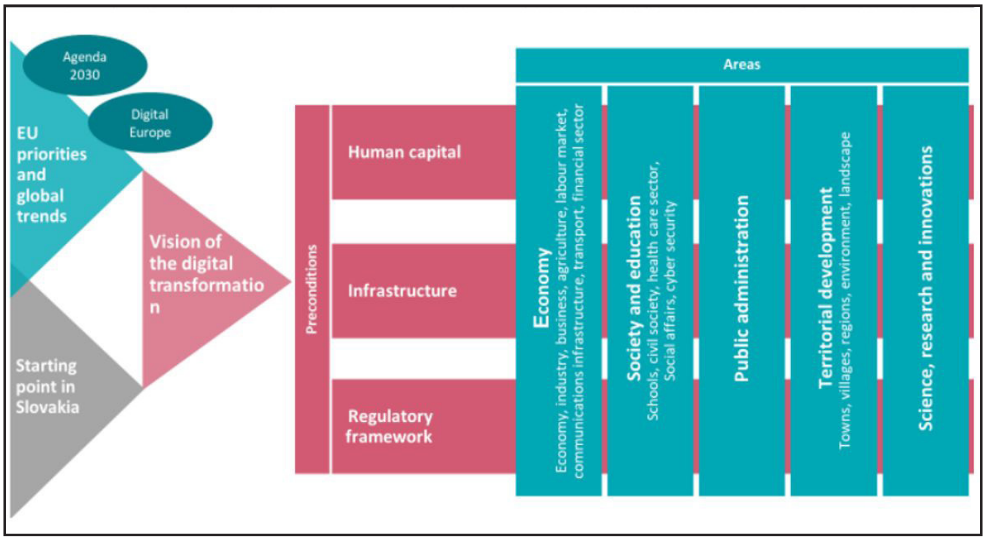
Figure 1: Current dimensions of the DESI index.

Results and discussion

In 2020, a new strategy was planned for Slovakia - Strategy for the digital transformation of Slovakia 2030. The strategy follows on from the creation of the new EU multi-annual financial framework for the years 2021-2027, including cohesion policy instruments, as well as directly managed programs (including the Digital Europe and the Connecting of Europe - digital part), where special attention is paid to the need to develop the digital economy. In addition to the above, it also directly reflects the conceptual materials and recommendations of international organizations, especially the Organization for Economic Cooperation and Development and the United Nations, which consider the process of digital transformation to be key to achieving sustainable and inclusive growth. Figure 2 shows the main objectives of the strategy.

For the given strategy, the initial state of Slovakia was evaluated, the basic prerequisites for implementation were identified, and the areas in which we absolutely need to multiply our potential through digital transformation were identified. The final goal of the process of building an information society and digital transformation will be the creation of conditions for the satisfied life of every person in the digital age in the context of respecting and building digital humanism.

Slovakia needs to create conditions for the gradual digital transformation of all sectors of the economy. This primarily includes the transformation of the current industry into Industry 4.0, by which we denote the current trend of digitization and the related automation of production and data exchange in production processes. Industry 4.0 will become the engine of the country's economic growth. The goal will be to use the technological potential and increase private and public investments in new technologies. It will therefore be necessary for the state to help businesses prepare for such a transformation. First of all, this preparation will be ensured by the state providing companies with knowledge and the means to access technologies, as well as incentives and initiatives to solve specific problems, which will be used for example by digital innovation hubs. Due to the gradual introduction of automated technologies, most industries will experience a growing shift in skills. When working with new technologies, workers must be able to take on complex, less automated tasks, such as being able to solve problems, create their own solutions and approaches, and have critical thinking skills. Likewise, cognitive skills, social skills, communication skills, organization, technological expertise, as well as creativity are categories whose importance will constantly grow and will be the most sought after on the labor market, to which the Slovak market will have to adapt effectively. Slovakia will also create the prerequisites for the emergence of a dynamic data economy. The legislative environment will be set up in a way to enable the application of new business models, built on platforms and AI in practice. There will also be sufficient demand within the economy for innovative solutions to create innovation. Slovak companies will thus employ a growing number of data analysts.



Source: 2030 Digital Transformation Strategy for Slovakia

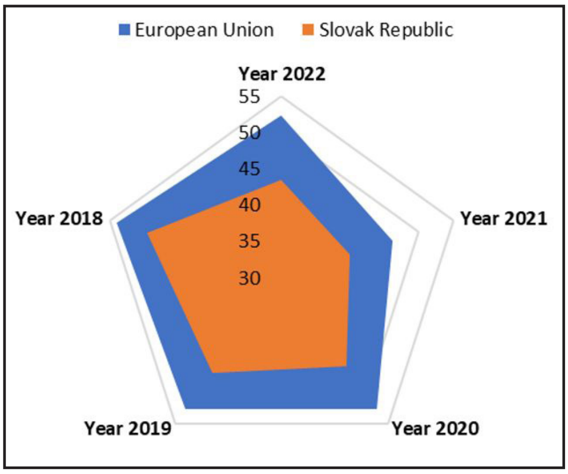
Figure 2: Vision of the digital transformation.

Digital Economy and Society Index

The European Commission monitors the digital competitiveness of member states according to the Digital Economy and Society Index (DESI) in the reports it has been issuing since 2015. These reports include profiles of individual countries as well as thematic chapters. DESI country reports are a combination of quantitative data obtained using DESI indicators in four areas within the index and an overview of country policies and best practices. The thematic chapters contain a Europe-wide analysis of broadband, digital skills, internet use, business digitalisation, digital public services, the ICT sector, and its R&D expenditure, as well as the use of Horizon 2020 funds in Member States. Slovakia ranked 23rd among the 27 EU member states in the European Commission's Digital Economy and Society Index (DESI) for 2022. Slovakia is just below the EU average or around it in terms of indicators in human capital. 55% of Slovaks have basic digital skills, which is slightly above the EU average of 54%. The share of experts in the field of information and communication technologies (ICT) from the total number of employees is 4.2%, which is just below the EU average (4.3%). Sixteen percent of ICT experts are women, the EU average is 19%. Slovakia's e-commerce score has decreased: 13% of small and medium-sized enterprises (SMEs) sell online, compared to 17% in 2020. In 2020, 16% of Slovak businesses used electronic invoices, compared to 32% in the EU. Although Slovakia has made some progress in all areas over the past year, especially in the indicators of core internet coverage and connectivity rollout, the improvements have not been sufficient to keep Slovakia in step with the EU average.

The Digital Economy and Society Index (DESI) is an online tool to measure EU member states' progress towards a digital economy and society. DESI currently combines 33 indicators (pillars) and uses a system of criteria weights to classify each country based on its digital performance. It collects a set of indicators that are in the various digital agendas of countries in Europe. The indicators are not immutable, as evidenced by the modification of the index over the years. The index is currently divided into four main dimensions, which in turn consist of pillars. The DESI score ranges from 0 to 1 or from 0 to 100, with the higher the score, the better the country's performance.

If we look at the comparison of the position of Slovakia and the EU for the period from 2018 to 2022, Slovakia significantly lagged the EU values in each year. The comparison is shown in Figure 3. The best value of the DESI index was achieved by Slovakia in 2018. On the contrary, the worst value was measured in the first year of measurement, that is, in 2022.



Source: European commission, own processing

Figure 3: Comparison of DESI values of the EU and Slovakia.

A more interesting view of the data is provided by the division of countries into groups according to what score they achieved and how much they increased from previous periods compared to the European average. Groups are defined as follows:

Rapidly developing countries – countries that score above the EU average and their scores are growing faster than the EU score in the last year. These are countries that are performing well and are developing at a pace that allows them to move away from the EU average.

Average developing countries – countries whose score is above the EU average but whose score is growing more slowly than the EU score in the last year. These countries are doing well, but their development is currently very slow compared to the progress of the EU.

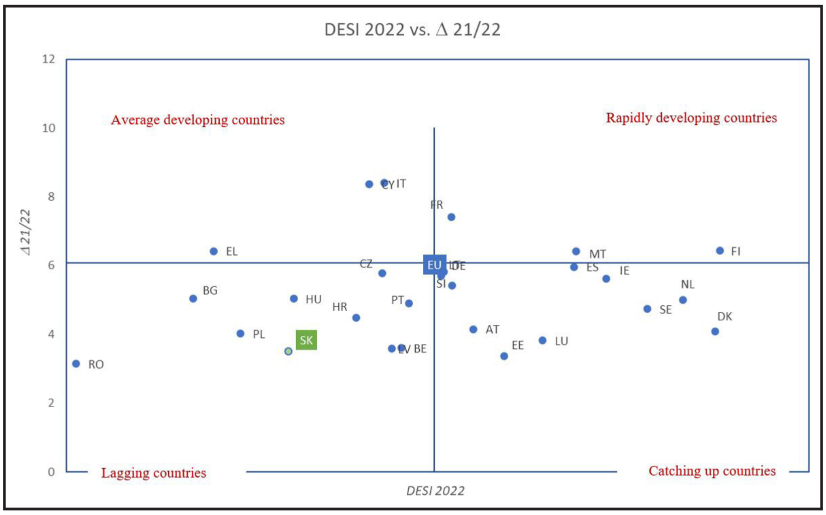
Catching up countries – countries whose score is below the EU average but whose score is growing faster than the EU score in the last year. These countries are developing faster than the EU as a whole and are therefore catching up with the EU average.

Lagging countries – countries whose score is below the EU average but whose development in the last year was slower than the EU score. These countries are less developed than the EU average and show anemic growth, distancing themselves from the rest of the EU.

Slovakia is included in the category of lagging countries, i.e. the results of the index are below the EU average and the country is also developing more slowly than the EU average. Figure 4 shows the classification of EU countries into clusters.

Integration of digital technologies in the business environment

The Integration of digital technologies dimension is mainly focused on businesses. It consists of 11 pillars listed in Table 1. There has also been a change in the pillars in this dimension compared to previous years. The pillars of radio frequency identification (RFID) and electronic invoices were taken away. The pillars of big data, artificial intelligence and ICT for environmental sustainability were added. Table 1 shows the pillars and their values for the years 2018 to 2022.



Source: European commission, own processing

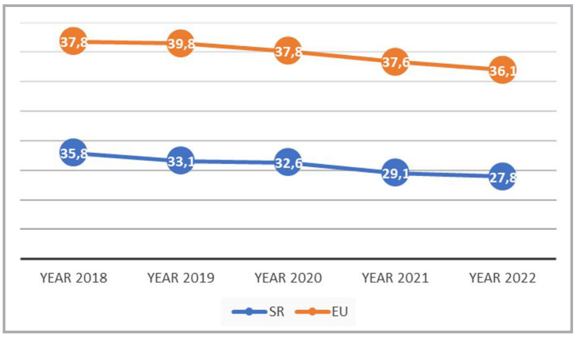
Figure 4: Classification of countries into groups.

List of pillars	Year 2018	Year 2019	Year 2020	Year 2021	Year 2022	EU 2022
SMEs with at least a basic level of digital intensity	NA	NA	NA	NA	43 %	55 %
Electronic information sharing	31 %	31 %	31 %	31 %	31 %	38 %
Social media	17 %	17 %	18 %	18 %	21 %	29 %
Big data	11 %	9 %	9 %	6 %	6 %	14 %
Cloud	15 %	13 %	NA	NA	31 %	34 %
AI	NA	NA	NA	NA	5 %	8 %
ICT for environmental sustainability	NA	NA	NA	76 %	76 %	66 %
List of pillars	Year 2018	Year 2019	Year 2020	Year 2021	Year 2022	EU 2022
e-Invoices	NA	NA	15 %	16 %	16 %	32 %
SMEs selling online	15 %	13 %	11 %	17 %	13 %	18 %
e-Commerce turnover	12 %	11 %	11 %	11 %	18 %	12 %
Selling online cross-border	8 %	8 %	7 %	7 %	7 %	9 %

Source: European commission, own processing

Table 1: Pillars of the third dimension Integration of digital technology.

Electronic sharing of information in Slovakia remained at the level of approximately 31% during the entire monitored period, which is below the EU average. Since 2017, a new pillar has been added to this dimension, namely Big Data. Slovakia is below the European average for this pillar. In the case of the use of cloud solutions, we are below the EU average, these values should increase soon mainly due to the pressure of Microsoft (the largest supplier of software solutions for businesses in Slovakia) to move to the cloud space and use products of the 365 series. Internet sales by small and by medium-sized enterprises decreased slightly compared to 2021, which further deepened the distance from the European average. The values in the pillars of e-commerce turnover and cross-border sales via the Internet are approximately at the same level as the EU, in the case of e-commerce turnover in 2022, it significantly exceeds the EU. Figure 5 shows the graphic development of the Integration of digital technology dimension.



Source: European commission, own processing

Figure 5: Integration of digital technology during years.

The digitization of enterprises is defined for Slovakia within the action plan of intelligent industry, which was adopted in 2018. The aim of this plan is support for industrial enterprises, service, and trade enterprises, regardless of their size, aimed at creating better conditions for the implementation of digitalization, innovative solutions and increasing competitiveness.

Slovakia signed the declaration of the European partnership for blockchain technology, as well as the declaration on cooperation on artificial intelligence. At the same time, it cooperates with other EU countries within the joint venture for European high-performance computing (EuroHPC). Overall, it can be concluded that Slovakia is intensifying its efforts to support the integration of technologies in businesses and is also closely connected with relevant European initiatives.

Electronization of processes is fully established in the administration of companies. In business relations, paper documents are gradually being replaced by electronic versions. Following the need to connect economic operations, financial resources are spent on process automation, data extraction, e.g., OCR (Object Character Recognition) technologies, approval of electronic documents, data export to accounting, etc. There is a need as well as an opportunity to find any data from documents entered in the system.

An important milestone in the electronization of processes was the adoption of Act No. 305/2013 Coll. on the electronic form of the performance of the powers of public authorities and on the amendment and addition of certain laws, as amended, for communication with public administration entities. Every entrepreneur is obliged to have software equipment for electronic communication with public administration bodies, whether it is filing tax returns or other notifications. According to surveys, the electronization of processes is commonly introduced in large companies. However, small companies, typical in the Slovak business environment, have a high proportion of paper documents that require manual processing. There is still a high proportion of paper archiving of accounting documentation in the external accounting, sometimes perhaps for reasons of legal certainty. In this area, progressive accounting software sets the direction for creating electronic documents and extracting data from paper documents. In any case, it is more flexible to deal with the conversion to electronic documents at the moment of initial processing and not at the moment of archiving the accounting documentation.

Amendment to Act No. 431/2002 Coll. on Accounting, as amended, defines electronic and paper accounting records, establishes requirements for their processing in the accounting and archiving of accounting documentation. The creation of electronic accounting records and their processing in accounting was also possible pursuant to the Act on Accounting effective before its amendment. From the aspect of computerized accounting, the amendment to the Accounting Act modifies:

- provability of electronic accounting records and their archiving,
- verifiability of paper accounting records and their transformation into electronic form.

It provides solutions for accounting purposes, which in many cases are also acceptable for other legal requirements. Special regulations may expressly require the document to be in paper form. For example, according to the current Labour Code (§ 38, article 1), it is not considered that the labour law agenda could be kept electronically. In other cases, the law requires an electronic document, e.g. e-invoice according to Act No. 215/2019 Coll. on guaranteed electronic invoicing and the central economic system and on the addition of certain laws or electronic documents when communicating with the Financial Administration, health insurance companies or the Social Insurance Agency. However, the amendment to the Act on Accounting does not establish technical parameters, it does not establish specific requirements for software programs, but it talks about the principles and methods that must be followed in the accounting. The accounting entity (this also applies to agricultural entities) has the obligation to prove that these accounting principles and methods are followed through program manuals and internal regulations for established processes.

Pursuant to the Accounting Act, the accounting is kept as a set of accounting records. An accounting record is a data that is a carrier of information that relates to the subject of accounting or the method of accounting. Accounting records include invoices, delivery notes, orders, decisions of general meetings, court decisions, payrolls, treasury documents, bank statements, warehouse records, VAT records, tax returns and several other records that form the basis for accounting. Currently, the accounting is practically conducted electronically, therefore the basic accounting records also include program documentation, the program manual of a software product for accounting, which can be elaborated in an internal accounting record. An internal regulation on the circulation of documents and the verification of documents is also included among the important underlying accounting records. Following the electronization of the process, a record is created expressing the provability of extracted data, access to cloud storage, and all that.

The amendment to the Act on Accounting defines the paper and electronic forms of accounting records. Paper accounting record is a record made on paper and a printed accounting record made using software. For accounting purposes, a documentary accounting record is considered to be one that is sent and received as a document or created in this way for the internal purposes of an accounting entity. Subsequently, it is possible to transform the paper accounting record into electronic form according to § 33 of the amendment to the Act on Accounting, while this electronic accounting record is archived as a part of the electronic accounting documentation. Electronic accounting record means:

1. Accounting record received or made available in an electronic format. The electronic format itself is determined by the creator of the accounting record or determined based on an agreement with the receiver of the accounting record.
2. Scanned document according to §33 of the amendment to the Act on Accounting

sent electronically. For the receiver of the accounting record, the accounting record that is sent as an attachment to the electronic mail is also considered to be the primary electronic accounting record.

3. An accounting record made in an electronic format for the internal purposes of an accounting entity.

The basic requirement of both the already effective Act on Accounting and the approved amendment is the provability of accounting records. An accounting record is considered to be provable if: the content of the accounting record directly proves the fact, the content proves the fact indirectly through the content of other provable accounting records, when recording and processing these facts, it meets the requirements of the credibility of the origin, the integrity of the content and the readability of the accounting record, from the moment the accounting record is made or from the moment the accounting record is received or made available until the end of the accounting documentation retention period. The accounting entity has the opportunity to ensure the credibility of the origin and integrity of the content of the accounting record:

1. Signature record of the responsible person; The accounting unit is obliged to adjust the details of the authorization, obligations and responsibilities of the persons in an accounting entity to whom the attachment of the signature record applies, in such a way that it is possible to determine independently the responsibility of individual persons for the content of the accounting record to which the signature records were attached.
2. Electronic data exchange, which means the exchange of structured messages between computers or computer applications, in which the processing of various electronic formats of accounting records takes place, which go through the process of verification, coordination, approval and settlement without the possibility of human intervention in the content of the accounting.
3. The internal control system of accounting records which means the determination of persons responsible for controlling of processing accounting records, while the control is sufficient to prove the fact that is recorded in the accounting record. The control method determined by the accounting entity is a part of the accounting record for bookkeeping and accounting record processing.

The amendment to the Act on Accounting clarifies what is meant by the term signature record. It can be a handwritten signature, a qualified electronic signature or a similar provable signature record replacing a handwritten signature in an electronic form, which enables clear, provable identification of the person who made the signature record. A qualified electronic signature is defined by the eIDAS regulation as an improved electronic signature created according to specific security standards. In the eIDAS Regulation, electronic signature means data in an electronic form that is connected or logically associated with other data in an electronic form and that the signer uses for signing. In principle, it can be anything that identifies the signer in an electronic environment.

Such a signature guarantees:

- The document integrity, i.e., that the document signed with a qualified electronic signature does not change during its transfer from the sender to the recipient,
- at the same time, it enables the identification of the signed person, as it is created using a qualified certificate and a private key issued by the NSA (National Security Authority) or other qualified confidential service providers, using a qualified device (e.g. reader and eID).

A personal access code, access name and password or an encryption key, which can be used to clearly and demonstrably identify the responsible person who used it, can also be considered as a similar verifiable signature record replacing a handwritten signature. The accounting entity is obliged to create a system for creating similar verifiable signature records in an electronic form, which ensures that they cannot be obtained, changed or otherwise misused by anyone other than the responsible person, and which are attached or logically associated with accounting records in an electronic form in order to ensure the origin and integrity of these data. The technical solution in practice always depends on specific software equipment, such as accounting software used by an accounting entity, software for document administration or archiving, etc.

A common part between accounting entities and within an accounting entity is the use of electronic data interchange (Electronic Data Interchange). It is an integrated data exchange that prevents manual and paper transactions. It can be used, for example, for the exchange of orders, for invoicing processes, where the electronic transfer of invoices allows quick review and processing of documents. Currently, accounting programs already use e.g. cloud services. It allows to log in to own accounting program via the website, and e.g. create invoices. Among the advantages is the use of several computers at the same time. Another advantage is easy data sharing. Online software solutions through smartphones and mini programs synchronize and send data to cloud storage.

The amendment to the Act on Accounting itself had a crucial impact on the electronic storage and protection of accounting documentation. In order to ensure more consistent accounting records during their storage, an accounting entity is obliged to follow the specified method of storage of accounting documentation. Due to the fact that accounting documentation is already stored electronically, electronic storage of accounting documentation means the storage of accounting documentation on a data carrier. The form of the data carrier can be chosen by an accounting entity arbitrarily, it is up to its decision. It can be a USB key, external disk, memory card, storage, etc. When storing accounting documentation, an accounting entity is also obliged to ensure compliance with the requirements of accounting records in an electronic form, if it only stores accounting records, the form of which is the result of the transformation of the accounting record (§ 35 article 5 of the Act on Accounting).

Conclusion

The coronavirus pandemic has fully demonstrated the importance of the existence of a digital economy. It is obvious that this segment will undergo rapid development in the upcoming years and the entire economy will undergo a digital transformation. Digital transformation stands for ongoing changes to business models, business processes and operations as well as customer interaction in connection with new information and communication technologies. The involvement of small and medium-sized enterprises will be crucial in the upcoming process of digital transformation. The EU must work on much closer cooperation with such companies.

Slovakia needs to create conditions for the gradual digital transformation of all sectors of the economy, this also applies to agricultural. The Digital Economy and Society Index (DESI) is an online tool to measure EU member states' progress towards a digital economy and society. DESI currently combines 33 indicators (pillars) and uses a system of criteria weights to classify each country based on its digital performance. Slovakia is included in the category of lagging countries, i.e. the results of the index are below the EU average and the country is also developing more slowly than the EU average. In 2022, Slovakia ranked the 23rd position among the 27 EU member states in the evaluation of the DESI. The rate of use of advanced digital technologies in enterprises lags behind the EU average. Electronic sharing of information in Slovakia remained at the level of approximately 31% during the entire monitored period, which is below the EU average.

Digitization is also coming to the accounting. The Slovak Republic also responded to the growing share of electronic accounting records, and the amendment to the Act on Accounting (§31 to §33) from 1 January 2022 specified the definition of an electronic accounting record. The current change in the amendment to the Act on Accounting thus offers completely new opportunities for working with corporate accounting in relation to internal processes in the company, but also in relation to financial administration or tax authorities. For several years, we have been working on solutions that can ensure the complex management of accounting documents from their entry into the company (this also applies to agricultural entities) to the final archiving with the possibility to search for any document. Electronic accounting can save companies The accounting entity (agricultural entities) has the obligation to prove that these accounting principles and methods are followed through program manuals and internal regulations for established processes. Accounting can be paperless. Physical documents do not have to be archived, companies do not have to worry about them not being destroyed, lost or damaged. Digitization of accounting also eliminates the frequent problem of finding documents. For example, an invoice can be searched in the electronic system by supplier, amount, date of issue or other attributes. It will no longer be a problem to find out whether the given invoice is approved, rejected or waiting for signature. The digital archive is also related to this. The amendment to the Act on Accounting thus opens the possibility for companies to move to a higher digital level and be more competitive.

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Effects of Land Quality on Land Use: Farm-level Panel-data Evidence from Viet Nam

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Abstract

The sustainable livelihoods framework (SLF) is a comprehensive way to study agricultural issues. So far, to our best knowledge, no study has applied the SLF to examine the influence of land quality on land use intensively. The current research examines the effects of land quality on farmers' decision-making on land use in Vietnam by modifying the sustainable livelihoods framework and using the fixed effects regression model. The method controlled the household and commune-level unobserved invariant characteristics and resulted in more robust estimates than pooled Ordinary Least Squares (OLS) estimation. The sample is a five-wave panel dataset of 2008-2016 with 1,534 farm households. The results reveal that land quality affects land-use choices through several aspects of land quality. More specifically, regarding topography, plot fertility level, plot locations, and soil and water conservation, results show that their effects reflect the cultivating practices for each land-use type in the sample. Findings also show that the irrigation system positively affects rice production in Vietnam. Policymakers should consider various aspects of land quality when designing policies and programs relating to land use, irrigation distribution, and especially the master plan for agricultural production and rural development. Flexible guidance for land uses of each type is closely connected with land quality in each region that may be most suitable for sustainable agriculture development.

Keywords

Farming household, fixed-effects model, land quality, land use, panel data, Vietnam.

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Introduction

Land-use changes significantly contribute to agriculture production in the world (Rabbinge and Van Latesteijn, 1992; Li and Wang, 2003; Yan et al., 2009; Yan et al., 2009; Hamblin, 2009; Angus et al., 2009; Tanrivermis, 2003; Zander and Kächele, 1999). Evidence shows that land-use changes increase the intensity of agriculture production (Li and Wang, 2003), land productivity (Yan et al., 2009), and poverty (Apata et al., 2021; Kotykova and Babych, 2021). Using land with strict agricultural land effectively mobilizes industrialization and urbanization in Turkey (Tanrivermis, 2003).

Small farm households in developing countries live in various physical and socio-economic conditions beyond the farm's decision-making. These conditions include climate variability (Thulstrup, 2015), local governance (Miratori and Brooks, 2015; Kyeyune and Turner, 2016), law (Nguyen and Tran, 2018; De Janvry et al., 2015), local institution (Marschke et al., 2014), and land quality (Bouma, 2002; Hardie and Parks, 1997; Eckhardt and Stackelberg, 1995).

Land quality is a crucial determinant of land use in developed and developing countries. Various pieces of evidence came from Podmanicky et al. (2011) in Europe, Salvati (2010) in Southern

Europe, Zambon et al. (2017) in Italy, Eckhardt and Stackelberg (1995), Hardie and Parks (1997), and Tong and Chen (2002) in the United States, Honisch et al. (2002) in Germany, Woli et al. (2004) in Japan, Xu et al. (2002) in China, Witcover et al. (2006) in the Amazon Basin, and Teshome et al. (2014) in Ethiopia.

While many studies have examined factors affecting land use, especially recently, those have considered climate change and extreme weather events in their research (Lambin et al., 2001; McCord et al., 2015; Lehmann, Briner, and Finger, 2013), little has been done to understand the effects of land quality on land-use choices in recent decades in the context of developing countries, especially countries in transition. The current study, thus, aims to fill this gap.

Consequently, the objective of this study is to examine whether the land quality may favor land-use choices in Vietnam. We use commune fixed-effects regression and five-wave panel data from Vietnam Access to Resources Household Surveys (VARHS) with 1,534 farm households, resulting in 8679 representative observations. In addition, we modify the sustainable livelihoods framework to incorporate land quality in land-use decision-making. Our key research question is: how does land quality drive farmers' choices, given several land-use alternatives.

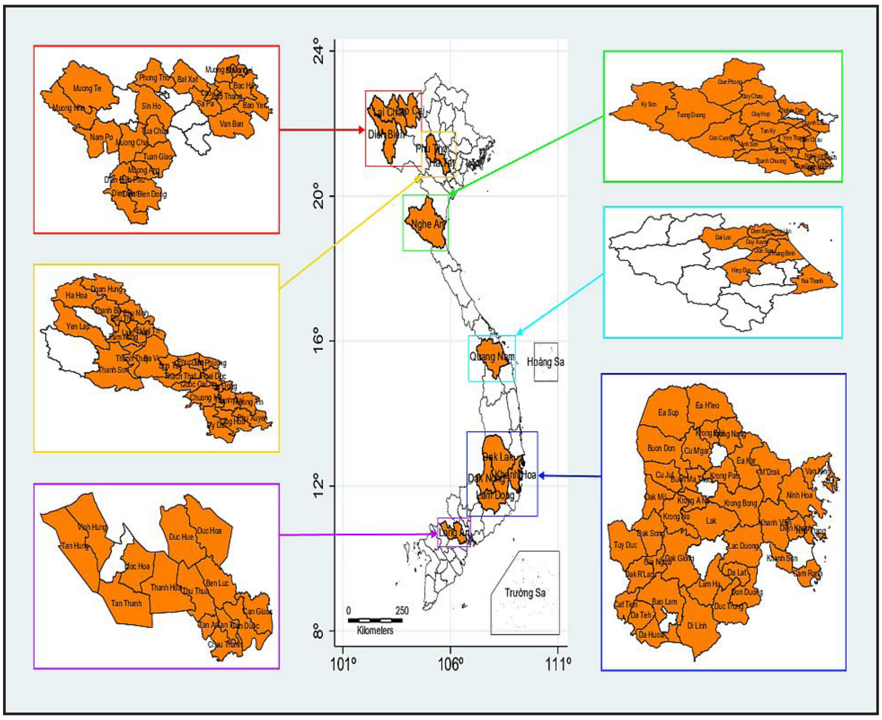
The study makes both empirical and methodological contributions to the literature on land use and sustainable livelihood in two ways: (i) enhancing the SLF by covering a more comprehensive range of land use choices such as rice land, land for other annual crops, land for perennial crops, forestry, and aquaculture area thanks to the availability of a unique dataset and (ii) paying more attention to land quality in examining land-use choices.

Materials and methods

Data

We used data from VARHS from 2008 to 2016. The VARHS was designed to cover the characteristics and living conditions of rural households in twelve provinces in Vietnam every two years, namely: Dak Lak, Dak Nong, Dien Bien, Ha Tay, Khanh Hoa, Lai Chau, Lam Dong, Lao Cai, Long An, Nghe An, Phu Tho and Quang Nam (Figure 1). There were 2,131 households interviewed in all survey rounds. The final number of panel households comes to 1,534 because of missing data. The VARHS has been used intensively in the works of Nguyen et al. (2018), Ngo et al. (2020), Markussen and Ngo (2019), and Markussen et al. (2011).

The VARHS also included a commune-level survey. Interviews with the commune administrators were performed in all communes where the VARHS



Source: Authors' creation

Figure 1: VARHS Site surveys.

households reside. Although families were spread over 465 communes, the commune balanced-panel data between the 2008 and 2016 surveyed round was 418.

The household questionnaire consists of several sections: (a) general characteristics of household members and housing; (b) agriculture activities; (c) employment, occupation, time use, and other sources of income; (d) expenditures, savings, durable assets; (e) credit; (f) shock and risk copping; (g) social capital and network; (h) trust, political connections, and (i) rural society.

Concerning land quality surveyed in the household questionnaire, some dimensions include (a) topography, (b) land with irrigation, (c) plot slop, (d) plot fertility level, (e) plot problem, (f) plot location, and (g) Soil and water conservation infrastructure.

The commune questionnaire consists of several sections: (a) demographic information; (b) migration; (c) development programs; (d) agriculture and land; (e) income and employment; (f) infrastructure; (g) shocks; (8) irrigation management; (h) credit and saving; (e) commune problems; and (k) access to services.

Methods

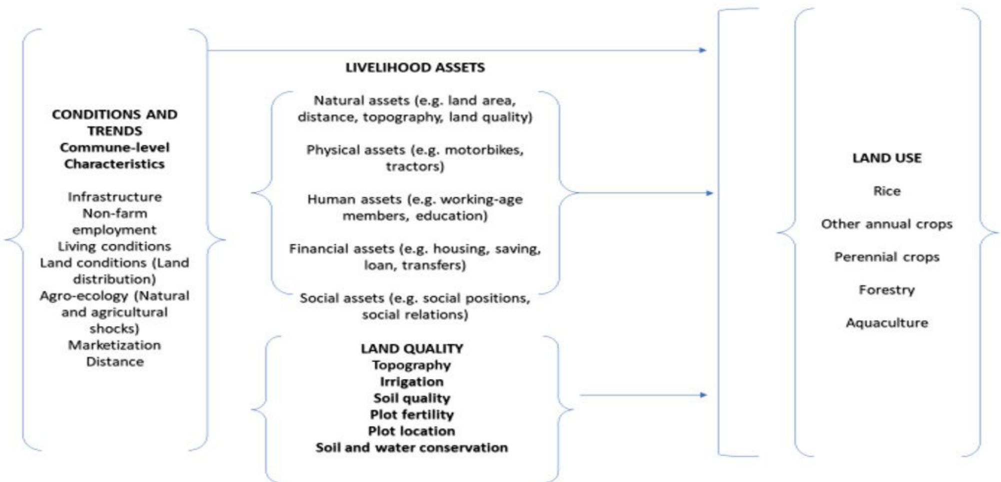
Conceptual framework

Land use is a persistently important issue in agriculture development. The driving forces of the various land-use decisions are not easy to generalize. There have been many types of research on land-use decisions under different approaches, such as the deforestation-based approach (Angelsen and Kaimowitz, 2000; Eakin et al., 2014; Liu et al., 2013) and the livelihoods approach (Nguyen et al., 2015; Baird and Gray, 2014). Hettig et al. (2016) conducted a meta-analysis of 91 recent empirical and theoretical studies on land-use changes at the farm-household level. They concluded that many studies rely on small samples and face problems of internal validity. Most recent research by Nguyen et al. (2017) examined determinants of farmers' land-use decision-making by extending the sustainable livelihoods framework (SLF), including factors belonging to the livelihood platforms, weather-shocked experiences and expectations, and physical-economic conditions of the local communities. So far, to our best knowledge, no study has applied the SLF to examine the influence of land quality on land use intensively. In this paper, we fill that gap by modifying the framework developed by Scoones (1998) and extended by Nguyen et al. (2017), focusing on land quality and using a sample of 1,534 farm households in 5 waves of surveys.

Livelihood includes five types of capital (assets): natural capital, physical capital, human capital, financial capital, and social capital (Scoones, 1998), as illustrated in Figure 2. These livelihood platforms clarify the factors featuring land-use choices by farmers. Accordingly, land-use choices are a function of various factors representing the endowments and constraints (Nguyen et al., 2017).

Specification of the econometric model

We use a fixed-effects regression model to investigate the effects of land quality on land-



Source: Authors' modification from Scoones (1998)

Figure 2: Land quality and farmers' decision-making of land use.

use choices, exploring a balanced panel dataset of five rounds from 2008 to 2016. The method is appropriate for controlling the household and commune unobserved invariant characteristics, resulting in more robust estimates than pooled Ordinary Least Squares (OLS) estimation (Damon, 2010). The model has the following general form:

$$Y_{itz} = f(X_{it,} V_{vt}) + \beta_{iz} + \mu_{itz}, \quad (1)$$

Where i, t, and z denote household i, in year t, and commune v; z is the types of land use, taking value from 1 till 5: (1) rice, (2) other annual crops, (3) perennial crops, (4) forestry and (5) aquaculture. Y is the shares of land use; X is a vector of the explanatory variables at the household level, V is a vector controlling for the commune characteristics, β is the invariant-unobserved, and μ is the variant-unobserved characteristics of the household.

The identification of independent variables is based on the SLM in Figure 2. At the household level, the following variables are used: First, in the current research, the natural assets are proxied by the farmland area (in ha). Since farmland area might be an essential factor in agriculture production, the share of land with land-using certificate (LUC) (in %) as land property rights strongly influence choices of land allocation by farmers (for example, through investment (Rigg et al., 2012), and the average distance from the living location to plots owned by the rural household (in km) (Nguyen et al., 2017).

Second, the human assets are examined through several variables: demographic characteristics (the dependency ratio (in %) (Nguyen et al., 2017), the age average of working-age members (in years) (Nguyen et al., 2017), the percentage of female-head share (in %) (Nguyen et al., 2017), working forces (the share of the household member at working ages (between 16 and 65 years old, in %) (Nguyen et al., 2017), and education levels (the educational levels as measured by the percentage of household members with the highest certificate, in %) (Nguyen et al., 2017).

Third, the physical assets are analyzed through the transportation assets (the number of tractors and motorbikes) and the production assets (the number of pesticide sprayers) (Nguyen et al., 2017).

Fourth, the financial assets are exhibited by housing (the area of the living house, in m2) (Nguyen et al., 2017), the saving (the total saving in a million Vietnamese currency (VND)), the borrowing (the total of the loan, in a million VND) (Menkhoff and Rungruxsirivorn, 2011), the private transfer and the public transfer (both in a million VND) (Nguyen et al., 2017).

Fifth, social assets are typified by trust relations and social connectedness (Pretty & Ward, 2001; Nguyen et al., 2017). The trust relations are signified by the sources of obtaining money by households when needing money (for example, they can choose to borrow from a relative, friend, neighbor, or other sources, in dummies). Social connectedness is measured by the membership of a household member in a socio-political organization (in a dummy variable) (Baird and Gray, 2014; Forsyth and Evans, 2013), such as: being an office head having a membership of the Communist Party of Vietnam (CPV), and being a member of the Women Union.

Local socio-economic conditions constrain farming households in rural areas. At the commune level, the following variables are used: First, non-farm employment: the number of firms or factories with at least ten employees in the commune (Bezu et al., 2012), firms with at least ten employees in the neighboring commune where people can work and come back within the day.

Second, the distance (in km) from the commune center to the nearest bus station, from the commune center to the main road.

Third, natural and agricultural shocks are measured by whether a commune has faced any problem of the flood, drought, typhoon, landslide, animal or livestock epidemics, plant disease, insects, or rats in the last two years (Povel, 2015; Doss et al., 2008).

Several alternative measures of land quality at the household level are used. Details are: (i) The shares of land measure the topography with different slopes (in %), namely: flat, slight slope, moderate slope, steep slope; (ii) Irrigation is exhibited by the percentage of irrigated land (in %); the shares of land measure (iii) Soil quality with various possible problems (in %) such as land with gullies, low-lying land, sedimentation land, stony soils/clay, land with no problem, and (iv) The plot fertility level is measure by the shares of land with different fertility levels compared with other plots in the village (in %), namely: less than average, average, and above average. Land quality also includes (v) the location of plots in the irrigation canal is measured by the shares of land in the head end, middle, and tail end (in %), and (vi) the condition of soil and water conservation infrastructure is measure by the shares of land with soil and water conservation infrastructure (in any terms of rock bunds, soil bunds, terraces, grass lines) and that of with none of soil and water conservation infrastructure (in %).

Estimation strategy

Since our key research question is how to land quality drive farmers' choices of land uses, we follow several estimation steps as follows:

Step 1 (Panel A1): Models are estimated with all household-level variables related to capital in the livelihood framework at the household level. In addition, commune-level variables, namely: (i) distance, (ii) non-farm employment, and (iii) natural and agricultural shocks, are included in the models.

Step 2 (Panel A2): Additions of household-level variables related to land quality into the models will be estimated. Specifically, Panel A2.1 deals with the topography, Panel A2.2 examines the role of irrigation, Panel A2.3 reveals various possible problems with soil, Panel A2.4 analyses the plot fertility level, and Panel A2.5 measures the effects of plot location in the commune irrigation canal. Panel A2.6 seeks the influence of soil and water conservation infrastructure.

Results and discussion

Statistical description

The descriptive statistics presented in Appendix 1 illustrate the livelihood conditions of rural households in Vietnam. Regarding natural assets, the land area per farm decreases over the period. Similarly, the share of irrigated land falls. The land value increased between 2008 and 2016, and it was at its highest in 2014 - the share of land with LUC increased between 2008 and 2016. The average distance from the living place to the plots more or less is unchanged during the period.

For human assets, the dependency ratio decreased between 2008 and 2016. Farm heads' percentage increases and farm households are older and less in terms of working-age member percentage. In addition, farm heads are more educated.

Regarding physical assets, farmers have higher numbers of motorbikes but fewer pesticide sprayers and tractors in 2016 compared to 2008. This is reasonable because, in general, economic growth in Vietnam. Regarding financial assets, farmers are better-off in 2016 compared to 2008, as they have more housing areas, higher saving volume, and higher annual public and private transfers. This is also partly because of the achievement in economic development in Vietnam during the decade from 2008 to 2016. More social trust is found when farmers in Vietnam rely more on relatives or friends regarding social assets. In addition, in terms of the social network, more farmers in Vietnam are observed to be members of socio-political organizations such as party members or members of the Women Union during the period.

Land quality statistics are presented in Appendix 2. Regarding topography, the land is more in unfavorable conditions in 2016 than in 2008. However, the land is improved over the mentioned period in irrigation. Concerning soil problems, it is shown that land is improved over the period, whereas the fertility level and plot location seem to be stable. Soil and water conservation infrastructure have not improved much during the period.

The descriptive statistics of the commune characteristics are presented in Appendix 3. As mentioned in the previous section, commune characteristics include (i) distance, (ii) non-farm employment, and (iii) natural and agricultural shocks. The opportunities for off-farm employment in the communes (proxied by the number of firms with more than ten workers) are better in 2016 compared to 2008. For variability, farmers in Vietnam experienced fewer weather shocks between 2008 and 2016.

Appendix 4 presents the farmland allocation in Vietnam. Observations can be made: (a) rice is still the dominant crop in Vietnam; (b) the land percentage of other annual crops grows up in the sample period; (c) the land proportion of perennial crops also increases in the studying period, (d) the land portion of forestry crops decreases in the study period, and (e) the land share of aquaculture tend to stand still in the period.

The basic model

Table 1 shows that the models explain 2-6% of the variation in the dependent variables (as shown in the third line from the bottom of Table 1). Firstly, regarding natural assets, the farmland positively affects the land for perennial crops (This is in line with Nguyen et al. (2017) for the case of Thailand), forestry, and aquaculture, whereas it negatively affects the rice land. Farmers may explore other crops or activities with higher income with more land.

Variable	(1) Rice land (%)	(2) Other annual lands (%)	(3) Perennial land (%)	(4) Forestry land (%)	(5) Aquaculture area (%)
Household-level characteristics					
Natural capital					
Land size (ha), log	-0.2700*** (0.0174)	0.0233 (0.0175)	0.0990*** (0.0116)	0.1260*** (0.0081)	0.0230*** (0.0054)
Land with LUC (%)				-0.0115** (0.0052)	
Distance to plot (km)	-0.0014* (0.0008)		0.0028*** (0.0005)		-0.0008*** (0.0002)
Human capital					
Dependency ratio (%)					-0.0119** (0.0052)
Female head (yes=1)	-0.0770** (0.0366)				
% of the household member at working ages			0.0005** (0.0003)		
% of "Cannot read and write"	-0.0864** (0.0431)	0.0500 (0.0437)			
% of "Completed Primary"	-0.109*** (0.0414)	0.0585 (0.0419)			
% of "Completed Lower Secondary"	-0.0789* (0.0423)	0.0309 (0.0428)			
% of "Completed Upper Secondary"	-0.0474 (0.0443)	-0.0003 (0.0448)			
Physical capital					
Number of motorbikes	0.0320*** (0.0095)	-0.0237** (0.0096)			
Number of tractors			-0.0459*** (0.0141)		
Financial capital					
Loan size (mill. VND), log			0.0011* (0.0006)		
Private transfer (mill. VND), log	-0.0035*** (0.0009)	0.0019** (0.0009)			
Social capital					
In case of needing money: ask a friend (yes=1)					0.0045* (0.0026)
Being an officer (yes=1)	0.0300* (0.0164)				
Commune-level characteristics					
Distance from the commune center					
To the main road (km)					8.19 x 10-5* (4.84 x 10-5)
To the extension shop (km)		-1.70 x 10-5** (8.56 x 10-6)			
Non-farm employment					
Non-farm employment type 1 (Numbers)			-0.0109** (0.0047)	0.0091*** (0.003)	0.0050** (0.0023)
Non-farm employment type 2 (dummy)					-2.75 x 10-5* (1.62 x 10-5)

Note: Standard errors in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1; HH: Household; Non-farm employment type 1: Number of enterprises with the size of 10 or more employees in the commune; non-farm employment type 2: Having enterprises with the size of 10 or more employees in the neighboring communes where people can work there and come back within the day (dummy).
Source: Authors' estimation from VARHS08-16.

Table 1: Determining factors of land-use choices (Panel A1) (To be continued).

Variable	(1) Rice land (%)	(2) Other annual lands (%)	(3) Perennial land (%)	(4) Forestry land (%)	(5) Aquaculture area (%)
Natural and agricultural shocks					
The flood last year (yes=1)				-0.0082** (0.0040)	
Landslide last year (yes=1)			-0.0233** (0.0092)		
Plant disease last year (yes=1)			-0.0133** (0.0064)		
Flood two years ago (yes=1)				0.0112*** (0.0038)	
Drought two years ago (year=1)				-0.0082** (0.0033)	
Typhoon two years ago (yes=1)	0.0157** (0.0074)			-0.0085** (0.0035)	
Landslide two years ago (yes=1)			0.0285*** (0.0094)		
Plant disease two years ago (yes=1)			0.0167*** (0.0064)		
Insects/rats two years ago (yes=1)	-0.0216*** (0.0074)	0.0186** (0.0074)			
Year dummies	Yes	Yes	Yes	Yes	Yes
Constant	0.8020***	0.1800***	0.1180***	-0.0166**	0.0180***
	(0.0445)	(0.0422)	(0.0443)	(0.0066)	(0.0044)
Observations	7,675	7,675	7,675	7,806	8,517
Number of households	1,747	1,747	1,747	1,759	1,945
F statistic	19.09	6.194	13.90	33.84	6.221
F for u (i)=0	8.833	5.750	11.22	2.819	8.160
R^2 within model	0.064	0.015	0.036	0.058	0.007
R^2 between model	0.125	0.0002	0.150	0.081	0.0003
R^2 overall model	0.139	0.006	0.133	0.060	1.79 x 10-5

Note: Standard errors in parentheses; *** p < 0.01, ** p < 0.05, * p < 0.1; HH: Household; Non-farm employment type 1: Number of enterprises with the size of 10 or more employees in the commune; non-farm employment type 2: Having enterprises with the size of 10 or more employees in the neighboring communes where people can work there and come back within the day (dummy).
Source: Authors' estimation from VARHS08-16.

Table 1: Determining factors of land-use choices (Panel A1) (Continuation).

While we find no effect on most land with LUC, the negative impact is seen on the land for forestry. The negative sign may be explained by the fact that Vietnam has achieved a high LUC coverage for rice and other annual crops. Forestry land, on the other hand, in principle, mostly belongs to state ownership. In addition, once farmers receive forestry with LUC, they may change the initial using purpose to other ones such as non-agricultural activities (such as relaxing areas or residential areas).

The distance from the living house to the farming plots is negatively associated with the rice land (This is in line with Nguyen et al. (2017) for the case of Thailand) and land for forestry but positively correlated with the land for perennial crops.

Second, for human assets, the dependency ratio negatively affects the opportunity to explore the aquaculture area, whereas a negative effect accompanies the female-head household on the rice land. More labor forces in terms of the percentage of household members of the working ages tend to promote more land for perennial trees. This is because perennial crops are usually cultivated in slope areas, and thus mechanization is bounded. The result is in line with Nguyen et al. (2017) for the cases of Thailand and Vietnam. Besides, the more the level of education of the household members, the less possibility that they will be involved in rice cultivation. This may be because the higher educated farmers tend to focus on off-farm or self-employment.

Third, regarding physical assets, the number of motorbikes positively correlates with rice land but is negatively associated with the land for other annual crops. This is because motorbikes are the main transportation means of rice in sampled provinces in Vietnam. The number of tractors negatively influences perennial land (This is in line with Nguyen et al. (2017). The adverse effect may reflect that tractors are not suitable for perennial crops (for example, due to the area's slope).

Fourth, regarding financial assets, loan size positively influences the land proportion of perennial crops. The positive effect might be because such activities require much investment. Concerning the private transfer, it negatively affects rice but has a positive one on other annual crops.

Fifth, regarding social assets, a close relationship with friends is positively associated with exploring the aquaculture area, whereas being in an office positively influences rice land. In Vietnam, as a rice (and aquaculture) exporting country, such social relationships support farmers in business.

Regarding the commune-level characteristics, firstly, households living in the commune with a longer distance to the main road would increase the aquaculture area. In contrast, the distance to the extension shop would decrease the land for other annual crops as farmers would regularly need technical support. The off-farm employment possibilities outside the commune might reduce the surface area for aquaculture. This is quite in line with Nguyen et al. (2017), who found that the off-farm wage employment opportunities would reduce the land share of rice. In addition, the off-farm employment opportunities inside the commune would decrease the probability of cultivating perennial crops and increase the chances for forestry and aquaculture.

Secondly, the commune that experienced a flood last year would designate less land for forestry. This is in line with Nguyen et al. (2017). The situation can explain the income shock prevented farmers from investing in forestry. In addition, forestry requires a high level of initial and continual investments and a long period to get back the returns. Similarly, households in communes face landslides, and plant disease also reduces land for perennial crops.

With the more prolonged time of shocks, namely two years, households in the commune where flood two occurred would allocate more land to forestry. Families in the commune that endured typhoons would give less land to forestry but more to rice land. Farmers in the commune that encounter landslides and plant disease would allocate more land to perennial crops. Farming households in the commune that observed animal/livestock epidemics would give less land to rice but more to other annual crops.

Effects of land quality

The results of estimating the influence of land quality on land use are shown in Table 2. All models include variables related to farming household characteristics, commune characteristics, and year-fixed effects. Model A2.1 deals with the topography, Model A2.2 examines the role of irrigation, Model A2.3 reveals various possible problems with soil, Model A2.4 analyses the plot fertility level, and Model A2.5 measures the effects of plot location in the commune irrigation canal. Model A2.6 seeks the influence of soil and water conservation infrastructure.

In general, the empirical results add evidence to the existing literature on the effects of land quality on land-use decisions in developing countries recently, such as Xu et al. (2002) for the Yellow River Delta in China, Woli et al. (2004) for in eastern Hokkaido (Japan), Witcover et al. (2006) for the Amazon Basin, and Teshome et al. (2014) for the North-Western Ethiopian Highlands.

First, regarding the topography in Model A2.1, farmers who own more percentage of flat land would apportion more land to rice, other annual crops, and perennial crops but less to aquaculture. In addition, farmers who experience more land percentage with a slight slope, a moderate slope, or a steep slope would allocate less land to rice since it is not favorable for rice cultivation. Moreover, farmers who process more land percentage with a slight incline, moderate slope, or steep slope would give more land to other annual crops, perennial crops, and forestry. In most cases, farmers appropriate less land for aquaculture, which can be explained that farmers may allocate land to aquaculture if sufficient water surface is available. Our results align with Teshome et al. (2014), who found that land quality (e.g., slope and soil fertility status) influences farmers' sustainable land management practices and investments.

Second, regarding the role of irrigation, the proportion of irrigated land has a positive influence on the rice area and a negative effect on other annual crops, perennial crops, forestry, and aquaculture. This finding makes sense since the irrigation system mainly serves rice production in Vietnam. Different types of crops also need water and mostly depend on water pumping.

Variable	(1) Rice land (%)	(2) Other annual lands (%)	(3) Perennial land (%)	(4) Forestry land (%)	(5) Aquaculture area (%)
Household-level characteristics	Yes	Yes	Yes	Yes	Yes
Commune-level characteristics	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes
Panel A2.1 - Topography					
Land share with flat (%)	0.0566**	0.1760***	0.0374**	0.0151	-0.2820***
	(0.0246)	(0.0251)	(0.0166)	(0.0116)	(0.0068)
Land share with slight slope (%)	-0.0286	0.2140***	0.0672***	0.0295**	-0.277***
	(0.0261)	(0.0266)	(0.0175)	(0.0123)	(0.0072)
Land share with moderate slope (%)	-0.1020***	0.2170***	0.0795***	0.0863***	-0.2750***
	(0.0290)	(0.0296)	(0.0195)	(0.0136)	(0.0079)
Land share with steep slope (%)	-0.1650***	0.1730***	0.1390***	0.1260***	-0.2660***
	(0.0454)	(0.0463)	(0.0306)	(0.0211)	(0.0124)
Observations	7,675	7,675	7,675	7,806	8,517
Number of households	1,747	1,747	1,747	1,759	1,945
F statistic	20.76	8.472	12.98	32.17	160.7
F for u (i) =0	7.988	5.708	10.31	2.639	5.330
R^2 within model	0.081	0.028	0.042	0.074	0.212
R^2 between model	0.170	0.006	0.182	0.112	0.535
R^2 overall model	0.187	0.0167	0.161	0.084	0.394
Panel A2.2 - Irrigation					
Land with irrigation (%)	0.1920***	-0.0837***	-0.0040	-0.0505***	-0.0540***
	(0.0123)	(0.0127)	(0.0084)	(0.0058)	(0.0038)
Observations	7,675	7,675	7,675	7,806	8,517
Number of households	1,747	1,747	1,747	1,759	1,945
F statistic	30.19	8.573	13.10	37.73	31.43
F for u (i) =0	8.218	5.311	11.18	2.621	7.901
R^2 within model	0.101	0.023	0.036	0.070	0.037
R^2 between model	0.206	0.040	0.148	0.116	0.043
R^2 overall model	0.206	0.044	0.131	0.084	0.037
Panel A2.3 - Problems with soil					
Land share with gullies (%)	-0.0632***	0.0553***	-0.0177	0.0283***	-0.0060
	(0.0168)	(0.0170)	(0.0112)	(0.0078)	(0.0052)
Dry land share (%)	-0.0230**	0.0319***	-0.0047	0.0039	-0.0079***
	(0.0097)	(0.0098)	(0.0065)	(0.0045)	(0.0030)
Low-lying land share (%)	-0.0113	0.0259	0.0053	-0.0084	-0.0133**
	(0.0179)	(0.0182)	(0.0120)	(0.0084)	(0.0056)
Sedimentation land share (%)	0.0091	-0.0164	0.0010	0.0021	-0.0102
	(0.0231)	(0.0235)	(0.0155)	(0.0109)	(0.0072)
Share of land with landslide (%)	-0.0493	0.00919	-0.0156	0.0583***	-0.0049
	(0.0473)	(0.0481)	(0.0317)	(0.0222)	(0.0140)
Land share with stony soils/clay (%)	-0.1030***	0.0678**	-0.0053	0.0509***	-0.0119
	(0.0279)	(0.0284)	(0.0187)	(0.0129)	(0.0086)
Observations	7,675	7,675	7,675	7,806	8,517
Number of households	1,747	1,747	1,747	1,759	1,945
F statistic	15.94	5.558	10.27	23.92	4.423
F for u (i) =0	8.312	5.647	10.93	2.750	8.053
R^2 within model	0.068	0.019	0.037	0.063	0.009
R^2 between model	0.138	0.003	0.142	0.090	0.0002
R^2 overall model	0.152	0.013	0.126	0.067	0.001

Note: Standard errors in parentheses; *, **, and ***: p < 10%, 5%, and 1%, respectively
Source: Authors' estimation from VARHS08-16.

Table 2: Effects of land quality on land-use choices (Panel A2) (To be continued).

Variable	(1) Rice land (%)	(2) Other annual lands (%)	(3) Perennial land (%)	(4) Forestry land (%)	(5) Aquaculture area (%)
Panel A2.4 - Fertility level					
Less than average	0.0181**	0.0169**	-0.0300***	0.0229***	-0.0255***
	(0.0077)	(0.0078)	(0.0052)	(0.0036)	(0.0025)
Average	0.0171***	0.0130**	-0.0207***	0.0160***	-0.0231***
	(0.0061)	(0.0062)	(0.0040)	(0.0029)	(0.0019)
Above average	0.0303***	0.0129	-0.0249***	0.0073*	-0.0221***
	(0.0089)	(0.0090)	(0.0059)	(0.0042)	(0.0028)
Observations	7,675	7,675	7,675	7,806	8,517
Number of households	1,747	1,747	1,747	1,759	1,945
F statistic	17.26	5.456	13.70	30.14	19.36
F for u (i) =0	8.637	5.753	10.88	2.780	8.147
R^2 within model	0.066	0.016	0.042	0.065	0.029
R^2 between model	0.133	0.0003	0.180	0.090	0.009
R^2 overall model	0.148	0.005	0.161	0.069	0.013
Panel A2.5 - Plot location					
Head end	0.0291***	0.0098	-0.0150***	-0.0161***	-0.0062**
	(0.0080)	(0.0081)	(0.0053)	(0.0038)	(0.0025)
Middle	0.0311***	0.0086	-0.0169***	-0.0174***	-0.0042**
	(0.0058)	(0.0059)	(0.0039)	(0.0028)	(0.0019)
Tail end	0.0114	0.0125	0.0150*	-0.0320***	-0.0060
	(0.0133)	(0.0136)	(0.0089)	(0.0063)	(0.0040)
Observations	7,675	7,675	7,675	7,806	8,517
Number of households	1,747	1,747	1,747	1,759	1,945
F statistic	18.04	5.321	13.15	30.93	5.211
F for u (i) =0	7.888	5.742	10.12	2.789	8.156
R^2 within model	0.068	0.016	0.041	0.067	0.008
R^2 between model	0.158	3.20 x 10-7	0.190	0.091	5.44 x 10-5
R^2 overall model	0.170	0.004	0.163	0.069	0.0002
P***anel A2.6 - Soil and water conservation***					
Land with soil and water conservation infrastructure	-0.0091 (0.0059)	0.0139** (0.0061)	-0.0123*** (0.0039)	0.0165*** (0.0028)	-0.0033* (0.0018)
None of soil and water conservation infrastructure	0.0125*** (0.0038)	0.0129*** (0.0039)	-0.0194*** (0.0026)	0.0004 (0.0018)	-0.0054*** (0.0012)
Observations	7,675	7,675	7,675	7,806	8,517
Number of households	1,747	1,747	1,747	1,759	1,945
F statistic	18.10	6.320	15.94	31.54	7.206
F for u (i) =0	8.183	5.767	10.22	2.780	8.148
R^2 within model	0.066	0.018	0.046	0.064	0.010
R^2 between model	0.141	0.0001	0.213	0.087	3.77 x 10-5
R^2 overall model	0.154	0.005	0.185	0.065	0.001

Note: Standard errors in parentheses; *, **, and ***: p < 10%, 5%, and 1%, respectively
Source: Authors' estimation from VARHS08-16.

Table 2: Effects of land quality on land-use choices (Panel A2) (Continuation).

Another possible: when the irrigated land share increases, farmers in Vietnam would switch from the other annual crops to rice. Xu et al. (2002) also found similar results when discovering that vegetation cover has expanded in the Yellow River Delta, China, with improved irrigation networks. Improvements in irrigation will strengthen the rice area, supporting food security in Vietnam.

Third, concerning possible problems with soil, farmers who witness more land with gullies, dry land, or land with stony soils/clay would allocate less to rice but more to other annual crops and forestry. Interestingly, farmers who have experienced more share of dry land or low-lying land would give less aquaculture. Xu et al. (2002) indicated that in the areas of increased salinization, cultivation on lands that are not suitable for farming has decreased. Witcover et al. (2006) found that soil quality matters for land use. For example, good-soil farms had higher forestry land rates than their medium-soil counterparts. Policies regarding rice land should reflect the land quality in the concerned area. Current strict rice-security guidelines may need to be revised now. Mechanisms for adaptation vary by soil quality level and may need to be guided. The master plan of national land use needs to change the land quality and land degradation in recent years of vast agriculture development and industrialization.

Fourth, referring to the plot fertility level, farmers allow more land for rice, other annual crops, and forestry regardless of the fertility levels, whereas farmers designate less land for perennial crops and aquaculture irrespective of the fertility levels

Fifth, regarding possible problems with plot locations, farmers who have explored plots at the head end or middle would allocate more to rice. However, they tend to apportion less land for perennial crops, forestry, and aquaculture.

Finally, concerning plot soil and water conservation, farmers who have had plots with soil and water conservation infrastructure would designate more to other annual crops and forestry but less to perennial crops. Given land plots without soil and water conservation infrastructure, farmers cultivate rice, other annual crops, but not forestry, and perennial crops. Woli et al. (2004) showed that river water quality affects intensive livestock farming areas, mixed agriculture, livestock farming, and grassland-based dairy cattle and horse farming areas. Infrastructure investment in the rural area may need to take land use and cultivation characteristics.

Conclusion

Land quality plays an important role in land-use choices. With a unique panel dataset of five-wave surveys from 2008 to 2016 with 8679 observations, the current study examines the effects of land quality on farmers' land uses among rural households in Vietnam. The fixed effects regression models that control the household and commune unobserved invariant characteristics are estimated. The current paper enhances the sustainable livelihoods framework by covering a more comprehensive range of land-use choices: rice land, land for other annual crops, perennial crops, forestry, and aquaculture. In addition, several new alternative measures of land quality at the household level are used, namely: (i) the topography, (ii) irrigation, (iii) soil quality, (iv) the plot fertility level, (v) the location of plots in the irrigation canal, and (vi) the condition of soil and water conservation infrastructure.

The results reveal that land quality also affects land-use choices through several aspects of land quality. More specifically, regarding topography, plot fertility level, plot locations, and soil and water conservation, results show that their effects reflect the cultivating practices for each land-use type in the sample. Findings also show that the irrigation system positively affects rice production in Vietnam. The framework in this study can be employed and expanded to examine similar topic in developing or transition countries.

The results confirm the critical role of land quality on land uses in a developing country. Thus, policymakers should consider various aspects of land quality when designing policies and programs relating to land use, irrigation distribution, and especially the master plan for agriculture production and rural development. Flexible guidance for land uses of each type is closely connected with land quality in various regions with different ecological conditions that may be most suitable for sustainable agriculture development.

This study has some limitations. First, land quality at the plot level has not been explored to bring into the analysis due to its handling complexity. Secondly, the sustainable livelihood framework has not addressed the relationship between land use and livelihood strategy. Third, the land quality that may be more specific in quantitative measurement is not available, and thus it does not allow us to give objective assessments. Future work can reply to more detailed surveys and go further in these research directions.

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Appendix

Variable	2008	2010	2012	2014	2016
Natural capital					
Land size (ha)	0.882	0.850	0.836	0.798	0.777
Land value (mill. VND)	152,496.11	314,564.42	470,638.82	1,271,661.85	559,216.49
Land with LUC (%)	0.761	0.731	0.807	0.807	0.795
Distance to plot (km)	1.050	0.970	1.083	0.958	0.978
Human capital					
Dependency ratio (%)	0.646	0.646	0.645	0.630*	0.599
Female head (yes=1)	0.075	0.082	0.090	0.101	0.108
Age average of working-age members (years)	33.356	34.423	38.350	40.892	36.068
% of household member at working ages	0.646	0.646	0.645	0.594	0.599
% of "Cannot read and write"	0.087	0.081	0.077	0.077	0.063
% of "Completed Primary"	0.258	0.245	0.233	0.187	0.161
% of "Completed Lower Secondary"	0.395	0.394	0.396	0.396	0.396
% of "Completed Upper Secondary"	0.236	0.266	0.276	0.318	0.360
% of "Can read and write but never went to school or did not finish primary school"	0.023	0.014	0.018	0.022	0.020
Physical capital					
Number of motorbikes	0.720	0.770	0.813	0.869	0.832
Number of pesticide sprayers	0.349	0.373	0.299	0.312	0.292
Number of tractors	0.032	0.019	0.020	0.016	0.016
Number of machines of all kinds	0.127	0.116	0.077	0.067	0.064
Financial capital					
Housing area (m2)	67.851	72.300	79.619	84.932	85.889
Saving volume (mill. VND)	12,996.47	29,813.06	44,730.87	40,065.39	39,918.89
Loan size (mill. VND)	11,984.93	14,048.06	13,920.12	17,448.83	12,037.33
Private transfer (mill. VND)	3,288.15	3,891.48	6,502.14	7,809.25	7,432.95
Public transfer (mill. VND)	3,127.77	3,856.01	4,836.24	6,834.55	7,405.69
Social capital					
In case of needing money:					
ask relative (yes=1)	0.724	0.801	0.797	0.806	0.766
ask friend (yes=1)	0.117	0.109	0.196	0.171	0.22
ask neighbor (yes=1)	0.292	0.235	0.229	0.172	0.195
ask other (yes=1)	0.063	0.032	0.019	0.024	0.037
Being an officer (yes=1)	0.056	0.059	0.045	0.056	0.058
Party membership of head (yes=1)	0.057	0.069	0.065	0.077	0.078
Member of Women Union (yes=1)	0	0.090	0.082	0.078	0.069

Note: Total observations in each year: 2,131.
Source: Authors' estimation from VARHS08-16.

Appendix 1. Statistical summary of the household-level characteristics, 2008-2016

Variable	2008	2010	2012	2014	2016
1. Topography					
Land share with flat (%)	0.438	0.396	0.385	0.061	0.027
Land share with slight slope (%)	0.240	0.254	0.258	0.142	0.243
Land share with moderate slope (%)	0.137	0.151	0.123	0.021	0.019
Land share with steep slope (%)	0.025	0.010	0.009	0.026	0.054
2. Irrigation					
Land with irrigation (%)	0.573	0.613	0.62	0.437	0.420
3. Problems with soil					
Land share with gullies (%)	0.070	0.073	0.062	0.052	0.050
Dry land share (%)	0.140	0.214	0.138	0.637	0.647
Low-lying land share (%)	0.100	0.078	0.037	0.038	0.034
Sedimentation land share (%)	0.041	0.056	0.023	0	0
Share of land with landslide (%)	0.015	0.012	0.013	0	0
Land share with stony soils/clay (%)	0.052	0.019	0.032	0	0
Land share with no any problem (%)	0.415	0.347	0.466	0	0
4. Fertility level					
Less than average (yes=1)	0.115	0.135	0.082	0.052	0.050
Average (yes=1)	0.660	0.642	0.646	0.637	0.647
Above average (yes=1)	0.065	0.034	0.047	0.038	0.034
5. Plot location					
Head end (yes=1)	0.065	0.046	0.055	0.070	0.020
Middle (yes=1)	0.144	0.172	0.115	0.120	0.196
Tail end (yes=1)	0.043	0.030	0.037	0.027	0.028
6. Soil and water conservation					
Land with soil and water conservation infrastructure (yes=1)	0.325	0.008	0.001	0	0.002
None of soil and water conservation infrastructure (yes=1)	0.515	0.447	0.376	0.361	0.327

Note: Total observations in each year: 2,131.
Source: Authors' estimation from VARHS08-16.

Appendix 2. Statistical description of variables related to land quality, 2008-2016.

Variable	2008	2010	2012	2014	2016
Distance					
Distance 1 (km)	9.978	9.927	10.898	9.939	11.196
Distance 2 (km)	2.745	3.412	2.529	2.025	7.067
Distance 3 (km)	12.453	11.482	42.522	11.493	11.225
Distance 4 (km)	5.932	6.358	75.989	7.397	5.440
Non-farm employment					
Non-farm employment type 1	8.458	19.23	17.028	21.466	27.711
Non-farm employment type 2 (dummy)	0.337	0.207	0.258	0.243	0.251
Natural and agricultural shocks					
Flood last year (yes=1)	0.437	0.396	0.319	0.322	0.202
Drought last year (year=1)	0.412	0.499	0.331	0.349	0.407
Typhoon last year (yes=1)	0.293	0.365	0.250	0.336	0.163
Land slide last year (yes=1)	0.188	0.175	0.128	0.080	0.068
Animal/livestock epidemics last year (yes=1)	0.389	0.420	0.400	0.358	0.243
Plant disease last year (yes=1)	0.410	0.480	0.392	0.348	0.241
Insects/rats last year (yes=1)	0.298	0.283	0.260	0.190	0.118
Flood two years ago (yes=1)	0.383	0.584	0.358	0.331	0.211
Drought two years ago (year=1)	0.410	0.415	0.328	0.335	0.362
Typhoon two years ago (yes=1)	0.289	0.335	0.291	0.306	0.174
Land slide two years ago (yes=1)	0.145	0.187	0.130	0.087	0.076
Animal/livestock epidemics two years ago (yes=1)	0.348	0.344	0.426	0.408	0.246
Plant disease two years ago (yes=1)	0.449	0.432	0.439	0.322	0.213
Insects/rats two years ago (yes=1)	0.269	0.292	0.272	0.14	0.130

Note: : Distance 1: Distance from the commune center to the nearest bus station (km); Distance 2: Distance from the commune center to the main road (km); Distance 3: Distance from the commune center to the extension center; Distance 4: Distance from the commune center to the extension shop (km). Non-farm employment type 1: Number of enterprises with ten or more employees in the commune; non-farm employment type 2: Having enterprises with ten or more employees in the neighboring communes where people can work there and come back within the day (dummy).
Source: Authors' estimation from VARHS08-16.

Appendix 3: Statistical summary of the commune-level characteristics, 2008-2016.

Variable	2008	2010	2012	2014	2016
Land size (ha)	0.882	0.850	0.836	0.798	0.777
% of rice	0.603	0.595	0.596	0.597	0.549
% of other annual crops	0.219	0.236	0.238	0.223	0.246
% of perennial crops	0.116	0.117	0.123	0.140	0.166
% of forestry	0.039	0.032	0.019	0.017	0.016
% of aquaculture	0.024	0.021	0.024	0.024	0.023

Source: Authors' estimation from VARHS08-16.

Appendix 4: Land and the share of land-use types, 2008-2016.

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Sustainability of Rubber Farmers Cooperatives: Empirical Evaluation of Determining Factors

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Abstract

The study investigated the factors that influence rubber farmers' cooperatives from the perspective of sustainability in Thailand. The research adopted a quantitative survey methodology with data purposively collected from 434 Thai rubber farmer groups. The variables included trust, sustainability, perceived value, satisfaction, loyalty, and brand image. The model was evaluated using Confirmatory Factor Analysis (CFA), while Structural Equation Modeling (SEM) was used to assess the hypotheses. The results indicated that the sustainability of the rubber farmers' cooperatives as a corporate entity is influenced by brand image, loyalty, and satisfaction. Trust was also found to have a significant effect on the satisfaction and loyalty of the rubber farmers' cooperatives. The research recommended that to enhance the sustainability of the rubber farmers' cooperative's brand image, loyalty, and satisfaction should be improved. The research's drawback is that it only looked at the rubber farmer cooperatives of Thailand as a corporation, and therefore, these factors should be taken into account when applying these results outside of this scope.

Keywords

Sustainability, rubber farmers, structural equation modeling, cooperatives, Thailand.

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Introduction

Thailand's rubber farmer cooperatives are considered vital as they play a crucial role in determining the sustainability guidelines of rubber plantation occupation, especially for small groups of rubber plantation farmers in terms of production, processing, and marketing. The rubber farmer's cooperatives have two groups. The first group is rubber farmer cooperatives, which are corporations such as associations and co-operatives, which are groups of farmers. The second group is rubber farmer cooperatives that are not corporations, such as groups of rubber plantation farmers and business groups. According to Section 4 of the Rubber Authority of Thailand Act, B.E. 2560 (2017), rubber farmer cooperatives must register with the Rubber Authority of Thailand to obtain support and assistance in organizing activities related to Para rubber. Recently, 789 groups of farmers have registered as rubber farmer institutions (Rubber Authority of Thailand, 2017). Nevertheless, the past activities organized by the rubber farmer cooperatives in relation to sustainability have still not convinced small rubber farmers to become members and participate in the activities due to many internal and external factors. The external factors are economic situations, societies, politics, cultures, and regions. There are two types of internal factors. The first type is behavioral and ideological, where members feel having different traits is a constraint in joining cooperative groups. They also set the various ultimate goals in the establishment of farmer institutions that affect the motivation to become a member of farmer cooperatives and the development of their participation in determining the development guidelines for farmer institutions that create stability and sustainability. The second type deals with the structure of the farmer cooperatives, such as rational criteria, establishment objectives, implementation process, budget, duration, target, and implementation guidelines.

In the past, the rubber farmer cooperatives called for a closer collaboration with the government for support. It suggested a lack of fortitude and resilience as if the farmer's institutions were unable to serve as a hub for resolving issues for small farmers. Besides, the world rubber price situation has been volatile and uncertain, and the prices of natural rubber depend on the price in the futures market with the speculation of market investors. In the situation of global rubber production in 2015, there were 28 rubber-producing countries with 77.60 million rai in total, and the total production was 12.0 million tons (Office of Agricultural Economics, 2015). Thailand is the second country with the most rubber plantation areas (the rubber plantation area in Thailand is 22,176,714 million rai, followed by Indonesia (Rubber Authority of Thailand, 2017). Moreover, Thailand is the world's largest producer and exporter of natural rubber and its natural rubber production is estimated at 4.5 million tons per year, with an annual export of 3,749,456 tons (BizVibe, 2022). Under those circumstances, the rubber farmer institutions that are the owners of products do not have opportunities to participate in setting the trading prices of rubber.

Although the cooperatives play an important role in promoting and assisting farmers, other factors cause the farmer institutions to lose their memberships and are not sustainable. The main factors are the motivation of small farmers to become members of the rubber farmer cooperatives, the rubber prices that the farmer institutions purchase from their members, dividend income paid by the farmer cooperatives, average refunds, and welfare. Other key factors are the convenience of traveling to sell products, the honesty of the farmers' institution committees, and the past participation that could not achieve the given policy or goal. All these factors make the farmer unaware of the importance of farmer institutions and lack confidence in farmer cooperatives; also, the farmers assumed that the group could not help or solve their problems. Some groups of farmers do not register as corporations due to several difficulties. For instance, they not only have to prepare income and expense accounts but also have to encourage the members to register as juristic persons. The framers cannot fully conform to legal acts with the status of non-cooperation.

The management lacks transparency because some members can manipulate the advantages. For instance, they can take benefits from the rubber prices that the farmer institutions purchase from members; the dividend income paid by the farmer institutions; the average refunds; the welfare; the convenience of traveling to sell products; and the integrity of the farmer institution committee and members, etc. Also, regarding the auction market of rubber products, there is a competition to launch the market, causing the separation of group members, and the government agencies promoting both policy and budget lack continuity, causing farmers to not see the benefits of farmer institutions. These reasons are the main factors of motivation that directly affect small farmers, leading to their applying for membership in rubber farmer cooperatives.

The uncontrollable external factors are other issues for the stability and sustainability of rubber farmer cooperatives, including economic conditions, societies, politics, cultures, crude oil prices, exchange rates between Thai Baht and other currencies, stock market movements, gold prices, climate conditions, natural disasters and speculation in the rubber futures market. When the rubber farmer cooperatives are stable and sustainable under a successful model of establishment, it will result in a gathering of members, products, dividends, working capital, brainstorming, and the concept of activity. Based on this background, this research investigated the determining factors of the rubber farmer cooperative's sustainability from the corporate perspective. The study objective focused on the sustainability of rubber farmers' cooperative and the impact on individual farmers who are members of the cooperative. This underscores the relevance of such groups and how they harness relationship and provide support effectively to group members. To this end, the specific objectives of the study include:

1. To ascertain the influence of the rubber farmers brand on farmers decisions.
2. To find out how perceived value affects loyalty and satisfaction to the rubber farmers' cooperative.
3. To explore the connection between trust and satisfaction with the rubber farmers' cooperative by rubber farmers.
4. To determine the influence of loyalty on sustainability.

Materials and methods

Since 1991, para rubber has been an important economic crop in Thailand. Today, Thailand is the world's No. 1 producer and exporter of para rubber, which makes hundreds of millions of baht per year for Thailand. In 2012, about 2.7 million tons of rubber was exported from Thailand, generating approximately 4 billion Baht. But in recent years, the price of rubber in the export market has been valued at about 183.64 Baht per kilogram in 2011, creating a highly volatile market and a gradual price decrease, resulting in losses for rubber farmers throughout the country (Rubber Authority of Thailand, 2017). Moreover, the continuously decreasing price of rubber raises concerns among rubber farmers throughout the country since the framers are not able to sustain the production costs with the low price of rubber.

Thailand has been recognized for its outstanding achievements in rubber production and export for over two decades. In 2014, Thailand, the world's biggest producer of para rubber, made 4.20 million tons of rubber production, with exports accounting for up to 34.37 percent, followed by Indonesia and Malaysia made rubber production of 3.17 and 0.84 million tons, equivalent to 25.94 percent and 6.87 percent of the global rubber production, respectively. Meanwhile, Thailand exported para rubber for 3.80 million tons, accounting for 37.15 percent or more than 1/3 of total para rubber export around the world. The major trading partners are China, Japan, and the United States, followed by Indonesia and Malaysia. The export was 2.90 and 1.36 million tons of para rubbers, accounting for 28.35 percent and 13.29 percent of the global rubber export volume, respectively (ERIA, 2016).

Over the past five years, natural rubber prices in Thailand have been plummeting since 2014, and the lowest price took place in 2015 because of the recession in European and American economies. Furthermore, China, the world's biggest rubber consumer, has faced a financial crisis, and the world market price of oil has been falling. Even though in 2016-2017 the rubber price has increased, it fell again in 2018 since the investors were reluctant to take a risk during the economic and political crisis, especially for international trade policy between China and America. Thus, rubber prices have fluctuated all the time.

The Sustainability Concept: Sustainable development is a key term in developing and emergent nations; moreover, some scholars and researchers have recognized and interpreted this term differently. Petushkova (2022) pointed out that the concept of sustainable development is a concept that compromises between a development-oriented group and an environmental-oriented group, in the rich zone and the poor zone. They are all satisfied with this concept because it is a concept that fosters both development and the environment. Sustainable development consists of various elements, which include:

1) The economy, which is a development to equally satisfy the needs of humans in the present era and the next eras without affecting future needs. It can produce a product that is friendly to the resources and needs of consumers.
2) The society, who's status is considered as sustainable for social development. It aims to provide humans with higher knowledge, performance, and productivity; and to promote a quality society, including a learning society, by organizing social systems as well as various businesses to be combined, harmonized, and united based on knowledge and reality.
3) Nature and the environment, which is the development of a sustainable environment that is based on the limits of natural resources and the environment, can meet current needs without adversely affecting future needs, and maintain the environment and nature as much as possible.
4) 4) The humans, applied to sustainable development: It is important to serve human development, both physical and mental aspects, such as good health, diligence, patience, responsibility, skill, knowledge, and expertise.
5) Technology, which is a technological development with the use of supportive technology. The framework of sustainable performance describes the application of sustainable development concepts to supply chain management to improve efficiency that affects the competitiveness of companies and organizations.

The frameworks of actions on the economy, society, and environment, which are mutual relationships, allow scholars to identify the most efficient approach from a sustainable development perspective, resulting in stable development. Moreover, this leads to a stable economy and encourages self-reliance, and economic immunity, as they are prepared for changes. Sustainable development is growth that does not destroy the environment; instead, it is sustainable and beneficial to the society for the long term.

Brand Image

In this research, the element of brand image proposed by Wijaya (2013) has been adopted as one of the frameworks since it is relevant to the sustainable model of the rubber farmer cooperative registered as a juristic person. The term "brand identity" refers to the name, logo, color, slogan, tagline, vision, and personality of the executive or typeface of the cooperative or group of rubber farmers. Previous research suggests that brand image is not only associated with perceived value but also customer loyalty. For instance, Jung et al. (2020) conducted a study on sustainable marketing activities in the traditional fashion market and brand loyalty. The finding revealed that sustainable marketing activities resulted in brand image, trust, and satisfaction positively. The activities also created brands of royalty.

Brand perceived value

Anderson et al. (1993) and Majerova (2020) noted that consumers' perceived value is a result of whether they are satisfied with the product or service. It is divided into two types: the perceived value of price and the perceived value of quality. Petrick (2002) reasoned that the instrument that had been used to measure the perceived value could merely indicate tangible results. Thus, he develops an instrument that covers other dimensions. Zeithaml (1998) developed the model of how perceived value could be measured. This method is called the SERV-PERVAL scale. The results of many studies revealed that SERV-PERVAL is reliable and accurate. The model consists of five related dimensions: quality, emotional response, monetary price, and behavioral price.

Concepts of Satisfaction

Satisfaction with service quality can be measured by the perception and evaluation of service quality from the feedback that the providers gain from various situations and timings and the expectation that the consumer has of the service. Hence, the components of consumer satisfaction and service quality are composed of two key elements. Chaipunya (1998) pointed out that attitudes are measured in the following ways: (1) Questionnaire: The questionnaire aims to gather information from respondents. The respondents are required to answer a series of question that is relevant to several dimension of satisfaction. (2) Interviewing: Structured interviews should be used for collecting reliable data and (3) Observation: This method can be performed by observing the language use, manner, and reaction of the target group. The procedure for the observation should be structural.

Brand Loyalty

Aaker (2014) noted that brand loyalty is the positive view and satisfaction of the consumer with a product. This perception leads to the tendency of consumers to frequently purchase the products. Having a strong and positive relationship with the consumer can benefit a business over its competitors. That the competitors offer the same quality of products or services is not important since the consumers still have confidence in the particular brand, and it continuously meets the consumers' needs. For this reason, brand loyalty is formed (Kositsurangkakul, 2003; Chaveesuk et al., 2020). Brand loyalty is probably a result of a positive attitude toward the brand and whether the consumers have confidence in the brand. It also comes from when the brand can meet the consumers' needs or when the consumers continue purchasing the same brand. However, the marketing strategy plays a crucial role in brand royalty since brand royalty should be built, otherwise, the consumer will purchase other brands.

Trust

Trust reflects the effectiveness, identity, and culture of the organization and it leads to the sustainability of the organization (Yuen et al., 2018). Fazal and Kanwal (2017) studied the factors that lead to brand royalty. The result revealed that the brand trust of customers plays an important role in creating brand loyalty. The most satisfied customers are the loyal ones. In Pakistan, customers preferred price comparisons among brands, which influence their loyalty to one brand over another. Trust in a brand is a result when the consumer can rely on the brand. Trust is one of the factors that lead to brand loyalty. For instance, Park and Kim (2015) analyzed the different sustainable fashion brands and fast fashion brands with a sample of 556 respondents. The results suggested that consumers form brand loyalty toward sustainable versus fast fashion in a different manner. Hence, the operators should put more emphasis on improving trust to increase loyalty among customers.

Conceptual framework and hypothesis development

From the discussion of the literature review above, the following conceptual framework and research hypothesis were developed

Hypothesis 1 (Hl): Brand Image has a positive effect on influencing perceived value.

Hypothesis 2 (H2): Brand Image has a positive effect on loyalty.

Hypothesis 3 (H3): Brand Image has a positive effect on sustainability.

Hypothesis 4 (H4): Perceived value has a positive effect on loyalty to the organization.

Hypothesis 5 (H5): Perceived value has a positive effect on satisfaction.

Hypothesis 6 (H6): Trust has a positive effect on satisfaction.

Hypothesis 7 (H7): Satisfaction has a positive effect on loyalty to the organization

Hypothesis 8 (H8): Trust has a positive effect on loyalty.

Hypothesis 9 (H9): Loyalty has a positive effect on sustainability.

Hypothesis 10 (H10): Loyalty significantly mediates the effect of independent variables on sustainability.

Constructs

The study adopted a descriptive quantitative survey design, aimed to define the determining factors of the rubber farmers' cooperative's sustainability. The population was 434 Thai rubber farmer groups/cooperatives that are corporations. The respondents were purposively selected and classified into 3 groups, namely as follows: 1) the group of rubber farmers in the advanced stage or developed stage; 2) the group of rubber farmers in the developing stage, and 3) the group of rubber farmers in the initial stage. Questionnaires were used as an instrument for data collection. The data was analyzed using Structural Equation Modeling (SEM), which is a statistical model that describes the linear causal relationship between external latent variables through the intermediate variables into internal latent variables. The variables included brand image; perceived value; Satisfaction; Trust; Loyalty and Sustainability.

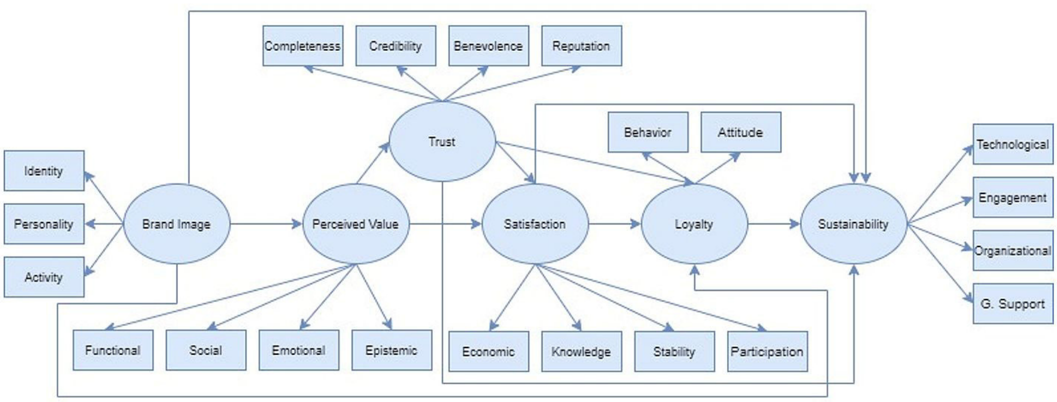
Data Collection and Analysis

The closed-ended questions were applied to ask respondents to choose from a distinct set of responses. The researcher sent a questionnaire to the sample group by sending a letter, online, or by mail, and handing out the questionnaire directly to the sample group. The questionnaire consists of questionnaires that have been reviewed by experts, along with a letter from King Mongkut's Cooperative of Technology Ladkrabang requesting cooperation. The first analysis was done on the basic statistics of samples by using descriptive statistics such as Frequency, Percentage, Mean, Standard deviation, Coefficient of Variation, Skewness, and Kurtosis. The Pearson's product-moment correlation coefficients are used to see the linear relationship among various variables. Confirmatory Factor Analysis to evaluate model fitness. Path Analysis using SEM was used for the survey of direct influence, indirect influence, and overall influence of factors affecting the sustainability of the rubber farmers' corporation.

Results and discussion

Demographic characteristics

The first evaluation done was for the demographic characteristics. A summary is presented in Table 1.



Source: Authors' elaboration

Figure 1: Conceptual framework.

		Frequency	Percentage
Gender	male	284	0.65
	female	152	0.35
			0.00
Age	20 -30	87	0.20
	31 -40	180	0.41
	41 - 50	102	0.24
	50+	65	0.15
			0.00
Rubber farming period	0-5 years	172	0.40
	6-10 years	209	0.48
	10+ years	53	0.12
			0.00
No. Rubber products	0-10kg	149	0.34
	10-50kg	189	0.44
	50+ kg	96	0.22
			0.00
Member of cooperative	yes	329	0.76
	no	105	0.24

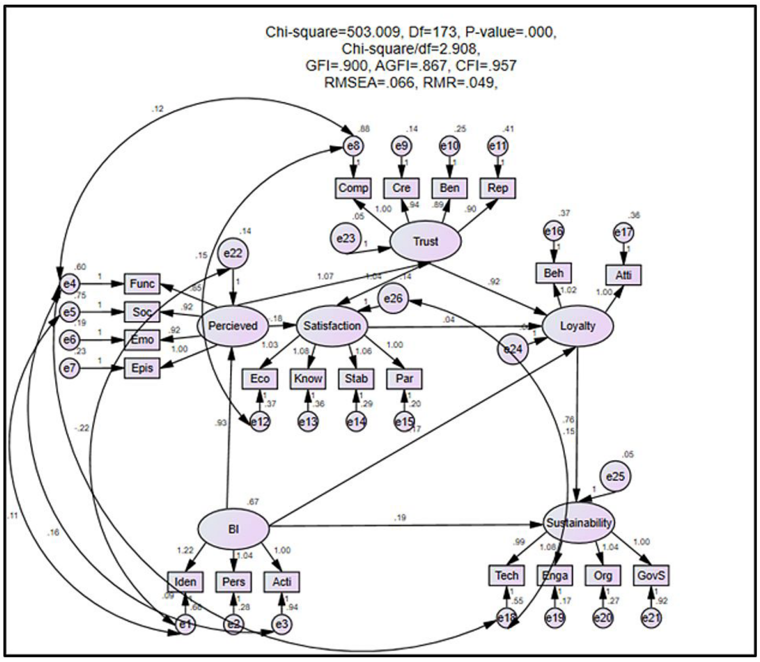
Source: Authors' elaboration

Table 1: Demographic features of respondents.

The results indicated that the majority of male respondents represented 65% of the sample, followed by female respondents, who comprised 35% of the sample respondents. Another characteristic that was evaluated was the age variable. The majority age group was between 30 and 40 years (41%) followed by those aged 40–50 years (24%), then there was the age group 20–30 years (20%) and lastly, the age group above 50 years (15%). Another variable that was evaluated was the rubber farming period in which the respondents had been engaged. The majority indicated 6-10 years (48%) followed by 0-5 years (40%) and lastly, 10+ years (12%). The number of rubber products was also considered where the majority was 10-50 kg, followed by 0-15 kg and lastly 50+ kg (22%). The respondents were also asked whether they were a member of the cooperative and 76% agreed while 24% did not.

Evaluation of the model

The proposed model for the study was analyzed for suitability. The confirmatory factor analysis (CFA) was conducted to determine the fitness of the model used in the analysis. The fitness aspects that were evaluated included model chi-square, goodness of fit (GFI), adjusted goodness of fit (AGFI), comparative fit index (CFI), root mean square error or approximation (RMSEA), root mean square residue. As presented in the following figure, GFI = 0.900, CFI = 0.957, satisfied the required threshold of >0.900. AGFI = 0.867 satisfied the required minimum threshold of >0.800. The Chi-square/df = 2.908 satisfied the required threshold for <5.00. The RMSEA = 0.066 which satisfied the required threshold of <0.08. These thresholds were suggested by Tucker and Lewis (1973), Byrne (1994), Schumacker and Lomax (2004) and Kline (2015). The satisfaction of these threshold confirmed that the data and study constructs fitted well to the model as shown in Figure 2.



Source: Authors' elaboration

Figure 2: Model evaluation.

The reliability and validity of the model was also evaluated, in addition to the model fitness. The reliability was evaluated using Cronbach's alpha and composite reliability. The required threshold should be >0.8 (Diamantopoulos et al., 2012; Trizano-Hermosilla and Alvarado, 2016). The results presented in Table 2 showed that these threshold were met clarifying the reliability of the variables. The validity of the model was evaluated using standardized factor loadings and average variance extracted. The threshold is considered to be >0.5 (Black and Babin, 2019). The threshold was also satisfied, clarifying the validity of the variables.

In addition to the above model evaluation, the discriminant validity test was conducted and presented in Table 3. The Fornell-Lacker criterion was applied where it measures the degree of differences between the overlapping construct. n the assigned construct have to be higher than all loading of other constructs with condition that the cut-off value of factor loading is higher than 0.70. This criterion was satisfied, confirming the construct validity of the research model.

The next analysis was the evaluation of the hypotheses of the study. The structural equation modelling was conducted to evaluate the relationship between the study variables. The results are presented and summarized in the Table 4 and Figure 3.

Variables		Items	Standardized factor loadings	Cronbach's alpha	Composite Reliability	AVE
BI	→	Acti	0.645			
BI	→	Pers	0.85	0.892	0.922	0.721
BI	→	Iden	0.777			
Loyalty	→	Beh	0.802	0.972	0.975	0.851
Loyalty	→	Atti	0.804			
Perceived	→	Epis	0.87			
Perceived	→	Emo	0.872	0.867	0.956	0.682
Perceived	→	Soc	0.668			
Perceived	→	Func	0.683			
Satisfaction	→	Par	0.893			
Satisfaction	→	Stab	0.869	0.952	0.957	0.859
Satisfaction	→	Know	0.85			
Satisfaction	→	Eco	0.836			
Sustainability	→	GovS	0.632			
Sustainability	→	Org	0.843	0.913	0.856	0.638
Sustainability	→	Enga	0.899			
Sustainability	→	Tech	0.718			
Trust	→	Comp	0.705			
Trust	→	Cre	0.919	0.852	0.897	0.762
Trust	→	Ben	0.857			
Trust	→	Rep	0.797			

Source: Authors' elaboration

Table 2: Reliability and validity estimation.

	1	**2**	**3**	**4**	**5**	**6**
BI	**0.897**					
Loyalty	0.782	**0.8323**				
Perceived	0.687	0.818	**0.973**			
Satisfaction	0.783	0.672	0.732	**0.893**		
Sustainability	0.872	0.723	0.792	0.732	**0.892**	
Trust	0.836	0.732	0.863	0.682	0.739	**0.983**

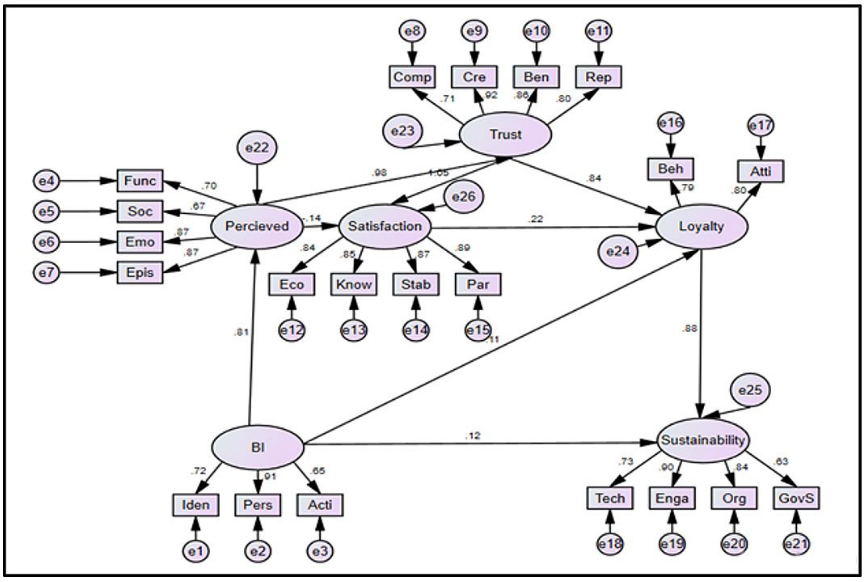
Source: Authors' elaboration

Table 3: Discriminant validity.

Path Relationships					β	S.E.	C.R.	P
Direct Effects								
BI	→			Perceived	0.826	0.064	12.98	***
BI	→			Loyalty	-0.104	0.061	-1.694	0.09
BI	→			Sustainability	0.111	0.052	2.16	0.031
Perceived	→			Satisfaction	-0.151	0.327	-0.461	0.644
Trust	→			Satisfaction	0.988	0.296	3.338	***
Satisfaction	→			Loyalty	0.194	0.077	2.515	0.112
Trust	→			Loyalty	0.705	0.096	7.352	***
Loyalty	→			Sustainability	0.846	0.077	11.03	***
Perceived	→			Trust	1.093	0.063	17.25	***
Indirect Effects								
BI	→	Loyalty	→	Sustainability	0.672	0.872	2.92	***
Satisfaction	→	loyalty	→	Sustainability	0.089	0.0563	8.872	***
Trust	→	Loyalty	→	Sustainability	0.278	0.0826	4.283	***
Perceived	→	Trust	→	loyalty	0.783	0.278	1.774	***

Source: Authors' elaboration

Table 4: Path relationships of the findings.



Source: Authors' elaboration

Figure 3: Empirical results.

The results of the SEM analysis indicate that BI has a positive and significant effect on perceived value (β = 0.826, $p<0.01$), confirming H1. BI was found to have negative and significant effect on loyalty (β = -0.104, $p<0.05$), rejecting H2. BI was found to have positive and significant effect on sustainability (β = 0.111, $p<0.05$), confirming H3. Perceived value was found to have negative an insignificant effect on satisfaction (β = -0.151, $p>0.05$), leading to rejection of H4. Trust was found to have a positive and significant effect on satisfaction (β = 0.988, $p<0.01$), confirming hypothesis 5. Satisfaction has a positive and insignificant effect on loyalty (β = 0.194, $p>0.05$), hence rejecting H6. Trust was found to have a positive and significant effect on loyalty (β = 0.705, $p<0.01$), confirming hypothesis 7. Loyalty has a positive and significant effect on sustainability (β = 0.846, $p<0.01$), confirming hypothesis 8. Perceived value has a positive and significant effect on trust (β = 1.093, $p<0.01$), confirming hypothesis 9. In addition, the mediating role of loyalty was evaluated. The results was found to indicate that loyalty was a significant mediator of the effects of BI, satisfaction and trust on sustainability ($\beta = 0.672, 0.089, 0.278$ $p<0.01$) respectively.

The purpose of this empirical research was to investigate the factors that influence the rubber farmers' cooperative sustainability aspect. Interesting results have been obtained regarding the relationship between the variables considered, and the effect of these variables on the sustainability of the rubber farmer's cooperatives. To start with, this research found that the sustainability of the rubber farmers' cooperatives is influenced by three factors – loyalty, brand image, and satisfaction. Sustainability of rubber farmer's cooperative was found to be significantly and positively be influenced by loyalty and its associated aspects such as behavior and attitude. If brand loyalty was improved by 1 unit, then sustainability would be improved by 0.543 units and vice-versa. These results were supported by Ismail et al (2019) whose results indicated that five major drivers showed the co¬operative's sustainability including strong members' support, a better support system, effective management, an established business strategy and direction, and good knowledge required of the board members. Satisfaction was also found to positively and significantly influence sustainability of rubber farmer's cooperatives. The aspects of satisfaction that were found to influence sustainability include economics, knowledge, stability, and participation.

Brand image was found to significantly influence the sustainability of the rubber farmer's cooperatives. The aspects of brand image that were considered relevant in this analysis included brand identity, brand personality, and activity. These results are supported by Ana Tur-Porcar et al (2018) whose results indicated that one of the factors that related rubber farmer cooperatives registered as juristic persons in Thailand was human relations, and business activity. Ethical principles and values, together with competitive intelligence, are crucial for undertaking actions that lead to sustainability.

Another important result to consider is that, perceived value has significant effect on trust of rubber farmer's cooperatives. The aspects of perceived value worth considering in this case include the functional value, social value, emotional value, and epistemic value (Kot and Brzezinski, 2015; Ayu et al., 2020). These results were in line with that of Karajaluoto et al. (2012) whose findings concluded that trust and value are the key factor of long-term relationships. Furthermore, it was found that perceived value, which is positively associated with trust leads to the relationship. Business image was also found to have positive and significant effect on perceived value of the rubber farmer's cooperatives. This was according to the findings of Amir Jalilvand et al. (2016) that corporate reputation was associated with perceived value.

The study critically found that a positive and significant influence of trust on both satisfaction and loyalty. According to the findings of this study, a unit increase in trust would lead to a more than a unit increase in both satisfaction and loyalty of the rubber farmers' cooperatives. It therefore indicated that trust is a critical factor as far as better performances of rubber farmers' cooperatives are concerned. In line with these findings, Koupai et al. (2015) result indicated that the trust had an effect on customer loyalty since it created customer satisfaction and form purchasing habit of the customer. Moreover, satisfaction variable was associated with trust and had a positive and significant influence on establishment of loyalty.

From the findings of this research, several recommendations are relevant. First, the rubber farmers cooperatives, over a long period of time have been in situations that needs urgent re-evaluation and improvement. The past activities organized by the rubber farmer cooperatives could not motivate and be a model of stability and sustainability to convince small rubber farmers to become the members and participate in the activities, due to many factors. There has also been lack of strength and ability to survive as if the farmer institutions were not able to be a center to solve problems for small farmers. To address this issue, it is relevant to improve the sustainability of the rubber farmer cooperatives. There are three factors that should be improved, in order to improve the rubber farmer cooperatives sustainability. These are brand image, loyalty, and satisfaction. For the brand image, the specific factors to improve include brand identity, brand personality, and activity; for the loyalty, the specific factors to improve include behavior and attitude; while the specific factors to improve for satisfaction include economics, knowledge, stability, and participation. This research also recommends that to improve the rubber farmer cooperatives loyalty and satisfaction, trust factor should be addressed and improved to significant levels.

Conclusions

Several conclusions could be highlighted from the research regarding the sustainability of rubber farmer cooperatives as corporations. The first conclusion is that three factors are significant when considering targeting and improving the sustainability of rubber farmer cooperatives as a corporation. These factors include brand image, loyalty, and satisfaction. Each of these variables has a specific aspect that should be considered necessary. For brand image, these factors include brand identity, brand personality, and activity; for loyalty, these factors include behavior and attitude; while the factors for satisfaction include economics, knowledge, stability, and participation. It is also concluded that trust is a critical factor as far as the satisfaction and loyalty of rubber farmer cooperatives are concerned. Trust has an effect on customer loyalty since it creates customer satisfaction and form purchasing habit of the customer. The limitation of this research is that it focused on Thailand's rubber farmer cooperatives specifically as corporations; therefore, the application of these results outside of this scope should be made with these considerations. Future studies can compare the applicability with rubber farmers in Thailand and other ASEAN countries to understand the dynamics of the data from Thailand. Another limitation was the use of only rubber farmers' who are members of rubber cooperatives. Future studies should consider rubber farmers who are not affiliated with any cooperatives. This is to ascertain their views on rubber cooperatives and why they are yet to join one, especially whether factors such as trust, attitude, brand image, and perception have any influence on their current and future decisions to join a cooperative.

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Direct Payments Distribution Between Farmers in Selected New EU Member States

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Abstract

The study aims to identify the degree of direct payments concentration in selected Central and Eastern European Member States (compared to the entire EU) and outline the perspectives and recommendations for the next programming period. The spatial scope of the study includes Poland, the Czech Republic, Hungary and Bulgaria. The time scope covers the period 2009–2019. The survey indicates that the payments distribution in Bulgaria, the Czech Republic, Hungary, and to a lesser extent also in Poland, is highly unbalanced. The analysed countries used the redistribution instruments, optional for the Member States, which were introduced by the 2013 CAP reform, to a moderate extent, in order to ensure a more even funds distribution between the beneficiaries. It cannot be ruled out that instruments ensuring a more even funds distribution would be politically easier to introduce at the EU level than at the national level. Nevertheless, also in the next financial perspective, in line with the subsidiarity principle, this issue is left to the Member States.

Keywords

Capping, Common Agricultural Policy, concentration of support, income inequalities, redistributive payment, single area payment.

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Introduction

The allocation of direct payments under the First Pillar of the European Union (EU) Common Agricultural Policy (CAP) is widely discussed not only in the scientific literature but also among policymakers, farmers and other stakeholders. Therefore, research in this area has a large application potential, and focuses in particular on (i) determining the impact of financial support on agricultural income and recognising its effects on the farm income distribution (Severini and Tantari, 2013; Sinabell et al., 2013; Severini and Tantari, 2015; Deppermann et al., 2016; Piet and Desjeux, 2021), (ii) determining the impact of financial support on the economic performance of farms and the entire sector – production profitability and competitiveness (Ciliberti and Frascarelli, 2015), technical efficiency (Minviel and Latruffe, 2017), productivity (Kazukauskas et al., 2014; Staniszewski and Borychowski, 2020), including capital productivity (Czyżewski and Smędzik-Ambroży, 2017), and (iii) determining the importance of financial support in promoting sustainable agricultural practices (Sadłowski et al., 2021) or in increasing the level of socio-economic sustainability of farms (Volkov et al., 2019b).

Fair criteria for the funds distribution between EU Member States and a fair support system to farmers in individual countries are still in statu nascendi. In the Treaty on the Functioning of the EU (Official Journal of the European Union, 2016), the CAP's objectives include "to ensure a fair standard of living for the agricultural community, in particular by increasing the individual earnings of persons engaged in agriculture". Thus, when formulating the most general (of the highest order) objectives of the CAP, the need to increase agricultural income was emphasised, and – since it is to ensure an adequate standard of living of the rural population – proportionally more aid should be directed to farmers with low income. Espinosa et al. (2020) see the proper targeting of direct payments as one of the main challenges faced by policymakers shaping the CAP.

Direct payments reduce the gap between agricultural incomes and those obtained in other sectors of the economy. At the same time, they usually have an equalising effect on incomes within the agricultural sector (Severini and Tantari, 2013; Severini and Tantari, 2015), wherein studies also indicate that not every CAP reform so far has been conducive to reducing the polarisation of farmers' incomes (Sinabell et al., 2013). When comparing the results of research done in this area, it should be taken into account not only their temporal and spatial scope, but also the material scope, i.e. which components of the direct support system were included in the analysis.

In the case of Central and Eastern European countries, an important aspect of studies is the impact of CAP on the processes of agricultural transformation and the pace of convergence of agricultural sectors in this group of countries with the agricultural sectors of the EU-15 (Bojnec and Fertő, 2015; Csaki and Jambor, 2016; Feher et al., 2017; Volkov et al., 2019a). A number of studies (Beluhova-Uzunova et al., 2017; Beluhova-Uzunova et al., 2020; Grochowska et al., 2021) analysed the distribution of financial aid through the direct payment scheme. The results of these studies give rise to the assessment of the allocation of support in terms of fairness as well as effectiveness and efficiency in achieving the assumed goals. In this context, a significant value can be added by the development of tools accelerating the economic convergence of EU Member States agricultural sectors and levelling the inter- and intra-sectorial discrepancy of income.

In general, the accession to the EU had a positive impact on the agricultural sectors of the Central and Eastern European countries, with the path of transformation and the progress of this process varying from country to country. These trends can be explained with the differentiation of (i) the degree of resource availability for agriculture, (ii) farm structures, (iii) institutional frameworks, and (iv) national policies (Csaki and Jambor, 2009). Despite the ongoing processes of sectorial and structural transformations, initiated or strengthened by the instruments of the CAP, the domestic agricultural models still differ significantly.

In the opinion of Volkov et al. (2019a), one of the main drawbacks of the direct payment system is that too much of the funds are allocated to already developed agricultural sectors in the old EU Member States, which is not conducive to achieving the convergence objectives of agricultural sectors and sustainable rural development across the EU. According to Sadłowski (2017b), in discussions on the reform of the method of funds distribution for the direct payments between the EU Member States (i.e. rules for setting of the so-called national ceilings), one should in particular consider the use of a multi-criteria method that would integrate a number of variables describing the agricultural sectors of the individual countries.

The values dispersion of the measures of the uneven direct payments distribution between the beneficiaries and the differentiation of the degree of the Lorenz curve concave to the center of the unit square are largely the result of differences in the agrarian structure of individual countries and in the shape of the direct support system. The heterogeneity of direct support systems is a consequence of the fact that the EU legal framework provides the EU Member States with a relatively large scope of decision-making in the selection of instruments and their financing structure, as well as the conditions for granting individual types of payments (Sadłowski, 2020).

The aim of the study is to identify the degree of concentration of financial support under the direct payments scheme in selected Central and Eastern European Member States (compared to the entire EU) and to outline the perspectives and recommendations for the next programming period. The importance of this issue is related to the high impact of direct payments on farm income.

The structure of the study is the following: First, after the introductory section, the research methods are described and the spatial and temporal scope of the research and data sources are indicated. The next part presents the results of empirical research, confronting them with the results of similar studies. As part of the discussion of the results, a comparative analysis of systemic solutions applied in individual countries, which largely affect the concentration of funds allocated in the form of direct payments, was performed. The last part of the paper contains the final conclusions and comments on the possibility of influencing of the aid concentration, considering the legal conditions of the next programming period and the reality of political decision-making.

Materials and methods

The most frequently used measure of the uneven distribution of the total fund of the value of a feature between general population units is the Gini coefficient (Alvaredo, 2011). On the other hand, the Lorenz curve is a set of points on the plane, the ordinate of which is the cumulative share of total income / assets, and the abscissa is the cumulative share of units obtaining income / having assets, and is used to graphically present the income / wealth distribution possessed (Ogwang and Rao, 2000). In the graphic interpretation, the Gini coefficient is the double area of the figure drawn by the line of even distribution (i.e. the diagonal of the unit square) and the Lorenz curve (Podgórski, 2010).

The results presented in this study concern the uneven aid distribution under the direct support scheme between farmers. Therefore, the equivalent of income is the amount of granted direct payments, and the counterpart of units receiving income are the beneficiaries of the direct support scheme for farmers.

The value of the Gini coefficient was estimated using the following formula (Podgórski, 2010; Starzyńska, 2012):

$$G = 1 - \sum_{i=1}^{k} (S_{z_{i-1}} + S_{z_i}) \times w_i \quad (1)$$

where: G – Gini coefficient; k – number of classes in the distributive series; i =1,2,…, k – class number of a distributive series; $S_{z_{i-1}}$ – cumulative share of the feature value for the class with number (i-1); S_{z_i} – cumulative share of the feature value for the class with number i; w_i – index of the abundance structure for the class with the number i.

On the other hand, the coordinates of the points forming the Lorenz curve are (F_{w_i}; S_{z_i}), where F_{w_i} (abscissa) is the cumulative index of the abundance structure for the class with the number i, and S_{z_i} (ordinate) is the cumulative share of the feature value for the class number i.

In case of this study, the Lorenz curve is a set of points, each of which carries information on what part of the beneficiaries population gets a given part of the funds pool paid in the form of direct payments or what part of the funds pool paid in the form of direct payments is absorbed by a given part of the beneficiaries population. Equality depicted by the line of equality (see Figure 2) would mean granting each farmer (regardless of the farm size, production specialization, area and structure of crops, number of farm animals owned, production volume, etc.) the same amount of aid, i.e. in fact granting a lump sum support.

In this paper, a comparative analysis shows the degree of support concentration and changes in the uneven of aid distribution in selected Member States as compared to the entire EU in the period 2009–2019.

The spatial scope of the study covers four countries of Central and Eastern Europe, namely Poland, the Czech Republic, Hungary and Bulgaria. In terms of population, these countries are ranked 1st, 3rd, 4th and 5th respectively among the 13 new EU Member States accessed the EU on or after May 1, 2004. Basic data on agriculture of the analysed countries in 2016 are summarised in Table 1.

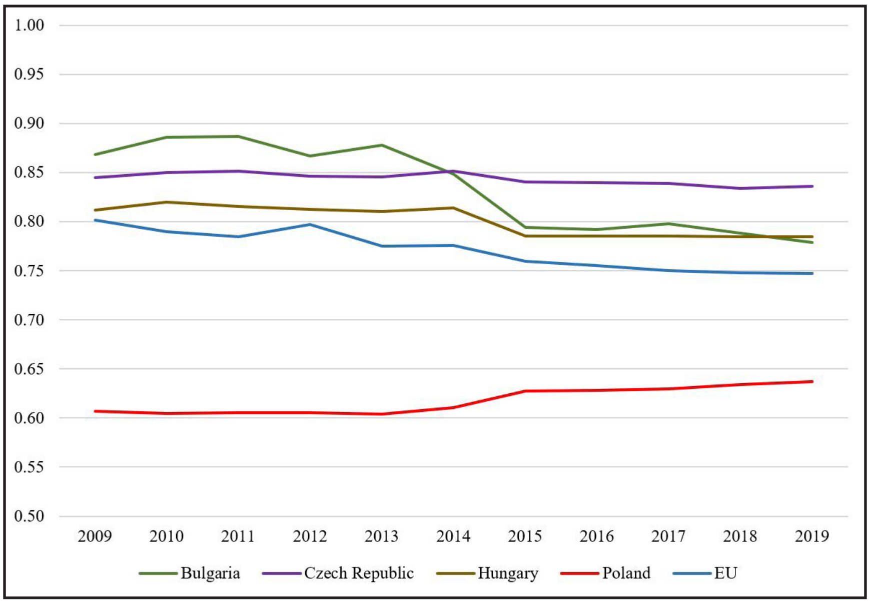
Results and discussion

Figure 1 shows the changes of the degree of direct payment concentration in the selected countries in 2009–2019 compared to the entire EU. The results indicate that for the three countries (Bulgaria, the Czech Republic and Hungary)

Country	Farm number	Utilised agricultural area (ha)	Average farm area (ha)	Value added of agriculture, forestry, and fishing (% of GDP)
Bulgaria	202 720	4 468 500	22	4.05
Czech Republic	26 530	3 455 410	130	2.09
Hungary	430 000	4 670 560	11	3.89
Poland	1 410 700	14 405 650	10	2.54

Source: own study based on Eurostat (2022) and World Bank (2022) data

Table 1. Basic data on agriculture of the analysed countries (2016).



Source: own study based on European Commission (2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019b, 2020, 2021) data

Figure 1: The value of the Gini coefficient as a measure of the degree of direct payments concentration in the countries analysed compared to the EU in the period 2009–2019.

analysed the value of the Gini coefficient was higher than the value of this coefficient calculated for the EU. Only in Poland, the concentration of aid was lower than in the EU, and the difference – although it is decreasing due to the convergent course of the charts – is still large.

The most marked decrease in the support concentration is observed in Bulgaria, with the decrease occurring from the highest (reaching 0.887) levels out of the compared countries. The high value of the index is due to the highly polarized structure of Bulgarian agriculture. In the period 2010–2020, the number of agricultural holdings in Bulgaria decreased by more than 64%, and the average size of the farms increased from 10 to 33 ha (Ministry of Agriculture, Food and Forestry, 2021). In Bulgaria, many small farms do not meet the minimum requirements for receiving payments and are therefore not included in the calculation. Although there is a tendency towards a more equal aid distribution, it should be highlighted that the decreasing payment concentration ratio is largely a consequence of the disappearance of small farms.

The greatest stability is demonstrated by the Gini coefficient calculated for the Czech Republic (0.834–0.852). Although there has been a slight downward trend since the middle of the analysed period, the index is still high, which is a consequence of the high land concentration in the conditions of a strong dependence of the support amount on the farm area. This country is distinguished by the largest average farm size in the EU, but at the same time the growing number of farms and decreasing average farm area – this is a opposite trend compared to EU where the number of farms is declining and the average farm size is increasing (Janovska et al., 2017). As a result of this process the degree of payment concentration in the Czech Republic has decreased over last time.

In Hungary, in the period investigated, the degree of support concentration was the closest to the EU level. Land use regulations, degressivity and capping contributed to decreasing farm sizes by splitting large production units into smaller ones. From 2014 to 2016, the number of farms with over 1200 ha (affected by capping) decreased by 41%. On the other hand, the number of holding sizes 600–1200 ha and 300–600 ha increased by 36% and 15%, respectively (Szerletics, 2018). Since 2015 the value of the Gini coefficient has remained almost constant at around 0.785, which is now very close to the value of this indicator calculated for Bulgaria.

Poland is the only country with a growing uneven of aid distribution in recent years, with different trends in the individual programming periods (relative stability versus moderate growth). On the other hand, Poland is the only country covered by the research with the Gini index below the EU level.

Based on the Lorenz curves presented in Figure 2, it can be concluded that the payments distribution in the analysed countries gradually became similar. The trend towards a more even support distribution observed in Bulgaria has led to a similar picture to Hungary, and the Czech Republic is now leading in terms of unequal of aid distribution. It must be noted that in Hungary the land transaction act accompanied by the introduction of degressivity and capping contributed strong to this result. Each year Poland was distinguished by the most even support distribution. Nevertheless, the Lorenz curve drawn for this country is moving further away from the equality line (it is more and more concave to the center of the unit square), which means that the payments allocation is becoming less and less egalitarian.

In Bulgaria, 10% of the funds were absorbed by approx. 85% of the smallest beneficiaries in 2009, less than 80% – in 2014, around 65% – in 2019. By contrast, 10% of the largest farms concentrated more than 85% of the funds in 2009. In 2014, they received approx. 80% of the funds, and in 2019 – approx. 70%.

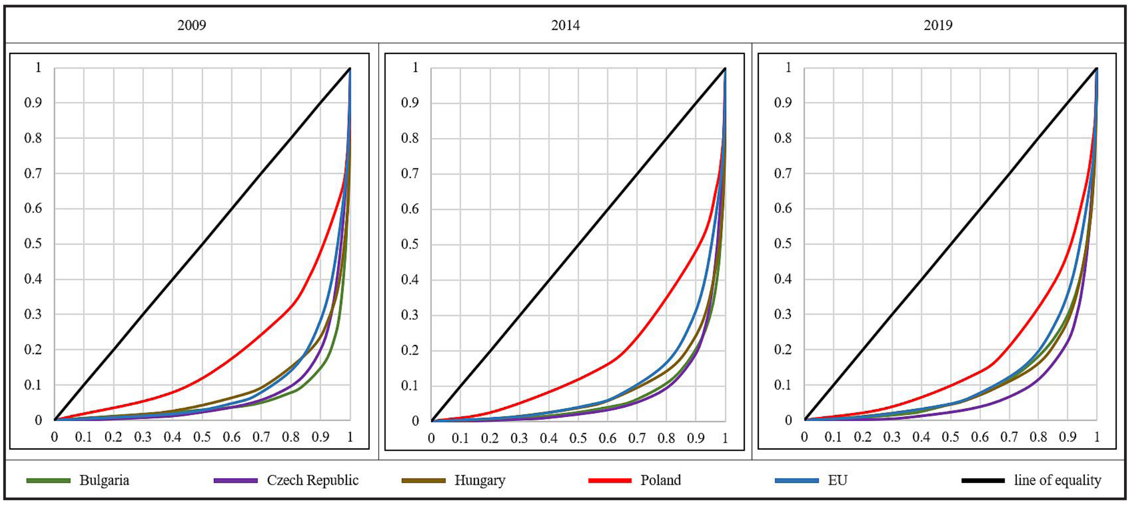
About 80% of the smallest farms receive only 10% of the national ceiling in the Czech Republic. On the other hand, 10% of the largest beneficiaries absorb as much as 80% of the support.

In Hungary, 10% of funds distributed under direct payments is sufficient to meet about 70% of the smallest beneficiaries. On the other hand, 10% of the largest farms absorbed approx. 75% of funds in 2009 and 2014, and approx. 70% in 2019.

In Poland, in 2009 and 2014, about 45% of the smallest beneficiaries absorbed 10% of the total granted payments, and in 2019 1/10 of the total support was granted to 50% of the smallest farms. On the other hand, less than 10% of the largest farms receive 50% of the direct payments.

In 2019, in Bulgaria and Hungary, the aid distribution was very similar to the support distribution in the EU in case of 70% of the smallest beneficiaries (almost overlapping Lorenz curves on section $x \in [0;0,7]$). On the other hand, in these two countries the largest beneficiaries receive a much larger part of the funds compared to the EU, which determines a higher Gini coefficient in these countries as in EU.

According to some authors (Csaki and Jambor, 2009; Severini and Tantari, 2013; Beluhova-Uzunova et al., 2020), a more even funds distribution between beneficiaries should be ensured. This should stimulate sustainable agricultural development (Kryszak, 2016) and promote social balance thanks to broader acceptance of the applied solutions. Since the reform of the CAP, which was implemented with effect from 2015, a more egalitarian payment distribution can be achieved by applying a redistributive payment (the redistributive impact of this instrument is so greater, the greater part of the national ceiling is allocated to its financing) and a mechanism of payments reduction in an appropriately restrictive – from the point of view of large farms – form. Nevertheless, the practice of implementation direct support



Source: own study based on European Commission (2011, 2016, 2021) data

Figure 2. Lorenz curves illustrating the uneven direct payments distribution between beneficiaries in the countries analysed compared to the EU in 2009, 2014 and 2019.

schemes shows that the EU Member States use only to a small extent the possibilities of reducing the degree of payment concentration. Moreover, the degree of use by a given country of the redistributive potential of instruments reducing disproportions in the support amount granted per beneficiary is not related to its place in terms of uneven funds distribution between farmers (Sadłowski, 2017a). Taking into account, on the one hand, the national decisions on the direct support system (European Commission, 2019a), including on the shape of the payment reduction mechanism (Table 2), and on the other hand – the possibilities provided by EU regulations (European Parliament and Council of the European Union, 2013), it can be concluded that:

1. Among the investigated countries, only Poland and Bulgaria introduced the redistributive payment, allocating for its financing appropriately approx. 8.5% and approx. 7% of the national ceiling, respectively, while the EU regulations allow for the financing level of this payment to equal 30% of the national ceiling. Although in Bulgaria a smaller part of the national ceiling has been set aside for financing the redistributive payment than in Poland, and the width of the hectare range covered by this payment is greater in Bulgaria (0; 30) than in Poland (3; 30), the redistributive payment rate (in EUR/ha) in Bulgaria was much higher. In Bulgaria, the redistributive payment resulted in a strong relative increase in the average level of support per hectare of agricultural land in small farms, which is a consequence of the fact that they constitute a relatively small group in this country, and thus the relatively small funds pool distributed under the redistributive payment allowed on the relatively strong increase of the average level of support per hectare in this group of farms (Sadłowski, 2022).
2. Mechanism of reduction of single area payment exceeding EUR 150,000 in the most restrictive form was introduced by Poland (reduction coefficient of 100%, i.e. capping, at EUR 150,000). A reduction coefficient higher than the minimum required by EU regulations, which is 5% for amounts exceeding EUR 150,000, was also applied by Hungary, but only for amounts exceeding 176,000 EUR (reduction by 100%) and Bulgaria, but from an even higher threshold, namely from EUR 300,000 (reduction by 100%). The Czech Republic applied a reduction coefficient at the lowest possible level (5%) to the entire surplus of the single area payment above the threshold of 150,000 EUR (no gradation of the reduction coefficient). Additionally, Bulgaria strongly limited the restrictiveness of the payment reduction mechanism, allowing beneficiaries to deduct the costs of hired labour from the reduction base.

Thus, among the countries included in the study, the redistributive potential of the two instruments mentioned above was used to the greatest extent by Poland, i.e. the country with the lowest support concentration. This contributed to a reduction in the dynamics of the increase in the concentration coefficient observed since 2013. Considering the possibilities offered by EU regulations, the degree of use by Poland of the redistributive payment and the payment reduction mechanism as instruments reducing the uneven aid distribution can be described at most as moderate. However, the caution in introducing restrictive redistribution mechanisms may result from Member States' concerns about the effectiveness of the provisions to prevent granting unreduced payments to farms that have made an "artificial" division so as not to exceed the threshold area of the holding.

The direct payments distribution in Bulgaria, the Czech Republic, Hungary, and to a lesser

Country	Degressivity	Capping
Bulgaria	YES, cut of 5% above 150,000 EUR	Cap at 300,000 EUR
Czech Republic	YES, cut of 5% above 150,000 EUR	NO
Hungary	YES, cut of 5% above 150,000 EUR	Cap at 176,000 EUR
Poland	NO	Cap at 150,000 EUR

Source: own study based on Anania and Pupo D'Andrea (2015)

Table 2: Mechanism of reduction of single area payment in the analysed countries.

extent also in Poland, is highly unbalanced, which is manifested by the dominance of large farms in the support allocation. In the case of Bulgaria, the Czech Republic and Hungary, a very large imbalance in the funds allocation can be recognised, greater than in the EU, respectively, with a clear, very weak and moderate trend in the last decade towards a slightly more egalitarian funds allocation. On the other hand, in the case of Poland, the imbalance is moderate – much lower compared to the EU, but yet in Poland the trend has been opposite for several years, i.e. the process of payments concentration is progressing.

The countries covered by the study used to a moderate or slightly extent the redistribution instruments, optional for the Member States, which were introduced by the 2013 CAP reform, in order to ensure a more even funds distribution between the beneficiaries. This may indicate that the degree of concentration of support granted under the direct payments scheme is generally at a politically acceptable level. However, perhaps it is a sign of a strong lobby of large farms. It cannot be ruled out that instruments ensuring a more even funds distribution would be politically easier to introduce at the EU level than at the national level. Nevertheless, also in the next financial perspective, this issue is left to the Member States in line with the subsidiarity principle.

The goal of ensuring a fair support distribution is derived from ideological, worldview, moral, etc. beliefs. Economic analysis may support the decision-making process consisting of selection of appropriate means of achieving the set goal, as long as it is concretized. The goal operationalization could consist in indicating the desired support distribution (the value of the Gini coefficient, the shape of the Lorenz curve). However, in practice, the goal remains not concretized, it is only indicative, and at the same time variable, and making decisions aimed at ensuring an equitable support distribution is more about using the monitoring-adjustment method to move within the area of acceptable results.

Conclusion

Based on the research, the following conclusions can be drawn:

1. Despite the opportunities after the 2013 CAP reform implementation, the study shows the unbalanced funds distribution under the First Pillar of the CAP and the serious dominance of large holdings in funds allocation.
2. The CEE countries do not use the potential of the available instruments to support the small and medium-scale farmers and instruments to reduce direct payments to large farms.
3. Pursuing a more even aid distribution should not overshadow the efficiency benefits of production scale and specialization. On the other hand, the excessive concentration of agricultural production causes strong pressure on the natural environment. It means that dilemmas related to the funds allocating between beneficiaries require a compromise in achieving social, economic and environmental goals (often divergent in the short- and medium-term perspective).
4. The new CAP, 2023-2027, is orientated towards greening, digitisation and young farmers. There are no serious changes in direct support targeting which could reduce the uneven funds distribution and prevent further polarization.
5. The convergence of support level between farmers and between Member States is lagging behind. Subsidiary principle and related to that Member States decision-making will determine the opportunities for more balanced and fairer financial support distribution.

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The Impact of ICT on Rural Livelihood of Farmers in West Bengal, India

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Abstract

Agriculture is a major contributor to West Bengal's economy, as the state's manufacturing sector is constrained by topographical constraints. As a result of the foregoing background, this study aims to investigate the effect of ICT on farmers' livelihoods in West Bengal.Primary data collection is done from the rural farmers in West Bengal, based on a pre-defined questionnaire.Data analysis is done via Cronbach's Alpha, factor analysis linear regression. Taking into consideration of 95% confidence level and 5% confidence interval, total sample size of 381 have been determined. All the five dimensions of livelihood -Financial Capital (FC), Human Capital (HC), Physical Capital (PC), Social Capital (SC) and Natural Capital (NC), have been considered in the present study.Based on the analysis it is found that ICT has a positive impact on all the five tenets of livelihood in the district of PurbaMedinipur, West Bengal.

Keywords

Farmer, livelihood, ICTs, factor analysis and impact.

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Introduction

In the context of any developing country, the constant focus has been to figure out the net end result based on the usage of the ICT usage by its various population segments. Out of the various segment special focus has been on the rural population to understand the impact. Out of the various impacts studied in different spheres, special focus has been on the economic impact and the subsequent upliftment of rural livelihood. The study on this economic impact and upliftment of rural livelihood gets a special attention as this in turn has the potential to influence the economy of the country.

Over a considerable time-scale, it has been noticed that there is a relationship between ICT, social capital and quality of life in developing countries. ICT as a tool can have a high success rate in affecting the social capital among communities in a positive manner and thus for improving the quality of life for the inhabitants. Another observation made is that ICT has the ability to reduce the costs associated with ambiguous information and hence intensify social relationships. In rural segment the gradual percolation of ICT needs constant attention. Post the regime of mobile telephony being ushered in rural areas of India, as an effect, quite a few positive changes have been noted in the rural livelihood segment. This is not only limited to social capital but in other aspects as well.Over the period of time there has been a general observation in regards to the point that mobile phones acts as a medium to reduce the cost of accessing information.

ICTs can be a powerful medium in removing the information barriers that often prevent the poor in remote areas from accessing markets, in turn leading to lower incomes. In the agriculture sector, ICT adoption can facilitate advancements by making available timely information about prices and quality needs, extension and latest technological inputs, and weather and water resources (Braun, 2010).

In rural America, telecommunication technologies could benefit various aspects of rural business by helping in faster communication with suppliers, customers and new market information (Korsching and Bultena, 1998). In the same study it was also highlighted thatICT can enable urban workers (in the information sector) to live in rural areas and telecommute to their jobs. The location of businesses in rural areas can also be facilitated with rapid and accurate distant transmission of data and information. ICT could maintain the viability of rural institutions such as schools, libraries, and hospitals by providing local access to distant, specialized information and other required assistance. Heeks, 1999 is of the opinion that the economically weaker section of the society is lacking information in relation to their local context and there is a definite need here. The gap can be fulfilled from interaction between communities and members rather than from an ICT-based data transfer. The new information can be best shared to the poor by the organic information systems that arise from their community only. In case of access issues and the aforesaid is a challenge, then same can be delivered by conventional telecommunication methods like telephones rather than new ICT tools. A study on the impact of mobile phones on the urban poor in India Sarin and Jain (2009) showcases the point that many believe that the mobile phone has indeed led to improvement in their economic level. In addition to the economic factor there has been a positive impact on the social front also.

In the rural China, the growth was happening at a steady rate. Internet spread was also in the rise in addition to mobile phones and the telecom service providers were also making profit (Harwit, 2004). In a study based out of Madhya Pradesh, Maharashtra and Andhra Pradesh, it was observed that the primary intention of spreading ICT was to create awareness among young and middle-aged farmers on the availability of ICT services. It was also highlighted that emphasis should be given in providing information related to farming as small and marginal farmers were using the ICT services (Meera et al., 2004). Due to gradual and well-regulated expansion of telecom services in the country, people in rural areas are having access to mobile services. This has been boosted by the prepaid (or "pay-as-you-go") services. The farmers are also reportedly using the mobile phones for a variety of purposes. But it is yet to be established the extent to which the farmers would be willing to use and pay for getting the information regarding agriculture through mobile (Ansari and Pandey, 2013).

In a study Zaremohzzabieh et al., (2014) have mentioned that in the recent past, the role of ICTs in promoting socio-economic development and sustainable livelihoods has become the subject of heated discussions. The available evidence suggests that ICTs have some constructive influences on sustainable livelihoods which include human, social, financial, physical and natural assets.

Zainudeen et al. 2006 looks at a different aspect, where the users at the Bottom of Pyramid (BOP), in the developing countries (specifically South Asian Region) face challenge in mobile use. The calls made are very few and many of which are not in relation to any decision making. As a result, in this category it is difficult to apply any specific strategy. As an example, the users at BOP do not seem to see how quick access to important information might be helpful in taking right decisions to enhance earning capacity or reduce transaction costs (De Silva and Zainudeen, 2007). A later study however provides a contrasting view. It shows that mobile phones now are increasingly affordable at BOP level in the same region and hence the penetration has increased. As a result, there is an increased potential to extend the overall social benefits to rural regions. This is turn will drive growth (De Silva et al., 2011).

Ginige and Richards (2012) highlights a study done on the farmers residing in rural areas in Sri Lanka. The research revealed that the farmers don't have proper access to information as the mobiles they are using are not connected to the Internet and there were no other ways or means of communication. The farmers, as a result, are not able to make any informed decisions about their livelihoods and as fallout; they are facing hardships in their day-to-day lives.

Most of the agricultural institutes and organizations have their own telephone based advisory services for farmers which provide telephone based Agri advisory services through a dedicated telephone number to provide on demand information and advisory. The on-line phone based expert advice service, Kisan Call Centres (KCC), launched by the Ministry of Agriculture, Government of India is available for all within the country since January 2004. The mobile based Agri Advisory services offers text, voice and video content based Agri information services through mobile phones. ITC's Agri Business Division launched "e-Choupal" in June 2000. As a part of it, village internet kiosks managed by the farmers (called "sanchalaks") themselves. 'e-Choupal' services now, reach out to over 4 million farmers (appx) growing a range of crops like soybean, coffee, wheat, rice, pulses, and shrimps.

Okyere and Mekonnen, 2012 highlights that the development of ICTs has facilitated the dissemination of knowledge and information and it has brought in a major change in the use of technology in agricultural production and provision of market information to maximize the returns from agricultural sector. The study highlights evidence that rural incomes have been increasing with the use of ICT tools. In spite of that there are challenges on the ground level in making ICT platforms available to a large number of the rural population who are engaged in agriculture. Access to the tools can expand further if the costs of the devices and connectivity go down.

Agriculture plays a vital role in Indian economy and also globally. According to the India Census (2011), 54.6 % of the total workforce is engaged in agriculture and allied sectors. According to the Agricultural Annual Report 2018-2019, the sector accounts for 17.7% of the country's Gross Value Added (GVA) for the year 2017-18 (at current prices). As per the Land Use Statistics 2014-15, the total geographical area of the country is 328.7 million hectares, of which 140.1 million hectares is the reported net sown area and 198.4 million hectares is the gross cropped area with a cropping intensity of 142%. The net area cultivated works out to be 43% of the total geographical area(India. Department of Agriculture, Cooperation and Farmers Welfare, 2015). But in spite of the fact that agriculture employs a huge number of people, agriculture as a field, it is a grossly an unorganised sector in India. ICT can play a definitive role in the agricultural in India.

The current research is limited to see the impact of ICT on the livelihood of the farmers in West Bengal. Agriculture is a prime contributor to the economy of West Bengal where expansion of industrial sector is limited due to its topographical constraints. In the various literature referred till now, there is no concrete work happening on the impact of ICT on rural livelihood in West Bengal.

Materials and methods

As per the Agricultural Census of 2011, the following are the classifications of farmers as per their land holdings. For the study two classes of farmers have been considered. They are the small farmers and the semi-medium farmers. For simplicity's sake, they have been classified as small and big farmers. Smalls Farmer (Small Farmer as per Agricultural Census 2011) means a farmer cultivating (as owner or tenant or share cropper) agricultural land of more than 1 hectare and up to 2 hectares (5 acres). Big Farmer (Semi-Medium as per Agricultural Census 2011) means a farmer cultivating (as owner or tenant or share cropper) agricultural land of more than 2 hectares (more than 5 acres) up to 4 hectares (9.88 acres).

According to the agricultural census 2011,classification of farmer as marginal is less than 1hectare, small farmer is 1-2 hectares, semi medium farmer is 2–4 hectare, medium farmer is 4-10 hectare and large farmer more than 10 hectares.

The population of the study consists of all small farmers and big farmers in PurbaMedinipur, West Bengal. The selection of the farmer segments is based on the fact that the small and big farmers have the necessary ability to adapt to technical changes in the district. The other block of farmers in the district are the marginal farmers, whose land holdings are less than 1hectares in most cases and the usage of ICT is sparse.

Total number of small and big farmers as on 12th March 2018 is 48435 as per Comprehensive District Agricultural Plan (C-DAP) for Purba Medinipur, West Bengal. This report is prepared by the Deputy Director of Agriculture (Administration), Purba Medinipur. No of big farmers is 9429 and no. of small farmers is 39006 (West Bengal. Department of Agriculture (Administration), Purba Medinipur, 2018). Total sample is 381 (95% confidence level and 5% confidence interval) Proportionate sample size of big farmer is 307 and a small farmer is 74. The study is mainly based on primary data. The tool of 'questionnaire' is used to collect the relevant information. However secondary data has also been collected for providing necessary background information of the study area.The questionnaire has been developed after considering the literature review, expert opinion, own observation and pilot study. To assess the reliability of the questionnaire, the computation of the coefficient of alpha is done. This coefficient measures the internal consistency of the items. Alpha was developed by Lee Cronbach in 1951 to provide a measure of the internal consistency of a test or scale. Internal consistency describes the extent to which all the items in a test measure the same concept or construct and hence it is connected to the inter-relatedness of the items within the test (Tavakol and Dennick, 2011). Data has been analysed using statistical software SPSS17. In examining relative impact of ICT on livelihood, livelihood status has been considered as a dependent variable and uses of ICT is treated as independent variables. In order to avoid multi co linearity effect among the independent variables factor analysis has been used (Deb and Singh, 2018). Factor scores have been treated as independent variables. In order to find the significant impact of ICTs on livelihood in PurbaMedinipur multiple linear regression line has been applied. Descriptive statistics mean, Standard deviation are used in the study in order to assess item statistics. Livelihood of farmers in five dimensions has been measured by interval scale. Each dimension consists of many statements. Likert scale of five levels has been used against each statement. A single interval scale has been developed by using weighted average method.

Results and discussion

Analysis and findings of the empirical examination of the study are discussed below.

Table 1 revailes how the extent to which ICT has affected farmer benefits. Producers are influenced by ICT in a variety of financial ways, ranging from 3.1832 to 3.7853. The greatest impact was shown in the financial side, with sales increasing (3.7853), followed by a better market price (3.6937), and lower expenses owing to simple access to information (3.4791).

Particulars	Mean	Std. deviation
Easy access to new clients	3.2565	.90907
Better market prices	3.6937	.76875
Reduced costs due to easy information availability	3.4791	.72331
Increased sales	3.7853	.89090
Reduced cost of travel	3.2513	.83222
Ability to check on availability of products before travel	3.2199	.87173
Less time needed to make business arrangements, e.g., delivery of produce	3.1832	.85906

Source: Author's compilation from the questionnaire

Table 1: Item Statistics (Influence of ICT on different financial aspect).

Measuring impact of ICT on Financial Capital

The items statistics for Financial Capital in relation to the various items are observed from the primary data (Table 2). The reliability of the scale is performed and coefficient of Cronbach's Alpha is found to be 0.739 for 7 items (or statements) considered for the study. A very high value of Cronbach's Alpha (0.739) is indicative of very high degree of reliability of scale and it also shows that the items are highly correlated. Scale Statistics is observed that mean score is 23.8691 which falls under high impact. Thus, it can be concluded that farmers are found to have high impact of ICT on Financial Capital. The respondents had been asked to rate the statements related to livelihood on a five-point Likert Scale. A score of 1, 2, 3, 4 and 5 was given to each statement for the responses strongly disagree, disagree, neither agree nor disagree, agree and strongly agree, respectively. Then a total score for livelihood impact has been found by adding the scores of all the statements related to all the dimensions of livelihood. There were 7 items considered to measure impact of ICTs on Financial Capital (livelihood) of farmers in East Midnapur of West Bengal. Maximum score for a respondent is 35 [7X5] and minimum score possible is 7 [7X1]. The difference between the maximum possible score and minimum possible score was 28. In order to make five-point scales to measure the impact of ICT on livelihoods of individual farmer, this range was divided by 5 and it is found to be 5.6. Adding 5.6 with 7 (minimum possible score), the score interval for very low impact is obtained which comes out to be 7-12.6. Similarly adding 5.6 with subsequent values, next higher range was obtained. In the following table attitude score is interpreted. Overall impact of all the respondents was calculated by adding their score in the Likert scale. Based on the percentage as shown in Table 3 (below), the impact of ICT on Financial Capital is quite high. The high impact percentage for the farmers with an effect in financial capital is 45.3%

Interpretation of scale value	Scale value				
	Financial Capital	Human Capital	Physical Capital	Social Capital	Natural Capital
Very low impact	7-12.6	4-7.2	5-9	8-14.4	8-14.4
Low impact	12.6-18.2	7.2-10.4	9-13	14.4-20.8	14.4-20.8
Moderate Impact	18.2-23.8	10.4-13.6	13-17	20.8-27.2	20.8-27.2
High impact	23.8-29.4	13.6-16.8	17-21	27.2-33.6	27.2-33.6
Very high impact	29.5-35	16.8-20	21-25	33.6-40	33.6-40

Source: Author's compilation from the questionnaire

Table 2: Interpretation of scale value

and farmers falling under the category of moderate impact is incidentally also 45.3%. Hence the data clearly shows that ICT have very significant impact on Financial Capital. Additionally, the combination of high and moderate impact has a total percentile score of "90.6%".

Impact of ICT on FC	Frequency	Percent
Very low impact	0	0
Low impact	17	4.5
Moderate impact	173	45.3
High impact	173	45.3
Very high impact	19	5.0
Total	382	100.0

Source: Author's compilation from the questionnaire

Table 3: Financial Capital.

Measuring impact of ICT on Human Capital

The items statistics for Human Capital in relation to the various items considered are presented in Table 4. The reliability of the scale is performed and coefficient of Cronbach's Alpha is found to be 0.651 for 4 items (or statements) considered for the study. Scale Statistics is observed that mean score is 14.8796 which falls under high impact. The overall level of impact of ICT on Human Capital is presented in the Table 5 (5.55%) of the farmers are having high impact on the human capital dimension of livelihood. Additionally, 24.6% of the farmers fall under the bracket of moderateimpact and 18.8% of the farmers are under very high impact as showcased. The combination of all the above percentages is 98.4%. Thus, it can be concluded that farmers are found to have high impact of ICT on Human Capital.

Particulars	Mean	Std. Deviation
Increase in jobs in farming due to increase in business.	4.0550	.78343
Increase in productivity due to easy information on weather and better agricultural practices.	4.2827	.66298
Alternative livelihood generation other than farming for family members.	3.4791	.88637
Enhancements in life skills due to knowledge via ICT.	3.0628	.83633

Source: Author's compilation from the questionnaire

Table 4: Item Statistics

Impact of ICT on HC	Frequency	Percent
Very low impact	0	0
Low impact	6	1.6
Moderate impact	94	24.6
High impact	210	55.0
Very high impact	72	18.8
Total	382	100.0

Source: Author's compilation from the questionnaire

Table 5: Human Capital

Measuring impact of ICT on Physical Capital

The items statistics for Physical Capital in relation to the various items considered are presented in Table 6. The reliability of the scale is performed and coefficient of Cronbach's Alpha is found to be 0.711 for 4 items (or statements) considered for the study. Scale Statistics is observed that mean score is 16.4541which falls under high impact. Thus, it can be concluded that farmers are found to have high impact of ICT on Physical Capital. The overall level of impact of ICT on Physical Capital is presented in the Table 7.

50 % of the farmers fall under the category of moderate impact, while 39% of the farmers are under the high impact bracket. Additionally, around 8.1% of the farmers are very highly impacted by ICT on the physical capital aspect. Hence, around 97.1% of the farmers are impacted by ICT in this particular scenario and it can be concluded that there is a significant impact of ICT on the Physical Capital.

Particulars	Mean	Std. Deviation
Increased information on access to road and transport.	3.8268	.75493
Getting required information on housing and safe buildings.	3.0236	1.01409
Desired information on access to water source/irrigation.	4.1549	.76754
Input received on clean and affordable energy.	2.8084	.78976
Access to desired information and communication.	2.6404	.83309

Source: Author's compilation from the questionnaire

Table 6: Item Statistics.

Impact of ICT on PC	Frequency	Percent
Very low impact	0	0
Low impact	11	2.9
Moderate impact	191	50.0
High impact	149	39.0
Very high impact	31	8.1
Total	382	100.0

Source: Author's compilation from the questionnaire

Table 7: Physical Capital

Measuring impact of ICT on Social Capital

The items statistics for Social Capital in relation to the various items considered are presented in Table 8. The reliability of the scale is performed and coefficient of Cronbach's Alpha is found to be 0.725 for 8 items (or statements) considered for the study. Scale Statisticsis observed that mean score is 31.3298 which falls under high impact. Thus, it can be concluded that farmers are found to have high impact of ICT on Social Capital. The overall level of impact of ICT on Social Capital is presented in the Table 9. In the case of Social Capital, 70.9% of the farmers fall under the category of high impact. This is quite significant and it can safely be concluded that ICT has brought in a sea change in this aspect of livelihood in the current study area.

Particulars	Mean	Std. Deviation
Increased speed of communication – get immediate answer compared to letters or even landline.	3.6806	.66213
Communication with Government dept.'s.	3.7670	.71037
More frequent contact with friends and relatives.	3.9503	.60195
Help quickly in cases of emergencies.	4.3770	.75940
Availability of professional staff – vets, para-vets, doctor, nurse etc.	4.4346	.70963
Better coordination with other group members.	3.0576	.93732
Better access to family health information.	3.7932	.66139
Improved information regarding deaths, marriages, births and future events.	4.2696	.78575

Source: Author's compilation from the questionnaire

Table 8: Item Statistics.

Impact of ICT on SC	Frequency	Percent
Very low impact	0	0
Low impact	1	.3
Moderate impact	28	7.3
High impact	271	70.9
Very high impact	82	21.5
Total	382	100.0

Source: Author's compilation from the questionnaire

Table 9: Social Capital.

Measuring impact of ICT on Natural Capital

The items statistics for Natural Capital in relation to the various items considered are presented in Table 10.The reliability of the scale is performed and coefficient of Cronbach's Alpha is found to be 0.705 for 8 items (or statements) considered for the study. Scale Statistics is observed that mean score is 31.3298, which falls under high impact. The analysed data in the table11 demonstrates that there is significant impact of ICT on Natural Capital of Livelihood. Highly impacted farmershave a percentage of 44.5%. Farmerswithmoderate impact on natural capital follows suit at a percentile of 44.5 %. In a mixed bag of moderate and high impact the total percentile stands at 89.8%. Thus, it can be concluded that farmers are found to have high impact of ICT on Natural Capital.

Particulars	Mean	Std. Deviation
Provide information on land usage in farming.	3.6466	.71227
Provide information on proper water usage in farming.	3.6492	.75119
Information on weather in general and storm protection.	3.9895	.79361
Increase skills and knowledge in farming with available information.	3.0340	.99942
Availability of knowledge for equipment/tools usage.	2.9319	.98043
Helped in better communication overall.	3.3874	.81756
Information on available sources of funds, loans etc.	4.0890	.83709
Provide right information on savings.	3.6702	.71070

Source: Author's compilation from the questionnaire

Table 10: Item Statistics

Impact of ICT on NC	Frequency	Percent
Very low impact	0	0
Low impact	5	1.3
Moderate impact	170	44.5
High impact	173	45.3
Very high impact	34	8.9
Total	382	100.0

Source: Author's compilation from the questionnaire

Table 11: Natural Capital.

Significant Impact of ICT on livelihood of farmers

To ascertain the impact of ICTs on livelihood, multiple linear regression line is used. Impact levels of livelihood for farmers, after using ICT tools, is considered as dependent variable and frequency of ICT usage is the predictor variable. It is coded in the SPSS as Y=1 (very Low impact), Y=2 (Low impact), Y=3 (moderate impact), Y=4 (high impact). Y=5 (Very high impact). Equal interval of impact level of five dimensions livelihood has been developed. As dependent variables are interval scale, five separate multiple linear regressions lines for five dimensions of livelihood have been used. ICTs considered in the study are Radio, TV, Mobile Phones, SMS, Smart Mobile App, Call centre/ IVR and website. Frequency uses of the ICTs are considered as independent variables. There is a high chance to have multicollinearity effect among the independent variables. In order to avoid multicollinearity effect, factor analysis for all the independent variables has been applied.Factor's score has been treated as independent variable. Factor analysis has been carried out for extracting the factor. In order to extract the factors and also to avoid the cross loading among the factors of the variables Eigen value criteria (greater than one) and Varimax rotation criteria have been used respectively. Sample adequacy has been checked using KMO and Bartlett's test which is satisfactory as the sample adequacy is 0.578. This shows that number of samples collected is adequate for the study.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.578
Bartlett's Test of Sphericity	Approx. Chi -Square	422.523
	Df	21
	Sig.	.000

Source: Author's compilation from the questionnaire

Table 12: Result of KMO and Bartlett's Test.

The Table 12 shows the summary results of the sample adequacy.In the second step, summary of the extracted factors and the total variance explained by total number of extracted factors have been presented. It should be noticed that these extracted factors are obtained after avoiding the cross loadings. It is found that three factors are loaded and with the help of those three factors which explains 64.317variance. Details description about the variables loaded in different factors are presented in Table 13.

In the Table 14, the results of rotated component matrix are shown. In this case, the variables are loaded under three factors and on the basis of the arrangement. From the Table 15 (below),

Component	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
Radio	2.065	29.503	29.503	2.065	29.503	29.503	1.903	27.191	27.191
TV	1.352	19.316	48.819	1.352	19.316	48.819	1.364	19.484	46.676
Mobile phone	1.085	15.499	64.317	1.085	15.499	64.317	1.235	17.642	64.317
SMS	.774	11.050	75.368						
SmartmobileApp	.741	10.583	85.950						
IVR	.723	10.330	96.280						
Website	.260	3.720	100.000						

Source: Author's compilation from the questionnaire

Table 13: Total variance explained.

Factors and Variables	**Factor 1**	**Factor 2**	**Factor 3**
ICT Core Tools (Factor 1)			
SMS	.590		
Smart mobile app	.877		
Website	.789		
ICT Devices (Factor 2)			
Radio		.628	
Mobile phone		.700	
ICT Peripheral Devices (Factor 3)			
TV			.551
IVR			.576

Source: Author's compilation from the questionnaire

Table 14: Varimax Rotated Loading.

it is found that Factor 1 and Factor 2 have significant impact on Financial Capital at 5 % level of significant as p value is less than .05. Factor 3 is found to be insignificant as p value is higher than .05. So, from the study it is seen that five ICTs variables like SMS, Smart mobile App, website, Radio and mobile phone are having significant impact on livelihood level for Financial Capital. From beta value in the table, it can be concluded that Factor 1 has higher impact than Factor 2 for higher beta value. Factor 1 (SMS, Smart mobile app and Website), Factor 2 (Radio and Mobile phone) and Factor 3 (TV and IVR).

Table 16, highlights that Factor 1 and Factor 2 have significant impact on Human Capital at 5 % level of significant as p value is less than .05. Factor 3 is found to be insignificant as p value is higher than .05. So, from the study it is seen that the five ICTs variables SMS, Smart mobile App, website, Radio and mobile phone are having significant impact on livelihood level for Human Capital. From beta value in the table, it can be concluded that Factor 1 and Factor 2 same impact with similar beta value. Factor 1 (SMS, Smart mobile app and Website), Factor 2 (Radio and Mobile phone) and Factor 3 (TV and IVR). Table 17, shows cases that Factor 1 and Factor 2 have significant impact on Physical Capital at 5 % level of significant as p value is less than .05. Factor 3 is found to be insignificant as p value is higher than .05. So, from the study it is seen that the five ICTs variables SMS, Smart mobile App, website, Radio and mobile phone are having significant impact on livelihood level for Physical Capital. From beta value in the table, it can be concluded that factor 2 has higher impact than Factor 1 for higher beta value. Factor 1 (SMS, Smart mobile app and Website), Factor 2 (Radio and Mobile phone) and Factor 3 (TV and IVR).

From the Table 18, it is found that Factor 1 and Factor 2 have significant impact on Social Capital at 5 % level of significant as p value is less than .05. Factor 3 is found to be insignificant as p value is higher than .05. So, from the study it is seen that the five ICTs variables SMS, Smart mobile App, website, Radio and mobile phone are having significant impact on livelihood level

	Un-standardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	3.508	.033		106.732	.000
ICT Core Tools (Factor 1)	.131	.033	.197	3.973	.000
ICT Devices (Factor 2)	.109	.033	.165	3.316	.001
ICT Peripheral Devices (Factor 3)	.034	.033	.052	1.046	.296

Source: Author's compilation from the questionnaire

Table 15: Impact of ICT on Financial Capital.

	Un-standardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	3.911	.034		116.550	.000
ICT Core Tools (Factor 1)	.176	.034	.251	5.243	.000
ICT Devices (Factor 2)	.179	.034	.256	5.330	.000
ICT Peripheral Devices (Factor 3)	.030	.034	.042	.886	.376

Source: Author's compilation from the questionnaire

Table 16: Impact of ICT on Human Capital.

	Un-standardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	3.524	.034		102.794	.000
ICT Core Tools (Factor 1)	.079	.034	.115	2.301	.022
ICT Devices (Factor 2)	.130	.034	.190	3.791	.000
ICT Peripheral Devices (Factor 3)	.046	.034	.067	1.336	.182

Source: Author's compilation from the questionnaire

Table 17: Impact of ICT on Physical Capital.

	Un-standardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	4.136	.026		158.351	.000
ICT Core Tools (Factor 1)	.084	.026	.159	3.225	.001
ICT Devices (Factor 2)	.120	.026	.227	4.594	.000
ICT Peripheral Devices (Factor 3)	.023	.026	.043	.867	.386

Source: Author's compilation from the questionnaire

Table 18: Impact of ICT on Social Capital.

	Un-standardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	3.618	.032		111.399	.000
ICT Core Tools (Factor 1)	.127	.033	.190	3.892	.000
ICT Devices (Factor 2)	.136	.033	.204	4.169	.000
ICT Peripheral Devices (Factor 3)	.086	.033	.129	2.635	.009

Source: Author's compilation from the questionnaire

Table19: Impact of ICT on Natural Capital.

for Social Capital. From beta value in the table, it can be concluded that the Factor 2 has higher impact than the Factor 1 for higher beta value. Factor 1 (SMS, Smart mobile app and Website), Factor 2 (Radio and Mobile phone) and Factor 3 (TV and IVR).

Table 19 (above), highlights that Factor 1, Factor 2 and Factor 3 have significant impact on Natural Capital at 5 % level of significant as p value is less than .05. So, from the study it is seen that the all the seven ICTs variables SMS, Smart mobile App, website, Radio, mobile phone, TV and IVR are having significant impact on livelihood level for Natural Capital. From beta value in the table, it can be concluded that factor 2 has higher impact than Factor 1 and Factor 3 for higher beta value. Factor 1 (SMS, Smart mobile app and Website), Factor 2 (Radio and Mobile phone) and Factor 3 (TV and IVR).

Conclusion

To ascertain the impact of ICT on rural livelihood, all the five tenets of livelihood have been assessed as a part of this study.The ICT toolsin focus for the assessment were Smart Mobile App, Website, SMS, Radio, TV, IVR and Mobile phones.

Natural Capital is seen to be significantly impacted by SMS, Smart Mobile App, Website, Radio, Mobile phones, TV and IVR. Radio and Mobile Phone has a higher impact than the rest here.It implies that the farmers in the study area havea better understanding of the natural resources at their disposal and have learnt to do an optimum management of the same.

For Physical Capital, the ICT usage among the farmers has led to some definite enhancements. With knowledge being available on equipment and transport infrastructure, there is betterment in this segment. It has also greatly influenced the access to desired communication. The usage has increased the knowledge of house/safe buildings and access to water for irrigation.

The main factor to highlight is the strong positive impact on the Financial Capital. The tools Smart Mobile App, Website, SMS, Radio and Mobile phones have contributed to this. ICT usage has led to a significant growth on the financial aspect in the study area. So, there is ample evidence that rural incomes have been increasing with the use of ICTs to access knowledge and information. Similar observations were seen in the different studies like, Chong et al., (2009) mentions increase of household income as a result of ICT usage. For the economic empowerment of the poor population in the rural areas, the mobile phones can be a very useful tool. Okyere and Mekonnen (2012) highlight that with the advent of the mobile services and increased usage in the rural segment; the farmers could use the price information from various places and sell their produce at an optimum price.

Social Capital is impacted by SMS, Smart Mobile App, Website, Radio and Mobile phones. But out of these, Radio and Mobile Phone have a higher impact than the rest. Hence mobile phone conservations and the radio broadcasts are playing a strong positive role. The research has also unearthed that for this tenet, 70.9% of the farmers are significantly impacted. It shows that ICT has brought in a sea change in this aspect of livelihood and there is a better connectivity/relationship in the area. It also indicates that greater household income (as a result of the positive impact seen in the financial capital), has led to a greater participation in external activities.

Moving ahead, the analysed data also indicates that ICT usage by the farmers has heavily impacted the Human Capital.Hence it can be clearly stated that ICT has led to skill development, nutrition and health.

Based on the positive impact seen on all the five segments/tenets of the livelihood, the collective statement at this juncture is that, ICT is truly impacting rural livelihood for big and small farmers of Purba Medinipur area of West Bengal. This in turn has the capacity to drive growth. Similar observations were seen in the different studies like De Silva et al. (2011) similarly highlights that ICT has increased potential to extend the overall benefits to the rural segment. Okyere and Mekonnen (2012) highlights that the development of ICTs has facilitated the dissemination of knowledge and information and it is revolutionizing agricultural production and provision of market information to maximize the returns to agriculture. ICT as a development tool is creating awareness among farmers and rural artisans for their betterment; geographical information system (GIS) is opening new approaches to regional planning and to management of natural resources.

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Optimal Farm Planning and Assessment of Conventional Agricultural Practices under Alternative Scenarios Integrating Life Cycle Analysis

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Abstract

Agricultural production and farm management are inextricable, since managerial aspects for safe and of high-quality food products have led to the development of successful production plans but multifaceted controversies as well. These controversies arise from the focus of policymakers, especially in the EU, to the environmental aspects of agricultural production, creating conflicting objectives for farmers. Energy from biomass derivatives could play a significant role in the dispute for economic and environmental sustainability in agriculture, along with the formulation of agro-energy districts. In this context, an MCDM model was developed integrating LCA data for the assessment of economic, environmental and energy sustainability regarding thirteen major crops in the Region of Central Macedonia in Greece. The model's objectives consist of maximization of farmers' gross income, minimization of emissions coming from farming practices and maximization of energy potentially coming from biomass. Furthermore, three different scenario-based directions allocate different weights to the respective objectives, creating different managerial strategies. The optimal production plan was the scenario in which the weights were allocated by goal programming. The optimal plan proposes the cultivation expansion of energy crops, tree crops, alfalfa and hard wheat to a higher degree. Moreover, a significant reduction to the cultivated areas of tobacco, rice, barley and soft wheat could lead to a potentially viable production plan.

Keywords

Farm management, multi-criteria analysis, life cycle assessment, mathematical programming.

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Introduction

Farm management in the EU consists of manifold conflicting aspects, while there is a strong need to rethink and re-design current farming systems. Such re-design process involves multiple objectives and stakeholders raising awareness for environmental sustainability in agricultural production. The increasing food demand and the unavoidable carbon footprint of agriculture will be the two major obstacles to overcome in the future (Mueller et al., 2012). Although farmers tend to comply with the imposed measures in order to be subsidized by the EU, new emerging challenges complicate their decision-making process. Agri-environmental measures were implemented for the first time in 1992 (Freibauer et al., 2004) and have been evolving through time, achieving an average positive impact to the primary sector of the EU (Batáry et al., 2015). Agri-environmental schemes were designed to alleviate the impacts of poor strategic planning regarding farm management (e.g., reduction of fertilizer and pesticide use), to promote alternative agricultural practices (e.g., integrated production, organic farming) and to enhance biodiversity (Science for Environment Policy, 2017).

The current regulatory framework for agri-environmental measures (REGULATION (EU) No 1305/2013, 2013) has contributed significantly to the reformation of rural development in the EU (Batáry et al., 2015; Carvalheiro et al., 2013). Although this regulation has been in force for a long time now, there are several amendments which have changed manifold articles, while the two latest have been enforced in 2021 (EU 2021/399 and 2021/1017). Nevertheless, Batáry et al. (2015) highlight significant costs regarding the subsidiary character of these measures, whilst several studies outline limited measure efficiency on a regional level (Cortignani and Dono, 2019; Nunes et al., 2017; Schmidt and Hauck, 2018). In this context, the political agreement (European Commission, 2021) emphasize on the necessity of a versatile and agile framework with simpler rules, more fair and more "green", for the future of CAP. Furthermore, the proposed green architecture of the new CAP entails the idea of eco-schemes (Meredith and Hart, 2019), a regional support framework for farmers that will be implemented in the newest CAP, based on regional characteristics of the different areas in the EU. In this context, the Renewable Energy Directive (EU, 2018) which promotes local renewable energy communities, could play a significant role to sustainable management in farming along with eco-schemes.

Furthermore, the updated European Bioeconomy strategy (European Union and Directorate-General for Research and Innovation, 2018) focuses on sustainable plans that efficiently allocate energy resources and promote renewable forms of energy, such as biomass (Ronzon and Piotrowski, 2017). Biomass is considered as an efficient, reliable and environmentally friendly source of energy (Manzano-Agugliaro, 2007) and it has already been proven that specific biomass utilization pathways could enhance the socioeconomic development of rural areas as a whole (Nishiguchi and Tabata, 2016; Rincon et al., 2019). Furthermore, the exploitation of energy crops is a key aspect in a sustainable and continuous provision of energy scenario (White et al., 2013). However, biomass conversion systems consist of several bio-energy pathways (Tziolas, Bournaris, Nastis, and Manos, 2018), which complicate the formulation of bio-based industries, due to conflicting interests among policy makers, stakeholders and farmers. The exploitation of conversion technologies in order to create sustainable forms of energy from agricultural produce and byproducts defines the term "agro-energy" (Frayssignes, 2011). The idea of independent or semi-independent rural areas that could generate sustainable forms of energy while achieving environmental and economic goals is strongly connected to the development of agro-energy districts (Macrì et al., 2016).

This multifaceted infrastructure of rural areas exploiting biomass with lower emissions from agricultural practices creates confusion to farmers, since their goals are usually related to maximization of income or minimization of costs. The new described challenges should comply with the traditional goals of farmers, thus entailing that agricultural landscapes should integrate a multifunctional character (Fischer et al., 2017). The mitigation of climate change impacts is one of the most significant aspects regarding environmental sustainability and this is illustrated by the national adaptation strategies implemented by several countries in the EU (Biesbroek et al., 2010), while the European Commission's Green Paper (European Commission, 2009) constitutes a wider urban and rural environmental framework for the Union. Therefore, rural areas and agricultural production should integrate these new challenges and address numerous competing demands, taking into account spatial heterogeneity (Verhagen et al., 2018). More specifically, ecosystem services strongly correlated with agricultural production (such as biomass derivatives, carbon stocks in soil, biodiversity etc.) could form a multi-criteria decision-making (MCDM) model along with traditional goals of farmers.

In this context, multi-criteria techniques have been implemented in conjunction with life cycle tools in agriculture by several studies (De Luca et al., 2017; Tziolas, Bournaris, Manos, and Nastis, 2018). Apart from the tangible quantitative aspects such as costs, subsidies or labour hours, environmental impacts (direct or indirect) have been integrated into multicriteria models as well. Climate change in agriculture is transmuted to soil composition aspects (Mandryk et al., 2017; Seyedmohammadi et al., 2018) or GHG emissions (Baležentiene and Užupis, 2012; Nakashima, 2010; Yue et al., 2016), imported to multicriteria models. GHG emissions are usually derived from Life Cycle Assessment (LCA) indicators, namely Global Warming Potential (GWP), since LCA is considered as a great methodological approach for the environmental evaluation of agricultural systems (Ekvall and Finnveden, 2001; Foster et al., 2006; Roy et al., 2009).

The main aim of this paper is the assessment of agricultural production in Northern Greece and the direction of different production plans, considering emissions from agricultural practices in the field, biomass production and economic aspects. The current work is a continuation of Tziolas et al. (2017), in which an MCDM model was implemented for optimal farm planning in the smaller municipality of Almopia. The present study constitutes a part of a broader research in the Region of Central Macedonia (RCM) in Greece, highlighting the economic and environmental assessment of the agricultural production on the area. The assessment is enriched with primary data obtained from a survey conducted in every sub-district of the Region. Three scenarios with different set weights on each objective are optimized. The first scenario distributes the weights in equal terms, whilst the second scenario depends on primary data from the questionnaires. The third scenario is based on percentage deviational variables, as it is widely implemented in several agricultural systems (Bournaris, Papathanasiou, Manos, Kazakis, and Voudouris, 2015; Gómez-Limón and Berbel, 2000; Sumpsi, Amador, and Romero, 1997).

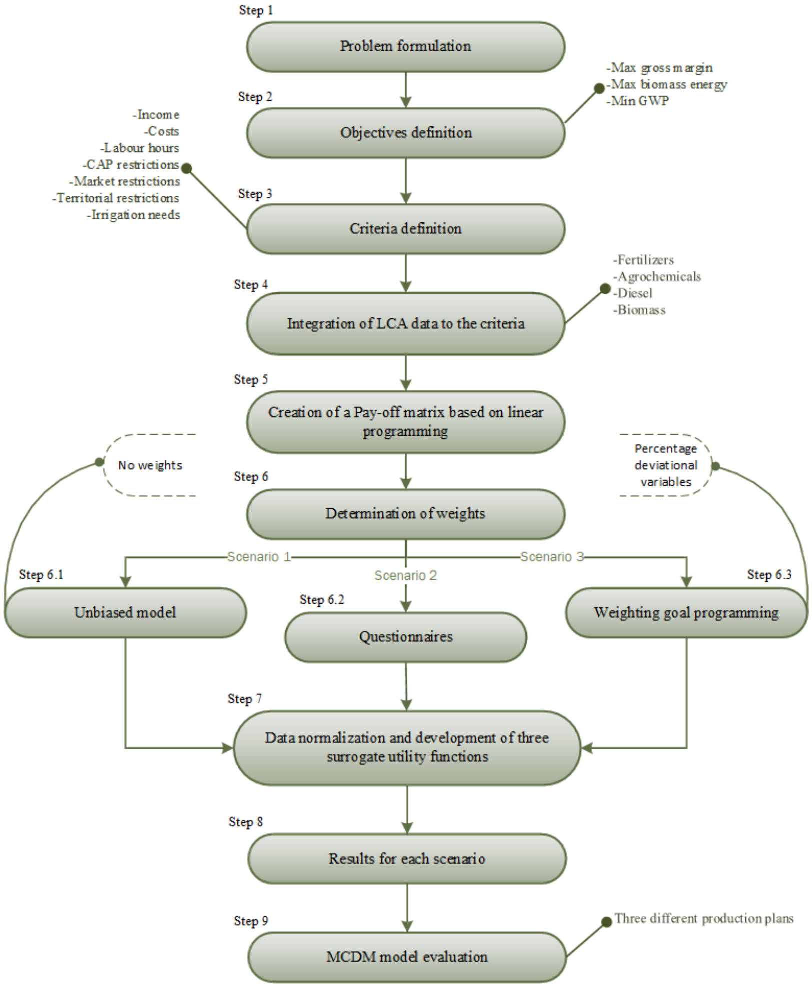
Materials and methods

In order to identify the optimum farm plan for the area of interest, an MCDM model with multiple scenarios was developed. The main objectives incorporate gross margin maximization, which is a traditional goal for farmers, energy maximization from biomass and minimization of the on-field GHG emissions. Emissions are measured in CO_2 equivalents, based on a unified LCA indicator (Global Warming Potential - GWP). The model outlines an assortment of managerial acts of agricultural production, regarding costs, labour hours, fertilizer application, income, irrigation needs, CAP obligations etc. Datasets for GWP indicators, potential energy from biomass, irrigation needs, fertilizer application, agrochemicals and diesel consumption have been derived from an LCA published research (Tziolas and Bournaris, 2019). All the relevant datasets regarding economic data were drawn from two private agricultural consulting firms located in the regional units of Thessaloniki and Pella. A sample of 502 farmers, meeting the research needs, was extracted from the firms' databases to create a reliable and representative sample for the entire region. The sample included only farmers who followed conventional agricultural practices and agriculture was their main source of income for the period 2016-2017. In addition to secondary data, we have also collected primary data (147 questionnaires out of the 502) from the farmers who accepted to cooperate via the mediation of the two private agricultural consulting firms. The main aim to acquire primary data was to capture useful factors for the LCA (e.g., kg of nitrogen fertilizers, working hours of an agricultural tractor per hectare, m^3 of irrigation per hectare, etc.) and to highlight the perspective of farmers in relation to the model's objectives.

Many producers appeared to be quite reluctant to provide information about their farms, despite the assurances of us and the two private agricultural consulting firms. This was the main reason for the cooperation with private firms, so that the results could be verified and up to date. Finally, the answers were cross-referenced with similar surveys carried out abroad in order to accurately depict the environmental data, since producers found it difficult to accurately estimate quantities of diesel used, hours of mechanical work per hectare, etc. The gist of the approach is the formulation of three scenarios, based on different weights for each objective. The model follows the methodological procedure designed and successfully implemented by Sumpsi et al. (1997) and Bartolini et al. (2007). The first scenario (SC1) allocates the weights equally to each objective. The second scenario (SC2) depicts the preferences of farmers based on questionnaires delivered in the sub-regions of the RCM, while the third scenario (SC3) is a weighted goal programming approach based on deviational variables. A surrogate utility function for each scenario should be introduced in pursuance of the simultaneous optimization of the three objectives simultaneously. The ideology behind this approach lies on the simulation methods of Sumpsi et al. (1997) and Amador et al. (1997), which have been implemented specifically on agricultural systems, allocating different weights to each goal. This approach has been successfully employed by several studies regarding water management in agriculture (Bartolini et al., 2007; Bournaris et al., 2015), farm planning (Bournaris, Moulogianni, and Manos, 2014; Manos, Papathanasiou, Bournaris and Voudouris, 2010) and environmental management (Manos, Papathanasiou, Bournaris and Voudouris, 2010). The MCDM model develops three different production plans for the area of interest, whilst a step-by-step procedure for the formulation of the MCDM model is depicted in Figure 1.

Model specification

The model specification section will provide an extensive overview of all the necessary information for the formulation of a linear programming model and, by extension, an MCDM model for the study area. In more detail, the decision



Source: Authors' elaboration

Figure 1: Step by step procedure for the MCDM model.

variables, the different goals, the constraints and useful features for the implementation of the model will be presented.

Decision variables

Each farmer manages a different mix of X_i variables (which are depicted as crops). The reorganization should be performed in a wider context, at the level of the entire study area. Thus, the decision variables will form an integrated production plan for the RCM, depicting the necessary fluctuations on the existent production plan, based on the examined objectives.

Objectives

The objectives of the MCDM model are outlined as necessary from the point of view of both farmers and policy makers and they also incorporate the rationale for investing in rural areas, through biomass industries. The mathematical expression of each objective is illustrated as follows:

- Maximization of gross margin, which is the main motivational factor in the decision-making process of farmers. Therefore, Gross Margin (GM) for each crop *i* is taken into account, whilst GM_i is calculated in euros per hectare:

$$max_{GM} = \sum_{i=1}^{n} GM_i \times X_i$$

- Maximization of the potential energy from biomass, which is a social and European goal for renewable energy sources. This objective has a social aspect, since apart from the autonomy, it can create energy communities and strengthen key elements of rural economic life (e.g., reduction of unemployment), while reducing burning of residues in open fields. The objective function to maximize energy (EN) from each crop i is defined as follows and the EN_i is calculated in Megajoules per hectare:

$$max_{EN} = \sum_{i=1}^{n} EN_i \times X_i$$

- Minimization of GWP from farming practices, which is expressed in CO_2 equivalents, is an aspect of the emission of harmful air pollutants into the atmosphere. This is a new objective, with multiple benefits for the local community, stimulating awareness for all the involved parties (farmers, political leadership, the EU). It is an environmental objective trying to minimize the total harmful emissions (GWP) of each crop $_i$, while GWP_i is depicted in kg of CO_2 equivalents per hectare:

$$min_{GWP} = \sum_{i=1}^{n} GWP_i \times X_i$$

Constraints

The data collected from the relevant sources (the Directorate-General for Agriculture and Veterinary, the Region of Central Macedonia's Directorate, the Hellenic Statistical Authority and the Ministry of Rural Development and Food of Greece), as well as those from the existing production plan, constitute specific constraints. For this model, the constraints concern multiple aspects of agricultural production and they are referring to: land availability, variable costs, fertilizers, labour, diesel, agrochemicals, CAP regulations and market constraints.

Land use and data analysis

The RCM covers an area of 18,811 km^2; it is divided into seven regional districts, namely Chalkidiki, Imathia, Kilkis, Pella, Pieria, Serres and Thessaloniki. The Region has a large number of protected areas (33.8% of its total area), though only half of the Natura 2000 sites have an organized management plan to provide a competent protection framework. Nevertheless, the energy from biomass derivatives is considered significant (Moulogianni & Bournaris, 2017), though the potential power plants' capacity is average (1-2 MW) due to the structure of the area (Bakos et al., 2008). Regarding the production plan of the RCM, hard wheat and soft wheat are the most widespread crops with 24.37% and 10.92% of the cultivated land (Table 1). On the other hand, rapeseed covers only 1.15% of the total cultivated area. However, it is a newly introduced crop, that gained more attention in recent years. Among the crops, there are also set-aside areas, which oblige farmers to apply tillage operations once per year according to Article 94 of the Regulation No 1306/2013 (EU), in order to be subsidized by the EU.

Apart from the production plan for the RCM, Table 1

Crops	Area (ha)	(%)	Gross margin (€/ha)	Biomass energy (MJ/ha)	GWP (kg CO_2 eq/ha)
Soft Wheat	57 431.60	10.92%	175.94	9 377.67	1 512.68
Hard Wheat	128 159.20	24.37%	274.67	8 540.38	1 512.68
Barley	29 700.10	5.65%	308.32	9 042.76	2 376.81
Maize	35 019.70	6.66%	442.68	22 162.80	5 096.92
Rice	27 508.60	5.23%	777.03	11 306.06	8 954.48
Tobacco	6 834.10	1.30%	1 450.85	2 740.13	4 715.80
Cotton	56 243.30	10.69%	1 030.00	8 731.80	4 405.36
Sunflower	22 515.60	4.28%	472.29	74 585.98	2 248.63
Rapeseed	6 049.70	1.15%	513.69	42 174.78	1 856.76
Alfalfa	23 793.10	4.52%	1 114.20	9 649.20	1 777.47
Peach trees	34 208.20	6.50%	2 947.86	18 673.32	4 510.86
Cherry trees	11 866.30	2.26%	6 006.32	11 099.09	2 767.24
Olive trees	40 253.30	7.65%	3 686.60	14 821.07	2 772.93
Set aside	46 398.30	8.82%	119.38	0	59.59
Total	525 981.10	100.00%			

Source: Data rerived from Tziolas and Bournaris (2019)

Table 1: Existent RCM production plan and relevant data.

depicts the figures of the three main objectives of the mathematical model for every crop. Tree crops pay the most significant amounts of gross margin (up to 6,006.32 €/ha for cherry trees), though there are area restrictions, based on the climatic conditions for each regional district, with low potential to the arboriculture's percentage fluctuation in the model. The two energy crops in the production plan (sunflower and rapeseed) are not cultivated in a large scale but generate high amounts of energy as expected, with 74,585.98 MJ/ha and 42,174.78 MJ/ha respectively. The biomass energy for the rest of the crops refers to the exploitation of agricultural residues. The large amounts of cobs and stalks from maize significantly increase the outcome of biomass energy by 22,162.80 MJ/ha. The final objective involves the on-farm emissions and it is depicted in kg of CO_2 equivalents per hectare. Rice emits the highest amounts of GHGs (8,954.48 kg CO_2 eq/ha), whilst hard and soft wheat produce only 1,512.68 kg CO_2 eq/ha. All the pertinent datasets have been derived from Tziolas & Bournaris (2019).

Scenario analysis

Multi-criteria mathematical programming is basically an extension of the mathematical programming theory and the gist of it is that there are multiple objective functions to optimize (Ehrgott, 2005). The main difference between the solution of mathematical programming problems with one goal or with multiple goals lies in the concept of the optimal solution. Solving a problem of multicriteria mathematical programming focuses on finding a compromise solution rather than the optimal one, since the latter does not exist. In this context, a surrogate utility function is calculated, integrating the three objective functions. The formulation of the surrogate utility function assigns different amounts of weights to each goal, according to the exposition of each scenario (Table 2).

The first scenario (SC1) is detached from any kind of bias, regarding allocation of weights to the goals. It is a scenario that integrates in equal terms all three objective functions. Scenario 2 (SC2) allocates weights to the goals, based on a broader research in all the sub-districts of the RCM. More specifically, 147 interviews were conducted, as described in the methodology section seeking farmers' preferences among the main objectives of the model, namely income, biomass exploitation and environmental impacts of farming practices. Farmers were asked which one of the three objectives was the major from their point of view and a set of weights from each goal was elicited. The third scenario (SC3) has its basis in weighted goal programming and is suitable for the analysis and simulation of agricultural systems (Amador et al., 1997; Bournaris et al., 2015; Manos et al., 2006; Sumpsi et al., 1997; Tziolas et al., 2017). Each one of the described scenarios will export a different production plan, based on the preferences introduced. The production plans integrate simultaneously all the given goals, with the same constraints, while allocating the crop mix differently. In order to determine the most efficient scenario, the Eco-Efficiency indicator was calculated (EE) (Bidwell and Verfaillie, 2000).

Eco-Efficiency relies on a simple ratio between economic outputs and emissions to highlight a key-aspect between economic and environmental sustainability for farm systems (Masuda, 2016b). Efficiency in farm-scale is usually measured with Data Envelopment Analysis (DEA) (B Manos and Psychoudakis, 1997; Nastis et al., 2012; Vlontzos et al., 2014), whilst DEA is also implemented with LCA datasets (Iribarren et al., 2010; Rebolledo-Leiva et al., 2017; Vázquez-Rowe et al., 2012). The huge disadvantage related to DEA efficiency is based on the high data requirements, while DEA can be implemented to assess separate farming practices (Nastis et al., 2012) or a group of regional aspects (Masuda, 2016a) and not whole regions. In this context, the authors employ Eco-Efficiency as an indicator for each scenario z which is presented below according to Masuda (2016b):

$$EE_z = \frac{TGM_z}{TGWP_z}$$

Where TGM_z is the total gross margin achieved and $TGWP_z$ is the total emissions from farming

	SC1	SC2	SC3
Weights	Equal	Farmers' preferences	Percentage deviational variables
Methodological approach	-	Interview based	Weighted goal programming
Normalization	✓	✓	✓

Source: Authors' elaboration

Table 2: Scenario aspects and approaches.

practices depicted in CO_2 equivalents from each scenario *z*. In this manner, EE_z is used as a managerial tool for the selection of the most efficient scenario in the study area.

Results and discussion

Pay-off matrix

The solution to each separate linear programming problem has exported three production plans and the Pay-off matrix is basically the depiction of these results. The Pay-off matrix essentially includes all the best values achieved for the goals' set (Table 3). The first column depicts the three main objectives (maximization of gross margin – GM, maximization of energy - EN, minimization of impacts – GWP), while the last column (real values) depicts the existing plan's results for each one of them. The rest of the columns represent the optimum results when linear programming is implemented for each objective. The results illustrate interesting extensions, since the three linear programming models achieve the defined objectives, but do not manage to achieve all three objectives at the same time.

The next step is to determine the weights for each scenario and assign them to the relevant goals.

Weight determination

The weights integrated in the model are illustrated in Table 4. SC1 is a scenario where all the weights are equally distributed, thus there is not any kind of moderation to the direction of the production plan. The SC2 is based on the broader research in the RCM. Questionnaires were distributed to farmers in each regional unit of the RCM in order to identify and document all the relevant inputs and outputs of agricultural practices in an LCA perspective (Tziolas and Bournaris, 2019). Apart from the primary findings, farmers' preferences were investigated, asking them to put a weight on each objective. From the results, it is obvious that the main goal of farmers in the region is maximization of income (69.4%). However, a significant percentage is allocated to the minimization of GWP and environmental protection consequently, which highlights the raising awareness regarding the mitigation of climate change impacts in agriculture.

Regarding SC3, the weighted goal programming model, which was based on percentage deviational variables, depicts the maximization of gross margin as the main objective (43%) once more, while sustainable development and the reduction of air pollutants generated by agricultural practices play an important, but secondary role. Optimization of biomass energy is an innovative goal that could be omitted for the other two scenarios, but it is less than a quarter of the weight preference (22.5%) for SC3. The analytical procedure for the weighted goal programming model is thoroughly described by Gómez-Limón and Berbel (2000).

Utility function

From the determination of weights, the utility function, which is essentially the unified form of the three objectives simultaneously, takes the form of one objective function for each scenario. The utility function should be integrated into the MCDM model, but the coefficients should be normalized first, since objectives are expressed in different units. In order to normalize weights, there is a need to find the difference between the ideal and the non-ideal value for each goal (Sumpsi et al., 1997). Each variation for the separate goals is divided by the corresponding weight given

Values	Optimum			Real values
	GM	EN	GWP	
GM (€)	544.773.004	502.313.301	484.342.000	514.351.918
EN (MJ)	6.889.808.721	7.684.419.705	6.778.164.351	7.029.814.718
GWP (kg CO_2 eq.)	1.356.666.577	1.274.523.714	1.002.569.986	1.463.794.051

Source: Authors´elaboration

Table 3: Pay-off matrix.

	GM	EN	GWP
SC1	-	-	-
SC2	69.4%	9.4%	21.2%
SC3	43.0%	22.5%	34.5%

Source: Authors´elaboration

Table 4: Scenario set of weights.

for the objective function. Thus, three different utility functions are formed as follows:

$$U_{SC1} = 1.65 \times 10^{-8}\ GM + 1.10 \times 10^{-9}\ EN - 2.82 \times 10^{-9}\ GWP$$

$$U_{SC2} = 1.15 \times 10^{-8}\ GM + 1.04 \times 10^{-8}\ EN - 5.98 \times 10^{-10}\ GWP$$

$$U_{SC3} = 7.09 \times 10^{-9}\ GM + 2.47 \times 10^{-10}\ EN - 9.74 \times 10^{-10}\ GWP$$

In this context, the depicted utility functions will be optimized under the same constraints, in order to elicit three optimal production plans for the region in discuss.

MCDM production plan

The output of each scenario develops different production plans, allocating inputs and cropland based on the set weights for every objective. Apart from the scenario outputs, Table 5 depicts the existing production plan as well. SC2 has a greater impact on inputs, especially for fertilizers (-10.84%) and agrochemicals (3.36%), though it is the only scenario that did not achieve all the objectives simultaneously, since biomass energy generation is reduced by 2.03%. On the other hand, SC1 and SC3 share a more rationalized perspective for the reorganization of agricultural production in the area, by achieving all the objectives simultaneously. The price to pay for this, is the little to none decrease of inputs. Figure 2 illustrates the percentage deviation of the output of the scenarios compared to the existing production plan.

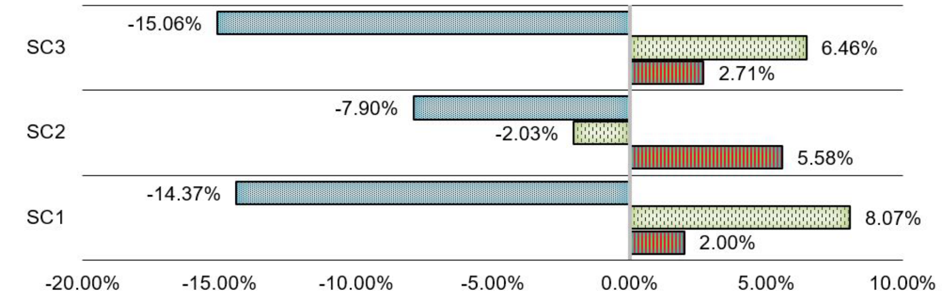
Under the current agricultural policies of the EU, a significant amount of greenhouse gas emissions could be mitigated if the relevant inputs were efficiently allocated. The fluctuation of the GWP indicator could reach a decrease between 7.90% and 15.06% depending on the selected scenario. The production plans of the scenarios have similarities in crop composition; hence, a main directive could be developed. The model proposes the augmentation of cultivated tree crops (+10% for cherry trees, peach trees and olive trees), energy crops (+30% for sunflower and rapeseed), hard wheat (+30%) and alfalfa (+10%) for all the scenarios. In this context, the expansion of arboriculture and energy crops could be the cornerstone for the RCM, to achieve a small step towards sustainable agricultural production.

Regarding annual crops, the crop plan is diversified significantly, based on the selected scenario. SC3

	Existing plan	SC1		SC2		SC3	
		Mod. Values	% deviation	Mod. Values	% deviation	Mod. Values	% deviation
GM (€)	5.10E+08	5.20E+08	2.00%	5.40E+08	5.58%	5.30E+08	2.71%
EN (MJ)	7.00E+09	7.60E+09	8.07%	6.90E+09	-2.03%	7.50E+09	6.46%
GWP (kg CO_2 eq)	1.50E+09	1.30E+09	-14.37%	1.40E+09	-7.90%	1.20E+09	-15.06%
Costs (€)	8.10E+08	8.00E+08	-0.57%	7.80E+08	-2.71%	8.00E+08	-1.32%
Labour (h)	4.00E+07	4.00E+07	0.00%	4.00E+07	0.00%	4.00E+07	0.00%
Diesel (l)	6.10E+07	6.10E+07	0.00%	6.00E+07	-1.27%	6.10E+07	0.00%
Agrochemicals (kg)	2.80E+06	2.80E+06	0.00%	2.70E+06	-3.36%	2.80E+06	0.00%
Fertilizers (kg)	1.20E+08	1.20E+08	-0.33%	1.10E+08	-10.84%	1.20E+08	-1.54%
Soft Wheat	57 431.60	49 954.50	-13.02%	0.0	-100.00%	52 912.10	-7.87%
Hard Wheat	128 159.20	166 606.70	30.00%	166 606.70	30.00%	166 606.70	30.00%
Barley	29 700.10	1 140.10	-96.16%	32 670.00	10.00%	11 585.40	-60.99%
Maize	35 019.70	42 024.00	20.00%	0.0	-100.00%	28 958.80	-17.31%
Rice	27 508.60	0.0	-100.00%	30 259.90	10.00%	0.0	-100.00%
Tobacco	6 834.10	0.0	-100.00%	3 923.10	-42.60%	0.0	-100.00%
Cotton	56 243.30	56 423.50	0.32%	62 691.60	11.47%	62 691.60	11.47%
Sunflower	22 515.60	29 270.80	30.00%	29 270.80	30.00%	29 270.80	30.00%
Rapeseed	6 049.70	7 865.00	30.00%	7 865.00	30.00%	7 865.00	30.00%
Alfalfa	23 793.10	26 172.30	10.00%	26 172.30	10.00%	26 172.30	10.00%
Peach trees	34 208.20	37 628.80	10.00%	37 628.80	10.00%	37 628.80	10.00%
Cherry trees	11 866.30	13 052.60	10.00%	13 052.60	10.00%	13 052.60	10.00%
Olive trees	40 253.30	44 278.30	10.00%	44 278.30	10.00%	44 278.30	10.00%
Set aside	46 398.30	51 564.60	11.13%	71 562.00	54.23%	44 958.70	-3.10%

Source: Authors´elaboration

Table 5: Model validation for the three scenarios.



	SC1	SC2	SC3
GWP	-14.37%	-7.90%	-15.06%
EN	8.07%	-2.03%	6.46%
GM	2.00%	5.58%	2.71%

Source: Authors´elaboration

Figure 2: Percentage deviation of the three scenarios' outputs.

is the only scenario which depicts a decrease in set aside areas (-3.10%), whilst SC1 and mainly SC2 present a significant raise. Cotton cultivation is encouraged by all scenarios, significantly by SC2 and SC3 (+11.47%), but to a lower extent by SC1 (+0.32%). Finally, barley cultivation is almost excluded in SC1 (-96.16%), while in SC2 it is increased by 10% and in SC3 by 60.99%. Finally, the only viable production plan that integrates tobacco cultivation is SC2, but requires a significant reduction in covered areas (-42.60%). It appears that tobacco and rice could be substituted by cotton and hard wheat, in order to adapt the production plan to the relevant constraints and objectives.

Eco-Efficiency indicator

Although farmers, policy makers and stakeholders may have different interests regarding the organization of agricultural production, weight allocation to specific goals develops an integrated approach. Therefore, to identify the optimal production plan for the area of interest, an eco-efficiency aspect of every scenario is presented. Eco-efficiency as an indicator of sustainable farm planning and it is based on the two aspects that were identified as the most important for farmers. Income is the one and emissions from agricultural practices in the field is the other. The eco-efficiency ratio is depicted in Table 6 for each of the scenarios analyzed.

SC1	SC2	SC3
0.4186	0.4016	0.4249

Source: Authors´elaboration

Table 6: Eco-efficiency ratio (€/kg CO_2 eq).

The results for the eco-efficiency ratio are quite similar among the three scenarios. SC2 is the most underachieving scenario, as it was in absolute numbers. It is obvious that the scenario based on the questionnaire answers from farmers is unbalanced resulting in the least efficient production plan. Thus, stakeholders and policy makers should be integrated to the decision-making process. The second most efficient scenario is SC1, while SC3, which allocates weights based on a weighted goal programming model, is the most efficient of all, achieving a ratio of 0.4249.

Discussion

In this paper, potential changes in agricultural production of the RCM are investigated, with the implementation of an MCDM model that allocates weights on three different objectives. The configured model is based on a linear programming rationale and these methodological frameworks feature a considerable amount of limitations (Viaggi et al., 2009). The objective of energy maximization, especially from agricultural residues, could be received as arbitrary, since the infrastructure for the incorporation of all residues in the area is limited. On top of that, risk and uncertainty of agricultural production are not considered in the model, similarly to Gómez-Limón et al. (2004) and Bournaris and Manos (2012), which are significant aspects of agricultural production. This is one of the major problems when large areas of land are considered, since each area faces different challenges. Therefore, the choice of the current methodological framework integrating multiple criteria in several agricultural systems is deliberate. It has been implemented several times to assess water directives (Bartolini et al., 2007; José A. Gómez-Limón et al., 2002), CAP policies (Basil Manos et al., 2011) and potential energy from agricultural residues (Tziolas et al., 2017) on farming systems.

Furthermore, the weight distribution of SC2 relies on the responses of farmers who implement conventional agricultural practices. Although most of the farmers in Northern Greece follow these types of practices, the weight percentages could develop a completely different strategy of crop production if other types (e.g. organic farming, reduced tillage) were included in the data sample. Regarding the set objectives, gross margin remains the main goal of farmers as demonstrated in other relevant studies (Manos et al., 2006; Tziolas et al., 2017). Environmental impacts in other studies could be illustrated as fertilizer application or water usage on the field (Bournaris et al., 2014), though the farmers' income remains the most relevant objective.

Farmers in the EU are highly dependent on subsidies (Falcone et al., 2016; Tziolas & Bournaris, 2019), thus the combination of LCA and MCDM could develop a solid policy framework, integrating economic and environmental impacts in order to find a compromise between the two aspects. The extension of tree crops is of utmost importance for the area, as suggested through the MCDM. The subsidiary framework could further focus on the costs for the establishment of tree crops, in order to promote their extension, though the budget proposal for the CAP after 2020 will decrease (European Commission, 2018a), leaving small to no hope for the investment provisions.

Conclusion

The main aim of this research is the identification of optimal agricultural production in the RCM, based on economic, environmental and energy generation parameters. Financing of the newest CAP will engage a more environmental friendly profile, contributing to climate change mitigation and to sustainable energy production (European Commission, 2018b). Based on the latest directives, farmers will be rewarded for undertaking commitments that go beyond the mandatory agri-environmental and/or climate policy requirements. This entails the major motivational aspect of farmers' preferences, which is maximization of gross margin in conjunction with environmental preservation. Therefore, the authors propose the extension of energy crops in the RCM, along with a decrease of tobacco and rice cultivation, based on the three main objectives of the MCDM. Annual crops of the production plan in the RCM, such as soft wheat, cotton, barley and maize should be handled differently, based on the outcome of each scenario.

The scenarios are designed to tackle regional economic and environmental problems, since local conditions may vary between different areas in the EU. Following the proposed new architecture of the CAP and the increased flexibility of eco-schemes, policy makers are considering regional needs to a higher degree. Future research should incorporate more environmental indicators (e.g., acidification, non-renewable energy etc.), though as stated by Falcone et al. (2016) the perspective of potential stakeholders should be taken into account, as well as regional characteristics. Finally, mid-point indicators (e.g. ionizing radiation, toxicity, etc.) could develop unified end-point indicators (e.g. human health, biodiversity, etc.), which could illustrate and draw conclusions on the social extension of agricultural production.

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