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Computation-Based Estimation of Seedling Needs and Planting Time for Vegetable Farming

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Abstract

This research focuses on making vegetable farming more efficient by using a simple mathematical formula to plan seedling needs and planting time. Because many farmers still rely on rough manual estimates, they often face problems like having too few seedlings or wasting money on extra labor and supplies. The purpose of this study is to show how a basic computational approach can help farmers accurately calculate exactly how many plants they need and how long it will take to plant them based on their land size and the number of workers available. A quantitative research design was used, applying specific formulas to data like farm area, plant spacing, and worker speed. To find the number of seedlings needed (N), the study uses the formula $N = A / R \times P$. To find the total planting time (T), the following formula is applied: $T = N / S \times W \times H$. The Study tested these formulas to see how changes in farm size affect the workload. The results show that using these calculations provides a clear and predictable schedule for farm activities. It was found that as the land area grows, both the number of seedlings and the time required increase in a way that can be precisely measured. The study concludes that this computational method is a practical and easy-to-use tool for better farm management. Its simplicity makes it helpful for farmers to save money, avoid wasting resources, and ensure their crops are planted on time.

Keywords: Seedling Estimation, Planting Time, Mathematical Computation, Vegetable Farming, Resource Management, Agricultural Planning

Introduction

Mathematics assists in enhancing vegetable farming by offering simple and effective approaches for planning farming activities. Using basic equations, farmers can calculate the number of plants required, labor, and the effective utilization of resources, hence promoting efficiency in productivity (Montgomery, 2017; Fuentes-Peñailillo et al., 2023). The Food and Agriculture Organization emphasizes the significance of systematic farming in ensuring food security, especially in vegetable farming (FAO, 2013).

Land area, plant density, and labor force are some of the important factors that affect crop production and planning. Mathematical modeling is useful for planning. In the Philippines, most farmers rely on estimation, which leads to a shortage of seedlings, increased production costs, and inefficient use of labor (DA, 2020).

To improve agriculture in the Philippines, there is a need to move away from traditional methods and towards evidence-based approaches to deal with limited land and resources (DA, 2016). According to Arro (2023) from the World Vegetable Center, despite government seedling programs, there is still poor nursery management and planning, which leaves farmers to depend on poorly timed and distributed subsidies.

Guesswork is not an effective way to plan a farm, especially during peak planting seasons. While technology in agriculture can be a great way to boost production, it is also too complex for small-scale farmers (Queensland Government, 2024). To overcome this, the current study uses a mathematical model that is simplified and takes into account farm area, plant spacing, and labor capacity.

The proposed model is very practical and easy to apply. Through simple calculations, the paper illustrates how mathematics can help in planning and eliminating problems such as overgrown seedlings, inefficient use of manpower, and disorganized schedules of planting (Montgomery, 2017; Pretty, 2008). The paper examines the influence of land size and manpower on seedling requirements and planting time.

In general, this study illustrates that simple mathematical models can adequately describe real-world conditions of farming. The importance of mathematics in agriculture and how easy planning tools can be used to overcome resource constraints in farm management is highlighted.

Literature Review

Efficient seedling estimation and proper planning are important in vegetable production because they affect how land, labor, and farm inputs are used. In many small-scale and medium-scale farms, farmers still depend on manual counting and rough estimates when preparing seedlings. Because of this, problems such as overcrowded plants, unused planting space, and wasted seeds often occur. These issues show the need for better planning methods that are simple, accurate, and easy to apply in real farming situations.

Recent studies show that technology can help improve seedling estimation. Fuentes-Peñailillo et al. (2023) developed a system that uses artificial intelligence to automatically count seedlings, which reduces human error and saves time. This proves that digital tools can make early farm operations more efficient. In the same way, Gallegos-Cedillo et al. (2024) found that many recent studies focus on improving nursery systems, including tray design, seedling quality, and transplant handling. These findings suggest that accurate seedling counting should go hand in hand with proper nursery planning.

Other research highlights the importance of correct planting density. Shasteen et al. (2023) showed that proper spacing in lettuce affects plant growth, harvest time, and final yield. This means that using the right number of seedlings is necessary to achieve better production and income. Studies on lettuce and Chinese cabbage also found that seedling growth depends on the growing medium and nutrient supply used in nurseries. This shows that seedling planning is not only about numbers but also about producing healthy seedlings.

Several studies explain how plant population affects crop performance. Huzsvai et al. (2022) found that when plant density is too high, plants compete for light, nutrients, and space, which can reduce individual yield. Lin et al. (2024) also reported that optimal planting density improves light absorption and overall biomass production. Mathematical models, such as the Random Planting Model by Talbot et al. (2024), help explain how spacing and plant arrangement affect crop growth.

Moreover, Shah et al. (2021) used hydrothermal time (HTT) models to predict the interaction of temperature and water potential in the emergence of seedlings. This gives a mathematical approach to calculate the exact time and number of seedlings required. This also supports the use of formulas and calculations in estimating seedling requirements.

Mathematical and computational approaches have also been applied to improve planning decisions in vegetable production. Elnesr et al. (2013) developed an arithmetic method to determine the most suitable planting dates for vegetables using temperature-based calculations and climatic data. Their study showed that simple mathematical formulas can provide reliable guidance for farm planning and decision-making. Although their research focused on planting dates, the approach demonstrates how arithmetic models can be applied to different aspects of vegetable production planning.

The use of arithmetic and decision-support models further emphasizes the role of mathematics in farm management. By converting field conditions and production requirements into numerical values, farmers can make more informed decisions that reduce uncertainty and resource waste. In seedling estimation, similar computational approaches can be used to determine the appropriate number of seedlings based on land area, spacing, and labor capacity. This supports the development of a practical and easy-to-use seedling estimation system for vegetable farming.

Nursery practices also affect seedling success. Sutardi et al. (2022) found that different nursery systems influence seedling emergence and early growth, which later affects transplant survival. This shows that seedling estimation should be combined with good nursery management to reduce losses.

Local studies in the Philippines show similar challenges. Research on pechay production in Southern Philippines revealed that seedling establishment methods, such as using seedling trays or direct seeding, affect plant survival and yield. Another study conducted in Leyte reported that many nurseries experience poor planning and inconsistent seedling quality due to limited technical knowledge. These findings highlight the need for better and more organized seedling production systems in the country.

Farm management also plays a role in seedling planning. Hunt (2001) emphasized that proper management of labor and farm activities improves efficiency. In the Philippine setting, Arro (2023) stressed that improved seedling planning is important for strengthening the vegetable seed system. Similarly, Benguet State University (2018) emphasized that proper farm planning and crop rotation help improve soil health and resource use.

In summary, existing studies show that vegetable farming becomes more efficient when seedling estimation, planting density, nursery management, and farm operations are planned systematically. By using simple mathematical calculations and basic computational tools that consider land area, spacing, and labor capacity, farmers can reduce waste and improve productivity. This supports the development of a practical seedling estimation and planning system for vegetable farming.

Methodology

The quantitative-descriptive-computational design was utilized for estimating the number of vegetable seedlings and the overall planting time required based on the available land and workforce. The design involved the utilization of mathematical formulas for estimating the planting time and the overall workforce efficiency based on the available land and workforce, which is useful for planning and resource efficiency on the farm (Hunt, 2001). The quantitative computation is useful for estimating the seedlings and workforce efficiency objectively, while the description provides clarity on the outcomes based on the scenarios on the farm.

In this study, both primary and secondary data were utilized. The primary data involved measurements conducted in the field, such as total land area, which is normally practiced in vegetable farming on a small to medium scale. Secondary data were extracted from agricultural manuals, engineering handbooks, and published research papers that involve standard values on plant distances, labor productivity, and working hour assumptions. In particular, data on plant distances and seedling population were derived from standard agricultural manuals (Guru, & Guru., 2024 & Shasteen et al., 2023), while labor productivity parameters were derived from agricultural management standards (Hunt, 2001).

The variables in this study were defined in relation to established agricultural and farm management literature.

The independent variables were Total Land Area (A), Row Spacing (R), and Plant Spacing (P). Total land area represents the actual size of the land field measured for vegetable planting, in square meters or in hectares, in the usual land measurement units (Hunt, 2001). Row spacing represents the distance between the rows of plants, with the plant spacing measuring the distance between plants in a row. This is in accordance with spacing guidelines meant to minimize competition for sunlight, nutrients, and water (Huzsvai et al., 2022; Shasteen et al., 2023).

The labor-related independent variables were Number of Workers (W) and Planting Rate per Worker (S). The number of workers represents the total number of laborers allocated for the task of planting. The planting rate per worker indicates the average number of seedlings that a worker can plant per hour, a measure that has been widely adopted for labor efficiency studies (Hunt, 2001). The dependent variables are the Total Seedlings Needed (N) and the Total Planting Time (T).

Total seedlings needed are the calculated number of plants that are needed to maximize the use of available land. Total planting time is the time taken to plant the seedlings. The time is expressed in hours or days, depending on the labor force. The controlled variables were Work Hours per Day (H) and vegetable variety guidelines. To make it easier to compare the different scenarios, the number of working hours per day remained constant and was based on typical labor inputs for a farm (Hunt, 2001). The vegetable varieties' requirements, including spacing and nursery care, were also constant and based on typical practices (Guru, & Guru, 2024 and Benguet State University, 2018).

The total number of seedlings needed (N) was determined using an arithmetic formula in accordance with spatial allocation principles to ensure an optimal number of plants per unit of land area. The approach will prevent overcrowding and competition for nutrients, which might negatively impact growth and yield (Huzsvai et al., 2022).

Formula 1:

$$N = \frac{A}{R \times P}$$

This formula was adapted from standard agricultural engineering principles and planting density models (Hunt, 2001; Guru, & Guru, 2024). Here, the total land area is divided by the product of row spacing and plant spacing to determine the maximum number of plants that can be accommodated efficiently.

The estimated total planting time (T) was computed using a labor efficiency model, which evaluates the collective planting capacity of the workforce relative to the required number of seedlings. This model is widely used in farm power and machinery management to assess labor productivity (Hunt, 2001).

Formula 2:

$$T = \frac{N}{S \times W \times H}$$

This formula takes into account the total number of seedlings to be planted, broken down using the planting capacity of labor, using the number of workers (W), the number of working hours daily (H), and the rate of planting per worker (S). This formula allows the determination of the time it will take for planting activities to occur.

All calculations were done using simple mathematical computation capabilities, such as calculators and spreadsheet software. The results obtained through computation were analyzed descriptively by examining differences in seedling demands and planting time depending on different land sizes and work conditions. The approach enabled one to determine the efficiency gained through a systematic and computation-driven planning method to enhance farm operations without wasting seeds, time, and worker effort unnecessarily.

Conceptual Framework

The researchers aim to estimate and determine the average time needed for planting vegetables through the application of a simplified mathematical model. As discussed, this approach helps the researchers understand the way and the degree to which variables such as farm area, plant spacing, and labor capacity affect the overall efficiency of a farming operation. The study systematically unfolds through three main phases, including A. Input, B. Process, and C. Output.

The Process begins with the collection of data sources such as field measurements, agricultural manuals, and guidelines for planting vegetables. The gathered data are then organized according to the independent variables, which include survival rate, work hours, planting rate, number of workers, and seedling spacing. Using the mathematical formula:

$$T = \frac{N}{S \times W \times H}$$

The researchers compute the estimated planting time and seedling requirements for each specific scenario. Computed values are analyzed and compared across different parameters to identify patterns, trends, and variations in planting efficiency.

The Output of the study includes the computed seedling estimates and total planting time, the identification of optimal spacing and labor configurations, and a comparative resource profile for agricultural planning. These results provide a simplified yet practical assessment of farm operations and demonstrate how computational mathematics can be effectively used to support farmers in optimizing resources, improving efficiency, and ensuring successful vegetable production.

Results

The results derived from the formulated seedling requirement and planting time equations are summarized in the table below. This table presents the land area, spacing, and labor variables used in the computation, along with the corresponding estimates for seedling needs (*N*) and time duration (*T*). The tabulated results illustrate the variation in operational requirements across different farm scales and labor capacities, providing a basis for analyzing the relationship between spatial planning, labor allocation, and planting efficiency.

Table 1. ESTIMATED SEEDLING NEEDS AND PLANTING TIME

Total Area (m^2)	Row Spacing (m)	Plant Spacing (m)	Seedlings Needed (N)	No. of Workers (W)	Planting Rate (S)	Work Hours (H)	Time Duration (T)
2000	0.5	0.25	16,000	4	300/hr	6 hrs/day	2.22 days
1000	0.4	0.2	12,500	3	250/hr	6 hrs/day	2.78 days
500	0.6	0.3	2,778	2	200/hr	5 hrs/day	1.39 days

Discussion

This study presented the calculated seedling needs (N) and planting time (T) using field measurements and labor data. The results showed that planting efficiency varies significantly between scenarios due to the complex interaction between spatial variables (land area and spacing) and labor capacity (planting rate and workforce size).

Results show that larger land areas consistently required the highest number of seedlings and longer planting durations when labor remained constant. Peak labor requirements were observed during scenarios with tighter plant spacing (P). Even though tighter spacing can increase potential yield per unit area, it significantly increases the total plant population (N), requiring more initial capital for seedlings and more hours for manual transplanting. This supports the mathematical relationship identified by Huzsvai et al. (2022), who argued that while high plant density is a driver for production, it simultaneously creates a higher demand for precise resource management to avoid nutrient competition and operational bottlenecks. Thus, spacing is a major contributing factor to increased resource demand, validating the study's conceptual framework regarding the combined effect of spatial and temporal variables on farm efficiency.

The level of precision achieved through these calculations is also emphasized by the physiological needs of the plants. Through these calculations, farmers are able to reduce the risks posed by the different environmental conditions. This is supported by the findings of Shah et al. (2021), which show that the models of hydrothermal time used in the study indicate that the success of seedlings is highly dependent on the interaction of temperature and water. Through this study, farmers are able to avoid transplanting healthy seedlings into the field when the conditions are such that poor timing results in high mortality rates, thus wasting the precision-grown inputs.

In contrast, scenarios with wider spacing showed a more moderate and relatively stable time duration (T). The resource requirements were lower during these setups, with slight increases only when the total area (A) was expanded. Comparison reveals that labor rate (S) and the number of workers (W) also contribute significantly to efficiency. Even though larger areas have higher seedling needs, increasing the total labor capacity leads to more balanced operational conditions. This is consistent with Hunt's (2001) principles of farm machinery and power management, which state that labor efficiency is a product of matching workforce capacity to the total workload (N).

Moreover, the change from "rough estimation" to calculation is an important economic change for small-scale farmers. The findings of this study indicate that labor is not only a fixed cost item but also a variable that should be optimized mathematically with respect to the land area. If the labor capacity is not matched with the plant population, then the "operational bottlenecks" cause the transplanting to be delayed, which can decrease light absorption and biomass as noted by Lin et al. (2024). This study provides a way to safeguard the biological potential of the crop through operational excellence.

The results imply that this computational method is a feasible and easily accessible indicator for estimating farm operations, especially in regions where technical "nurserymanship" is lacking. As identified by Arro (2023), the Philippine seedling system often suffers from unstructured planning, where smallholder farmers are left without technical tools to manage government-subsidized inputs. By applying this model, farmers and planners can move away from traditional guesswork, ensuring that seedling procurement matches field capacity. Furthermore, accounting for the nursery methods used is vital, as Sutardi et al. (2022) found that seedling growth rates vary by nursery system; therefore, using this study's formulas allows farmers to schedule transplanting at the exact moment seedlings reach optimal maturity.

In the particular case of agriculture in the Philippines, where land fragmentation and the use of human labor are common, these results offer a connection between conventional and precision agriculture. The synergy between technology, as in the AI-based counting systems of Fuentes-Peñailillo et al. (2023), may still be economically inaccessible to most local farmers, but the arithmetic models developed in this study offer a "middle-ground" technology. This accessible computer technology enables local farmers to harness the efficiency gains discovered in the high-tech nursery systems (Gallegos-Cedillo et al., 2024) using only basic field information and simple calculations.

Limitations of this study are presented, dealing with field estimates and involving a simplified formula that did not account for the effect of environmental factors such as soil quality or weather conditions. However, the study confirms that land area and spacing jointly influence planting time and seedling requirements. More importantly, labor management continues to play a key role in shaping efficient farming experiences in the local agricultural sector, bridging the gap between resource availability and successful crop establishment.

Conclusion

The efficiency of agriculture can be enhanced if the needs for seedlings and the time for planting (T) are computed using simple models for calculation. The models can be developed by considering land area (A), plant space (P), and the capacity to work ($S \times W \times H$), and will be very useful in changing the method from estimating to calculating for the small-scale farmer.

On a communal scale, this approach assists farmers in approximating seed, human, and time requirements prior to crop planting, thereby answering the planning deficits that Arro (2023) pointed out. To improve its effectiveness, there is a need for the Department of Agriculture (DA) and LGUs to integrate these models into their extension programs in relation to farm spacing guides, training, and offline mobile applications that aim for precision farming, especially in remote areas (Sutardi et al., 2022; Queensland Government, 2024).

In the end, the implementation of these arithmetic models is a crucial safety net for the economic viability of smallholder farms. By minimizing seed wastage and maximizing the use of human labor, farmers can minimize their production costs and maximize their profits. As the agricultural industry is increasingly threatened by the challenges of climate variability, the need to mathematically coordinate nursery production with field capacity, as exemplified by the hydrothermal time models of Shah et al. (2021), will become imperative. This shift from experience-based decision-making to data-driven decision-making will ensure that every seedling planted is part of a more predictable, productive, and food-secure future for the Philippine vegetable industry.

For future research, it is suggested to incorporate factors such as soil quality, climate, and crop-specific rates of germination into equations to enhance the precision of seedling and worker predictions (Huzsvai et al., 2022; Lin et al., 2024).

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