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Research Article

Development of an Android Application for Manure Management

Sude Mutlu[1] **Dilek Selçuk**[1] **Özlen Tepeli**[1] **Ünal Kızıl**[2*]

[1]Canakkale Onsekiz Mart University, School of Graduate Studies, Department of Agricultural Structures and Irrigation, Canakkale, Turkiye
[2]Canakkale Onsekiz Mart University, Faculty of Agriculture, Department of Agricultural Structures and Irrigation, Canakkale, Turkiye
*Corresponding author: unal@comu.edu.tr

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Abstract

Manure management planning is especially important to ensure the sustainable use of soil and water resources. The main purpose of planning is to apply the nutrients available in the manure produced in the operation and in the soil to the land at the appropriate time, taking into account the needs of the plant. For this purpose, a mobile application has been developed to run on Android-based mobile phones or tablets. In a case study where plant and animal production is carried out, management planning was made for corn and tomato plants in a dairy cattle enterprise with a capacity of 60 heads. As a result of the calculations, it was seen that the financial value of the manure produced by the animals in the operation was approximately $14000. It shows that if the manure produced is used to provide the most optimum benefit, the amount that needs to be spent on additional plant nutrients will be $7800 for corn and $27332 for tomato. As a result, it has been determined that the developed mobile application can be used in manure management planning for sustainable agricultural production.

Keywords: Manure, Manure management planning, Agricultural waste management, Mobile application.

Gübre Yönetimi İçin Android Aplikasyon Geliştirilmesi

Öz

Gübre işletim planlaması özellikle toprak ve su kaynaklarının sürdürülebilir kullanımını sağlamak açısından oldukça önemlidir. Planlamanın temel amacı işletmede üretilen gübrede ve toprakta hali hazırda bulunan besin elementlerini bitkinin ihtiyaçlarını da dikkate alarak araziye uygun zamanda uygulamaktır. Bu amaçla Android tabanlı cep telefonları veya tabletlerde çalışacak bir mobil uygulama geliştirilmiştir. Bitkisel ve hayvansal üretimin yapıldığı örnek bir işletmede mısır ve domates bitkisi için 60 baş kapasiteli süt sığırı işletmesinde gübre işletim planlaması yapılmıştır. Hesaplamalar sonucu işletmede hayvanlar tarafından üretilen gübrenin maddi değerinin yaklaşık olarak 14000 $ olduğu görülmüştür. Üretilen gübrenin en optimum faydayı sağlayacak şekilde değerlendirilmesi durumunda ilave bitki besin maddesi için harcanması gereken miktarın mısır için 7800 $, domates için ise 27332 $ olacağını göstermektedir. Sonuç olarak, geliştirilen uygulamanın sürdürülebilir bir tarımsal üretim amacıyla gübre işletim planlamasında kullanılabileceği tespit edilmiştir.

Anahtar Kelimeler: Gübre, Gübre işletim planlaması, Tarımsal atık yönetimi, Mobil uygulama.

Introduction

Agriculture is essential to maintain life for human beings (Ravindran et al., 2018). With the increase in agricultural production, the amounts of animal waste, agricultural product residues, and agro-industrial by-products also increase. The challenges in managing the resulting waste can lead to air, water, and soil pollution. As livestock production increases worldwide, the environmental impacts of animal waste are becoming an increasing risk (Catelo et al., 2001). Although the growing number of farm animals globally has a positive effect on reducing hunger and malnutrition, it brings a significant waste burden on the environment. Animal excreta can contain harmful chemical residues and zoonotic pathogens to human health (Singh et al., 2017). Improper management of animal waste can damage agricultural lands, water resources, soil fertility, and the atmosphere, leading to environmental problems. Hazardous gases such as H_2S, CH_4, CO_2, and NH_3, along with various chemicals and foul odors from farm animal manures, contribute to air pollution. Furthermore, manures contain heavy metals, antibiotics, and nutrients (especially nitrogen and phosphorus) (Kraham, 2017). Water pollution arises when animal wastes are spread over crops and pastures. These wastes are used to fertilize the soil and enrich it with various forms of nitrogen. However, unplanned fertilizer applications (Kızıl and Lindley, 2001) can result in nitrogen, which is not fully absorbed by crops, leaching into groundwater along with excessive amounts of applied animal excreta. This leads to nitrate transportation from the soil to groundwater, causing various problems. Leaching and runoff losses to underground and surface waters are one of the main ways nitrogen is lost from the field (Rotz, 2004). Additionally, the resulting leachate indirectly contaminates the drinking water sources of both humans and animals.

The resulting agricultural wastes must be processed or disposed of in a way that does not pollute the environment or harm the health of living things. Animal waste can be a rich source of nutrients and can increase soil fertility by using it as plant nutrients. It can also contribute to sustainable agricultural practices. Animal waste, which contains essential nutrients such as nitrogen, phosphorus and potassium, provides elements that are of great importance for the growth and development of plants. In this way, in addition to the use of traditional fertilizers, the use of animal waste in agricultural production can both improve soil quality and reduce fertilizer costs. The application of animal manure to agricultural lands appears to have become a suitable alternative as it provides high crop productivity and soil fertility for longer periods than synthetic fertilizers (Leclerc and Laurent, 2017).

There are many options for the disposal and use of animal manure. However, direct land spreading method is the most widely preferred method used among farmers (Jiang et al., 2014). In the past, manure management focused on using nutrients from manure for crop production (Millner, 2009). Although animal manure has high nutritional value, excessive application may cause negative effects on plant and environmental health. Therefore, it is important to apply fertilizer according to the needs of the plant and the current condition of the soil. The fertilizer to be applied must be applied at the right time, in the right amount and in the right way. This ensures efficient use of fertilizer to meet the nutritional needs of plants while minimizing environmental impacts.

The use of technology in agriculture is considered an important element of sustainable agriculture. Modern agricultural technology has been developed to obtain the highest yield and provide the most economic gain. To achieve these goals, basic practices such as the use of inorganic fertilizer, irrigation, soil tillage, control of chemical pests, and plant genetic manipulation come to the fore (Rehman et al., 2016). Advanced farming techniques, precision farming practices and digital farming practices play a key role in production by using resources more effectively and help increase productivity. With these technologies, environmentally friendly agricultural practices can be developed. For example, sensors and automation systems that enable smarter use of water and fertilizer can minimize the negative effects of agricultural waste on water resources and soil fertility.

Technologies used in agriculture such as smart agricultural practices and digital applications will enable farmers to become more conscious about production. Agricultural applications have the potential to improve agricultural production processes while increasing farmers' productivity. The application of innovative agricultural technologies makes a significant difference in the agricultural sector, making farmers' daily work easier and increasing productivity (Khan et al., 2021). By using applications, it will be easy to access data such as fertilization plans and weather forecast. Accessing such information will be a great convenience for manufacturers. Additionally, mobile applications and other agricultural technologies can help farmers make realistic decisions. In this way, technology will allow agriculture to be managed in a more sustainable and environmentally friendly way. Being aware of utilizing animal waste and using technologies and practices appropriately will contribute to more conscious and effective production. The aim of this study is to raise awareness by proving that animal waste can be used consciously, minimizing its damage to the environment, and using technologies such as digital agriculture and mobile applications in a more sensitive and conscious way.

Materials and Methods

Android Programming

MIT App Inventor, one of the development environments used to design Android applications, is maintained by the Massachusetts Institute of Technology (MIT) (Hong and Hwang, 2020). MIT App Inventor is a web-based and free development platform with a graphical interface where fully functional Android applications can be designed (Pokress and Veiga, 2013). MIT App Inventor has two primary editors: the Design Editor and the Block Editor. The Design Editor is a drag-and-drop interface used to edit the application's user interface elements. The Block Editor allows application developers to visually organize the logic of the application by combining color-coded blocks (Patton et al., 2019). Since moving from Google to MIT, a number of improvements have been made to App Inventor. App Inventor platform was preferred in the application because it provides easy testing.

General Principles of Fertilizer Management Planning

The method used to recycle the manure produced in an agricultural enterprise as plant nutrients is generally called nutrient budget. When making a nutrient budget, plant nutrient resources that enter the enterprise, are produced in the enterprise, and leave the enterprise as a result of production must be taken into account. When considered on a farm basis, animal feed, inorganic and organic fertilizers, plant residues in the soil and even rainfall can be taken into consideration as nutrient input tools. Animal and plant products and losses during production are considered as output tools in the nutritional balance calculation. Major losses include ammonia volatilization, deep soil leaching, denitrification, runoff and erosion.

Studies have shown that more than 60% of the nutrients remain in the enterprise, but a smaller part leaves the enterprise in the form of products and losses (Klausner, 1997). In the calculation of the amount of fertilizer to be applied to the land, there are inputs, losses and outputs, just like on a farm basis. The basis of the application developed in this study is based on the calculation principles and formulas given in MWPS (1993).

Kizil et al. (2016) developed a computer program using the same formulas and approach. However, developing technology makes it inevitable for applications to run on smart mobile phones, which are widely used by almost everyone, without a computer. In this context, Aksu et al. (2017) developed only a map-based application for Çanakkale Province, Gümüşçay Town. However, this application provides fertilizer application rates calculated for the number of animals in the town and the products produced on a parcel basis. That is, the database of the application (plant and animal information) must be updated by the developers every year and a new version must be published. Therefore, it does not have a dynamic structure and does not provide the opportunity to see different scenarios. The developed mobile application can make calculations according to the flow diagram below using the nutrient budget approach (Figure 1). Here, the parameters given in different colors above the flow chart indicate the data that needs to be entered. It shows which data is used in which step. In the developed application, the amount of fertilizer to be applied to the land is calculated separately according to both nitrogen and phosphorus requirements. At this point, the user must specify the purpose of fertilizer application. If the fertilizer is intended to meet all the nitrogen and phosphorus needs of the plant, the greater of the calculated values is considered. If the purpose of fertilizer application is to maximize the use of plant nutrients in the fertilizer, the smaller of these two values is used. The developed application can also calculate the amount of land required to dispose of the fertilizer produced in the enterprise.

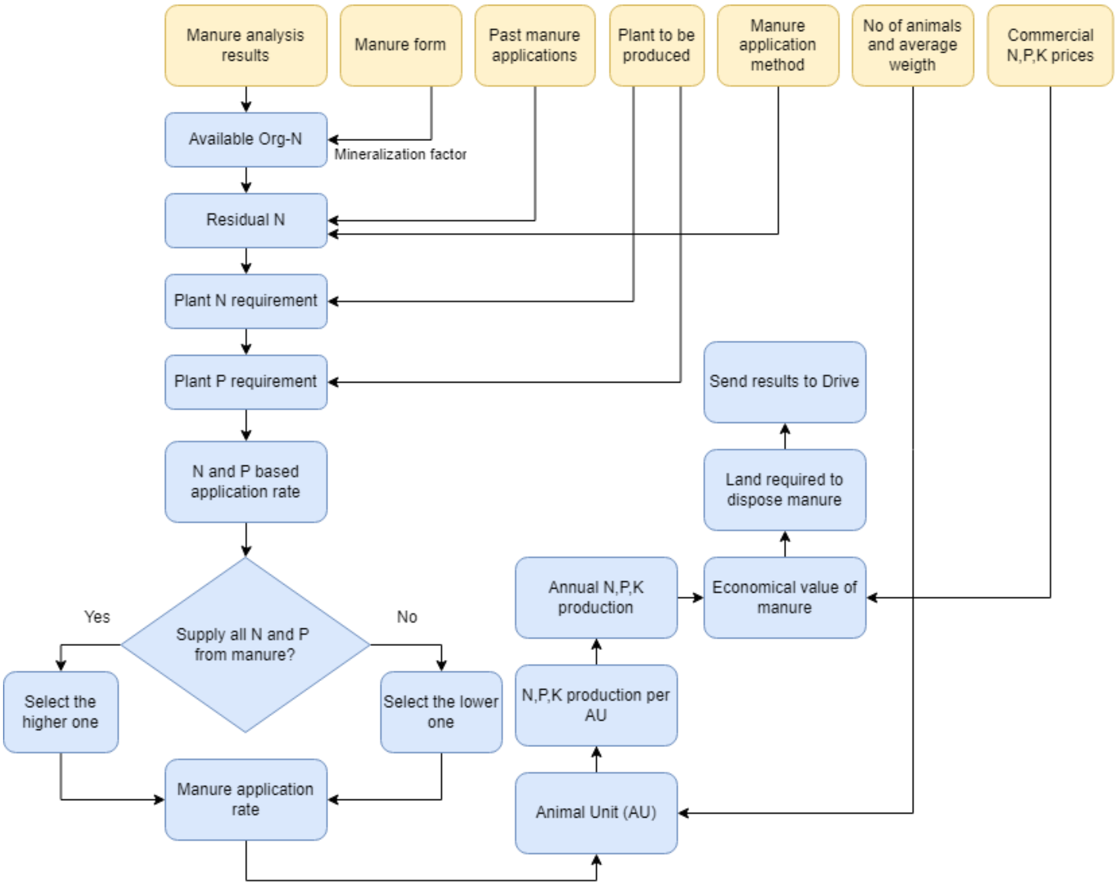

Figure 1. Application flow chart

With the application, annual production amounts of major plant nutrients originating from fertilizers can be calculated. Therefore, it is possible to calculate the economic value of fertilizer. For this purpose, the approximate economic value of the fertilizer can be revealed by entering the pure N, P_2O_5 and K_2O prices in the market.

Creating a Cloud Database

It is very important to keep the fertilizer operation plans of a business in a database on a yearly basis. Because knowing the amount, method and preferences of fertilizer application and animal presence in the past years will contain important data for fertilizer applications in the coming years. In this context, it is aimed to collect a fertilizer operation plan developed in an easily accessible, usable, and shareable database. Considering that smart mobile phones or tablets offer internet connection, the use of cloud data systems will provide significant advantages. For this purpose, Google Sheets, a cloud-based platform, was used. The URL address of the Sheets file to be created is used so that Google Sheets can receive data from the smart device. Google Sheets, an online version of MS Excel files, can collect and store incoming data in a certain hierarchy. It is a simple coding (Script) file created on Drive that enables communication with the smart device using the URL address of Sheets files accessible via Google Drive. Storing the calculated values and data in the developed application on the Sheets file is schematized as follows (Figure 2).

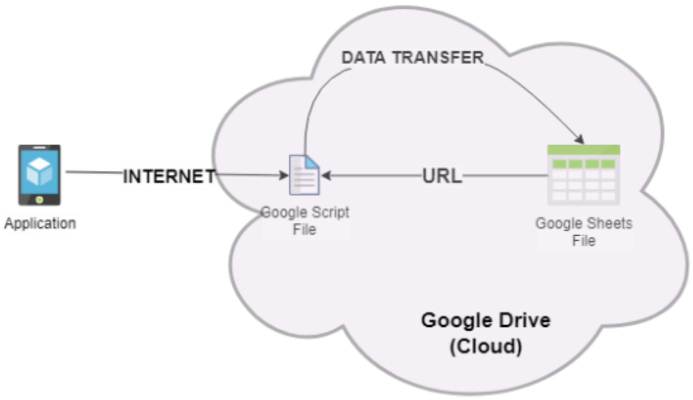

Figure 2. Cloud data storage hierarchy

Application Interface and Usage

The application has been tested on devices with Android operating system. The design of the user login screen to enable data entry is given in Figure 3. In the first stage, all data to be calculated must be entered. Here, fertilizer and soil analysis results, fertilizer application method (injection or surface application), application purpose, plant to be produced, animal information (number and average weight), commercial fertilizer prices and exchange rate must be entered, respectively. Then, when the Calculate button is pressed, the management plan appears on the screen. Finally, if desired, the calculation results are transferred to the Sheets file on Google Drive.

Figure 3. User interface and data entry of the application

Sample Application

Using the application, a sample nutrient management plan was prepared for a dairy cattle farm with a 60-head loose dairy barn located in Durali Village, Çan District, Çanakkale Province, Türkiye. The dairy barn has an area of 25×30 = 750 m^2 and ridge height of 6 m. The average milk yield in the farm is 20 lt day^{-1}. The enterprise has an agricultural land of approximately 200 decares. Tomatoes, corn, and other plants dominant in the region are generally cultivated.

The first and most important data to be entered in the application is the manure chemical analysis results. These values can be obtained through laboratory analysis as well as literature. However, laboratory analyzes can take up to a few weeks, and during this period, changes occur in the chemical contents of the pile from which the manure is taken. Precipitation, wind and temperature are the most important reasons for these changes. The disadvantage of using literature information is that manure characteristics vary significantly even from one enterprise to another (Kızıl and Lindley, 2001). In this study, to reduce this disadvantage, dairy cattle manure analysis results obtained under the conditions of the Çanakkale Region published in Aksu and Kızıl (2015) were used (Table 1).

Table 1. Manure chemical analysis results (%)
Çizelge 1. Gübrenin kimyasal analiz sonuçları (%)

Total N	0.86
NH_4-N	0.00
NO_3-N	0.00
P_2O_5	0.40
K_2O	0.50

Surface application was preferred as the manure application method since the producer does not have a manure injector like many other producers in the region. The aim was to meet all plant nutrient requirements from the manure. Hence higher of N and P based application rates was chosen at the beginning. However, in order to evaluate the result of other option, maximizing the use of plants nutrients in manure, both situations were simulated. In order to determine the amount of organic-N that will be mineralized in the season of manure application, the form of the fertilizer must be determined. For this purpose, the solid manure with bedding was used since the enterprise was in a loose barn system. Plant selection was based on tomatoes and corn. Accordingly, the nutritional requirements of these plants were automatically retrieved from the application's database. As stated above, the enterprise is a 60-head dairy operation, and the average animal weight is 450 kg. Finally, in the calculations, the market value of pure N, P_2O_5 and K_2O and the daily exchange rate were determined. Using March 2024 exchange rates, N, P_2O_5 and K_2O prices were used to be 2156, 1281 and 1625 \$ t^{-1}, respectively.

Results and Discussion

After the necessary data entries and preferences were entered, manure management plans were evaluated for different scenarios. In Table 2, the management plan to be obtained if the manure produced is applied as a nutrient to corn and tomatoes and the amount of land required to dispose of the manure are shown. Two separate calculations were made for both plants, depending on the application purpose. The option of the manure meeting all the nitrogen and phosphorus needs of the plant and the option of keeping the use of plant nutrients in the manure at the highest level were examined in two separate columns.

Table 2. Summary of alternative scenarios
Çizelge 2. Alternatif senaryoların özeti

	Corn		Tomato	
Parameter	Unit^1	Unit^2	Unit^1	Unit^2
Manure Organic-N (kg t^{-1})	7.83	7.83	7.83	7.83
Organic-N available at the end of the first year (kg t^{-1})	1.96	1.96	1.96	1.96
Plant available-N (kg t^{-1})	1.96	1.96	1.96	1.96
Required N (kg da^{-1})	25.0	25.0	30.0	30.0
N-based manure application rate (t da^{-1})	12.8	12.8	15.3	15.3
P_2O_5 based manure app. rate (t da^{-1})	3.6	3.6	2.2	2.2
Application rate to be used (t da^{-1})	**12.8**	**3.6**	**15.3**	**2.2**
N utilized from manure (kg da^{-1})	**25.0**	**7.0**	**30.0**	**4.3**
Additional N requirement (kg da^{-1})	**0.0**	**18.0**	**0.0**	**25.7**
P2O5 utilized from manure (kg da^{-1})	**46.5**	**13.0**	**55.8**	**8.0**
Additional P_2O_5 requirement (kg da^{-1})	**0.0**	**0.0**	**0.0**	**0.0**
K2O utilized from manure (kg da^{-1})	**58.1**	**16.3**	**69.8**	**10.0**

Table 2. Summary of alternative scenarios (cont.)
Çizelge 2. Alternatif senaryoların özeti (devamı)

	Corn		Tomato	
Parameter	Unit[1]	Unit[2]	Unit[1]	Unit[2]
Additional K2O requirement (kg da-1)	0.0	0.0	0.0	50.0
Annual average animal unit (AU)	54	54	54	54
Annual nutrient generation per AU				
Plant available-N (kg AU^{-1})	30.7	30.7	30.7	30.7
P_2O_5 (kg AU^{-1})	57.1	57.1	57.1	57.1
K_2O (kg AU^{-1})	71.4	71.4	71.4	71.4
Annual total nutrient generation				
Plant available-N (t y^{-1})	1.7	1.7	1.7	1.7
P_2O_5 (t y^{-1})	3.1	3.1	3.1	3.1
K_2O (t y^{-1})	3.9	3.9	3.9	3.9
Land required (da)	**66**	**237**	**55**	**386**

[1] Provide all plant nutrients from the manure.
[2] Maximize the use of all plant nutrients in manure.

As summarized in Table 2, if all the nutritional requirements of corn are met from manure, there is no need to use additional chemical fertilizer, but only an area of 66 da can be fertilized with the manure produced. In other words, there will be enough fertilizer for only 66 decares of the 200 decares of land owned by the business. If the small application rate (3.6 t da^{-1}) is used, it will be possible to apply the fertilizer in an area of 237 da with an N supplement of 18 kg da^{-1} without the need for additional P_2O_5 and K_2O. Therefore, although it was initially aimed to meet all the plant nutritional needs of the operation from manure, as a result of the calculations, it can be said that it would be more appropriate to use the smaller application rate. The cost of the calculated 18 kg da^{-1} additional N requirement in a 200 da area will be approximately $ 7800, considering the above exchange rate.

Similarly, looking at the results obtained for tomatoes, it seems that it would be more appropriate to choose the lower application rate (2.2 t da^{-1}). It is seen that choosing the larger value will meet the nutritional needs of approximately ¼ of the land. When the smaller rate is selected, the entire land will be fertilized in return for an additional requirement of 25.7 kg da^{-1} N and 50 kg da^{-1} K_2O. Under this condition, the amount of additional N and K_2O in the 200 da production area will be 5.14 t and 10.00 t, respectively. Again, considering the exchange rate, it can be seen that the costs of additional nutrient requirements will be $11082 and $16250 for N and K_2O, respectively.

Considering the number of animals, the annual manure production rate and the manure analysis results, the annual N, P_2O_5 and K_2O production amounts are given in the table. Again, the financial value of the fertilizer produced was calculated approximately, considering the exchange rate and the nutrient prices in the month in which the calculations were made. Accordingly, the economical values of N, P_2O_5 and K_2O produced in the operation are $ 3665, $ 3971, and $ 6337, respectively. This shows that the value of the fertilizer produced in total as plant nutrients is approximately $14000.

In this case study, when corn is produced, the cost of chemical fertilizer as an input decrease significantly compared to tomatoes. If tomatoes are planted, the total cost of chemical fertilizer is approximately $27,300. This is approximately 3.5 times the cost of additional fertilizer required for corn production. Of course, it would not be correct to make a production plan based only on these results. In production planning, many factors such as other production costs and the market price of the product produced should be considered. However, considering that one of the most important production costs in plant production is fertilizer, it is obvious that more precise production planning can be made with the developed application.

Conclusions

In Türkiye, manure resulting from animal production is generally disposed of in a way that causes significant environmental problems. In cases where it is used as a plant nutrient, it is applied to the land in certain rates without relying on any calculation. The amount of nutrients already presents in the soil, the needs of the plant and the amount of nutrients available in the manure are generally ignored. This causes either more manure to be applied than needed or excessive application and unnecessary fertilization. To ensure sustainability in agriculture, fertilizer, which is an important plant nutrient, must be applied to the land in appropriate amounts.

In practice, manure management planning can be easily made for different scenarios and production conditions in a short time by easily changing many parameters such as fertilizer source, number of plants and animals grown. Today, the widespread use of smart mobile phones will make the work of producers easier in fertilizer operation planning, as in other areas. In addition, storing the manure management plans in a database constitutes an important data source. This is very important for sustainable agricultural production in the long term.

Authors' Contributions

The authors declare that they have contributed equally to the article.

Conflicts of Interest Statement

The authors of the article declare that they have no conflict of interest.

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