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**RESEARCH ARTICLE**

# DEVELOPMENT OF MOBILE-BASED GUIDELINE MODEL OF GOOD AGRICULTURAL PRACTICES FOR POTATO FARMERS IN SRI LANKA

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**ABSTRACT**

**Potato is the most popular root crop and represents a significant portion of the world's food requirements. However, it has been notified that the quality and safety of potatoes produced in Sri Lanka suffer from inappropriate farming practices. Therefore, this study aims to develop a mobile-based guideline model of Good Agricultural Practices (GAPs) by reviewing a present farming practice in potato cultivation and to explore farmers' view on GAPs for potato production in Sri Lanka. The GAPs based guideline model was designed according to the Design Science Research methodology with primary and secondary data, which obtained from 225 potato farmers through a pre-tested structured questionnaire, formal and informal discussions. Then designed model was verified and validated through domain experts. Finally, information and guidance in the designed model is fed through a mobile application. Interestingly, 96% of farmers have a general idea on GAPs, 98% are willing to know about GAPs and the majority (92%) like to follow guidelines based on GAPs. Moreover, age (p=0.000), education level (p=0.001), farming experiences (p=0.008) and willingness to know GAPs (p=0.000), were affect significantly on farmer willingness to follow GAPs through the mobile-based application system. Moreover, the farming practices attached with the usage of synthetic chemicals and fertilizer, soil fertility management, postharvest handling were not properly practiced (78%). Further, spearmen correlation analysis showed that age (p=0.000), education level (p=0.014), and farming experiences (p=0.000), were affect significantly on farmers' awareness of GAPs. The findings shed a green light for introducing a mobile-based guideline model to provide actionable information and guidance of GAPs to the farmers through a "*Govi Nena*" real-time mobile-based application. Further it supports farmers to overcome improper farming practices of potato cultivation in Sri Lanka that ultimately enhancing the potato production in Sri Lankan context.**

Keywords: Design Science Research Methodology, Farmer awareness, Farmer willingness, Good Agricultural Practices (GAPs), Mobile based Information Systems

## INTRODUCTION

The Potato *(Solanum tuberosum)* has been popularly known as 'The king of vegetables', which has emerged as one of the most important root crops in the world. The potato tubers come in thousands of varieties with great differences in size, shape, colour, texture, cooking characteristics and taste (Rivelli and De Maria, 2018). Potato has been the fourth most important global crop after maize, rice, and wheat with an annual production of 381 MT (FAO, 2007). Potato has steadily expanded in over 149 countries under temperate, subtropical and tropical conditions by consuming more than one million people (Birch *et al*. 2012).

In Sri Lanka, the potato has been identified as one of the economically attractive upland crops and it has mainly grown in two districts in Sri Lanka, namely Nuwara Eliya and Badulla with a land extent of 5000 ha and an average yield of 15 tons per hectare

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(Department of Agriculture, 2014). Due to the favorable agro-climatic conditions, 99% of the total land of potato cultivation has been concentrated into two districts of Nuwara Eliya (1463 ha) and Badulla (3500 ha) (Department of Census and Statistics, 2018). Nuwara Eliya district's peak planting periods fall on August-September (*Yala* season) and February-March (*Maha* season). In Badulla, there are two growing seasons, one in the uplands in November-December (*Maha* season) and the other in June-July (*Yala* season) in the paddy fields of the plains after the rice harvest (Department of Agriculture, 2019). Department of Census and Statistics, 2018 and Central Bank of Sri Lanka, 2020 revealed that, the annual potato production of Sri Lanka is on averagely 101,642 MT, 88,897 MT, 73,358 MT, and 95,805 MT for 2019, 2018, 2017 and 2016 respectively. However, Sri Lanka has imported 140 810 MT potatoes annually to fulfil the local demand and the total annual expenditure is nearly 42 million USD$ in the year 2020 (142,086 MT; 2019, 158,695 MT; 2018, 151,438 MT; 2017, 148,081 MT; 2016) (Department of Census and Statistics, 2020; 2017, Sri Lanka Custom, 2021; Central Bank of Sri Lanka, 2018, 2019, 2020).

Over the past few decades, food quality and food safety have drawn high attention, particularly among consumers mainly due to the use of various chemicals for crop cultivation and storage (Uçar *et al*. 2016). Therefore, consumers were more interested to know the cultivation, storage and processing processes of food chains. Food and Agriculture organizations and individual governments developed a set of principles, regulations and technical recommendations to applicable in production, procession, storage and transport ensuring the quality and the safety of the final product. Those are named as Good Agricultural Practices (GAPs). In Sri Lanka, the department of Agriculture also has developed GAPs for many crops other than potato. Although a proper guideline has not been developed in Sri Lankan context, several GAPs in potato production and processing have been published by many international organizations such as Food and Agriculture Organization (Senanayake and Ratnayake, 2015).

GAPs are practices that address the environmental, economic, and social sustainability of on-farm processes and result in the safety and quality of the final products (FAO, 2007). The main purpose of the GAP is to produce foods that are safe and wholesome to consumers by applying ecologically sustainable agricultural methods (Schobesberger *et al.* 2008). GAPs come to the fore in this backdrop and it can be simply defined as doing things well and guaranteeing it has been done (Bamunuarachchi *et al*. 2019). Further, it has included a set of principles, regulations and technical recommendations applicable to production, processing and food transport, ensuring safety and quality of produce in the supply chain, capturing new market advantages by modifying supply chain governance, improving natural resources use, worker health and working conditions and creating new market opportunities for farmers and exporters in developing countries in particular (FAO, 2007).

The quality and safety of potatoes produced in Sri Lanka suffer from improper pesticide and fertilizer usage, poor storage conditions, pest and diseases management, improper irrigation and fertigation, availability of good quality seeds, unavailability of storage and transport facilities like poor methods and practices from production to the post-harvest stage (Weerakkody and Mawalagedera, 2020; Kumara *et al*. 2015). Improved post-harvest technologies alone cannot ensure the quality and safety of potato production because the effect of the pre-harvest factors such as crop management, field sanitation, and post-harvest losses also contributes to crop losses and reduce the quality and safety of the potato (Harrison *et al.* 2015).

Maintaining quality of any production, yields promising results and better crop management is essential in this regard. When considering crop management, the fertilizer requirement is estimated according to the expected yield, yield potential of the variety, the level of available soil nutrients, the intended use of the harvested crop *etc*. (Roy *et al*. 2006). However, similar to the other crops the

extreme usage of chemical fertilizer is one of the main problems in potato cultivation (Carvalho, 2006). Further, crop protection, crop damages and losses of the potato cultivation can be controlled by basic precautions such as crop rotation, use of pest & diseases tolerant varieties, use of healthy certified seed tubers and regular monitoring of farm *etc*. (Alptekin, 2011). Quality and healthy, purified seed tubers can be increased yields by 30 to 50 percent, when comparing the low-quality seed potatoes (Sands *et al*. 2019). Under these conditions, recommended chemical control methods and integrated pest management practices can be controlled by ensuring the quality and safety of the crop (Alptekin, 2011). Further, proper storage facilities have been an essential good agricultural practice (GAP) to guarantee an adequate supply of ware potatoes and seed tubers up to the next cropping season and prevent post-harvest losses of potatoes destined for fresh consumption or processing (Pinhero *et al.* 2009). Ware potatoes have stored at a temperature of 5-8°C, in a dark, well-ventilated environment with a high relative humidity of 85-90% to prevent "greening" and losses in weight and quality (Wasukira *et al.* 2016). The seed tubers should be stored, instead, under diffused light in order to maintain their germination capacity and encourage the development of vigorous sprouts (Lutaladio *et al.* 2009). Moreover, improper agronomic practices, pest and disease incidence, high cost of production, problems in marketing, potato importation, high cost of farm inputs and low yield have been identified as major issues in whole potato production and these will constantly affect the food and safety of the potato in Sri Lanka (Mohemad *et al.* 2021; Eswaran *et al*. 2016; Ugonna *et al*. 2013).

In addition, when compared to the other developed countries, availability of the quality and safety of potatoes are relatively low with the high cost of production. The quality and the average cost of production of potato greatly varies due to the type of seeds and other farming practices. Due to that, potato farmers faced more and more challenges such as lack of the quality of the production, increased post-harvest losses, and decreased market value (Mahmud *et al*. 2009). Further, as stated in Sri Lanka Fruit and Vegetable Producers, Processors and Exporters Association (LFVPPEA) over usage of chemicals and usage of banned chemicals in agricultural lands, poor packing methods and lack of post-harvest technologies were the current major issues that the industry should address that was detected by the European Union (Bamunuarachchi *et al*. 2019). The unavailability of GAPs triggers this situation. On the other hand, it is necessary to explore farmers views, the way of programme should be carried out and the potential of these GAPs, especially related to potato cultivation.

Hence, GAP is a globally accepted phenomenon, it should be sustained while overcoming the barriers, catering to local and export markets. Further, the development of the potato subsector in Sri Lanka can be enhanced by applying GAPs. Therefore, special attention should be drawn to and action should be taken in that regard. Identifying and implementing guidelines, interventions should be made to clear the avenues for smooth dissemination of GAP as an innovative farm practice. Since this practice is a novel experience in Sri Lanka. Therefore, it is very hard to find literature in this regard in particular in the Sri Lankan context.

However, the unavailability of such a guideline model that reaches farmers in an effective and timely manner hampers the expected outcome of the cultivation of any crop. If crop cultivation in Sri Lanka can be promoted by introducing a proper and effective, timely available GAPs based guideline model, it will surely improve food quality and safety. Moreover, it may support achieving high prices in the market through the production of quality and hygienic products. This allows farmers to have a high fixed income without risk and uncertainty in selling the harvest by reducing the unnecessary expenditure on agricultural inputs while earning higher profits (Department of Agriculture, 2019). Accordingly, the GAPs based on the certification / guideline model

for potatoes will have a great value in the Sri Lanka context and it will be a sound solution to quality and safety issues in potato cultivation. Further, consumers will enjoy better and safe quality food with sustainable production and the population will benefit from a better environment. Since that information and guidance should be correctly and quickly disseminated to farmers in a proper time, the usage of Information and Communication Technology (ICT) seems fruitful in this technologically advanced era.

In this innovative era, most people use the new technology and ICT for almost all day-to-day activities and to fulfil their needs (Walisadeera *et al.* 2016). The smartphone has become an essential piece of equipment in society. It has made people's lives easier than before by being useful for essential purposes. Modern technology and ICT have become major approaches such as mobile platform to manage agriculture, rural development, make plans and agribusiness tasks in many agricultural countries (Henegedara, 2015). Moreover, ICT plays a vital role in sharing knowledge and information for agriculture and supports farmers to make effective decisions (Chhachhar *et al.* 2014). Cieslik *et al.* (2018) stated that, increasing of the availability of ICT ensure management and monitoring the complex ecological problems and enhance knowledge sharing among relevant parties by generating timely context-specific information. However, the expansion of mobile phone applications, coverage and usage have been increased among the farmers from different ICT tools (Muto and Yamano, 2011). When considering the Sri Lanka, the Central Bank (2019) stated that, mobile phone usage has increased among the people in Sri Lanka in the recent past. Therefore, providing agricultural information by connecting to the increased use of the internet and use of other digital technologies and mobile phones, brings attraction among worldwide farming communities. This is a viable solution dissemination of modern agricultural techniques accurately and quickly between farming communities than traditional knowledge sharing methods.

Digital agriculture can play a major role in food security by reducing wastage, predicting demand, providing real-time information, feedback and much more. Govi-Nena mobile application is such a game-changing technological application specially designing and developing for Sri Lankan farmers (https://govinena.lk/). Several mobile applications have been introduced for different sectors of agriculture in Sri Lanka such as for crops, soil, fertilizers, diseases and so on. However, there is no application which includes all the aspects of agriculture. "Govi-Nena" is a mobile-based application that provides knowledge and guidance for farmers for their farming activities. Therefore, this seems as the most appropriate knowledge delivery method to disseminate the right knowledge of the good agricultural practices guidelines to overcome the major challenges in the crop/potato production of Sri Lanka. It will provide vital information accurately at the right time in the most appropriate way. This work-related to provide information and knowledge to the farmers through a "*Govi Nena*" real-time mobile-based application has been developed in three parallel streams including A; ontological crop knowledge base development, B; developing a model for achieving equilibrium between supply and demand through incentives, system deployment, and testing, and C; mobile-based platform development. The development of Mobile-based Guideline Model of Good Agricultural Practices has been aligned with stream A.

Therefore, the study aims are 1) to identify present farming practices in potato cultivation, 2) to explore farmers' views on guidelines of the Good Agricultural Practices (GAPs) for potato production in Sri Lanka 3) to assess farmers' willingness to follow GAPs based guidelines through mobile-based application and 4) to develop a model for the guidelines of Good Agricultural Practices (GAPs) attached with existing "Govi-Nena" mobile-based application.

## MATERIALS AND METHODS

This study was conducted in major potato growing areas in Sri Lanka, Badulla and

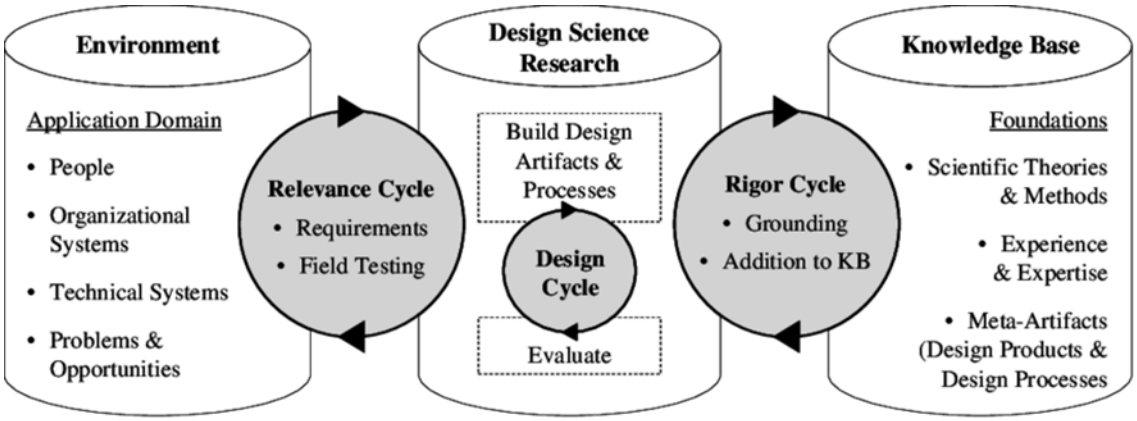


**Figure 1: Design Science Research (DSR) cycles**

Source: Urbach and Wurz, 2012

Nuwara-Eliya districts. To fulfil the objectives of the study, altogether 225 farmers, 100 from Nuwara-Eliya district and 125 from Badulla district were selected using the snowball sampling technique. The Design Science Research (DSR) methodology was used as the research approach to propose a model for developing the guidelines of the Good Agricultural Practices (GAPs) as used by many scholars in this field (Urbach and Wurz, 2012). DSR consists of three cycles; Relevance, Design, and Rigor (Figure 1). The relevance cycle finds out the requirements, problems such as environmental, social, economic problems and opportunities from the environment/ application domains (in this context, the problems faced by the Sri Lankan potato farmers). Through this cycle, the designed GAP model, farmers willingness to follow GAPs, perceptions, can be tested through the field testing. As a result, artifacts were produced for these problems. Here an artifact refers to the guideline/ certification model for effective potato production. The rigor cycle gives grounding knowledge including secondary data, scientific theories & methods, experience & expertise to take part in the research activities and new knowledge will be included as a result of these activities. Then, the guideline model construction and evaluation under the research activities will be carried out in the design cycle operation through domain expertise (agriculture instructors, experienced farmers, research officers *etc*.). Finally, the model will be refined and generalized based on the famer's feedback, perception and evaluation comments from domain experts and popularized through the "*Govi Nena*" mobile-based application.

The primary data were collected through face-to-face interviews by using two pre-tested questionnaires, field surveys and telephone conversations. One questionnaire was prepared to identify the present farming practices in potato cultivation. As the key variables, major farming practices were selected. Another questionnaire was used to identify the farmers' views on the guidelines of the Good Agricultural Practices (GAPs) for potato production in Sri Lanka. The key variables which collected from the second questionnaire are summarized in Table 1.

The secondary data were gathered from relevant intuitions such as the Department of Agriculture, Sri Lankan Standard Intuition, Agriculture Research, and Development Center – Seetha Eliya, HARTI, Department of Census and Statistics, and research articles and books. The data were tabulated and analyzed through inferential statistics (Spearman's rank correlation) and descriptive statistics (Bar charts and pie charts) with help of SPSS statistical software. The correlation coefficients were calculated using Karl Pearson's correlation coefficient and Spearman's rank correlation coefficient.

**Table 1: The description of the key variables measured in the questionaries.**

| Variable | Measurement | Description |
|---|---|---|
| Farmer's age, | Ratio | **1** for 20-30 years,<br>**2** for 31-40 years,<br>**3** for 41-50 years,<br>**4** for 51-60 years and<br>**5** for Above 60 years. |
| Farmer's education levels, | Ratio | **1** for Primary,<br>**2** for O/L,<br>**3** for A/L and<br>**4** for Diploma or Graduate |
| Farmer's experience | Ratio | **1** for below 5 years,<br>**2** for 6 years to 10 years and<br>**3** for Above 10 years |
| Awareness on GAPs, | Likert scale | **1** Not Aware, 2 Aware and<br>**3** for Highly Aware |
| Willingness to know GAPs guideline | Likert scale | **1** for Not willing,<br>**2** for Somewhat willing and<br>**3** for Willing |
| Willingness to follow GAPs guidelines through mobile-based information system for potato production in Sri Lanka | Likert scale | **1** for Not willing,<br>**2** for Somewhat willing and<br>**3** for Willing |
| availability of certificates for potato cultivation | Ratio | **1** for Yes, **0** for No |
| Willingness to take certificates by following GAPs guidelines. | Ratio | **1** for Yes, **0** for No |

## RESULTS AND DISCUSSION

### Present scenario of the potato cultivation in Sri Lanka

Among the 225 potato farmers, 100 were in *Nuwara Eliya* and others in the *Badulla* district. In Badulla district, the majority of farmers (31%) were in the 51- 60 years age group while 30% of *Nuwara Eliya* farmers were in the above 60 years age group. Moreover, results indicated the majority (39%) of the farmers have education up to Ordinary Level in Badulla district with a smaller number of farmers (6%) having Diploma or Degree level qualification in both districts. However, in Nuwara Eliya district 40% of farmers have education up to Advanced Level. In addition to that, the majority of the farmers have more than 10 years of experience with potato cultivation in Badulla (57%) and Nuwara Eliya (66%) district.

Figure 2 shows the farming practices adopted by potato farmers in both districts. 82% of farmers in Nuwara Eliya and 92% of farmers in Badulla district cultivated potato with vegetable crops rotationally. The majority (90%) of them in the Badulla district cultivated potatoes in the paddy field during the "*yala*" after paddy cultivation. Kuruppu *et al.* (2020) reported that paddy cultivation provides good fallowing conditions for successful potato production. Some farmers (21% in Nuwara Eliya and 32% in Badulla) were practiced intercropping with potato and short-term vegetables. It is obvious that, farmers who engaged in intercropping, gained extra income at a low cost of production by proper land use and maximum utilization of natural resources such as water and nutrient. However, 40% of the farmers were not aware of the benefits of intercropping. Meanwhile, 50% to 55% of farmers in both districts claimed that they did not have vital information such as crop choices, cropping patterns, amount of potential harvest, *etc*.

When comparing the other farming practices, most farmers (78% to 80%) were practiced soil conservation methods such as contour ploughing and terrace farming during the land preparation. However, they do not test the soil and water quality. Most of them (30% in Badulla and 43% in Nuwara Eliya) were used sprinkler irrigation systems for the water application and they used manual methods for many activities such as fertilizer application, harvesting *etc*. When considering type of fertilizer application, the majority (97%) of them used organic fertilizers (5%) and inorganic fertilizer (90% - 95%). Department of Agriculture, (2019) recommended required inorganic fertilizers amount for potato cultivation in Nuwara Eliya and Badulla district as a 132kg/ac of Urea, 108kg/ac of TSP and 100kg/ac of MOP (Total amount of inorganic fertilizer: 340kg/ac). However, most of them were using a large amount of inorganic fertilizer (500kg/ac) beyond the recommendation. Furthermore, the study found that many farmers (97% in Nuwara Eliya and 94% in Badulla) did not follow prevention methods for pests and disease incidence. In the first instance of the pest and disease attacks or assuming such an incidence farmers use chemical treatments and it takes considerable cost in potato production.

The Integrated Pest Management (IPM) concept has four essential components such as accurate pest identification, field monitoring, control action guidelines and effective management methods (Alptekin, 2011). The seed quality and certification, biological control, resistant cultivars, chemical control with pesticides, sanitation, crop rotation, seed treatment, irrigation, fertilization, harvesting methods, sprout inhibitors are some of the IPM practices in potato cultivation. In earlier times, they have used the IPM concept in their potato field. However, nowadays they are unable to practice it due to the lack of vital information, insufficient knowledge and guidance on those activities. Many of them (72%) express their willingness to practice IPM methods again. The majority of farmers (89%) were using manual harvesting methods and others used harvesters. Their harvesting time mainly depends on the current market price of the potato. Due to the lack of storage facilities, the majority of farmers (90%) were cultivated potatoes for ware consumption than seed potato production. According to Shanadi *et al.* (2020), most of them sell on the day of harvesting. In the Badulla district, 10% of farmers keep less amount (5%) from their harvest for the production of seed potatoes and others use it for consumption. Comparatively storage facilities/conditions

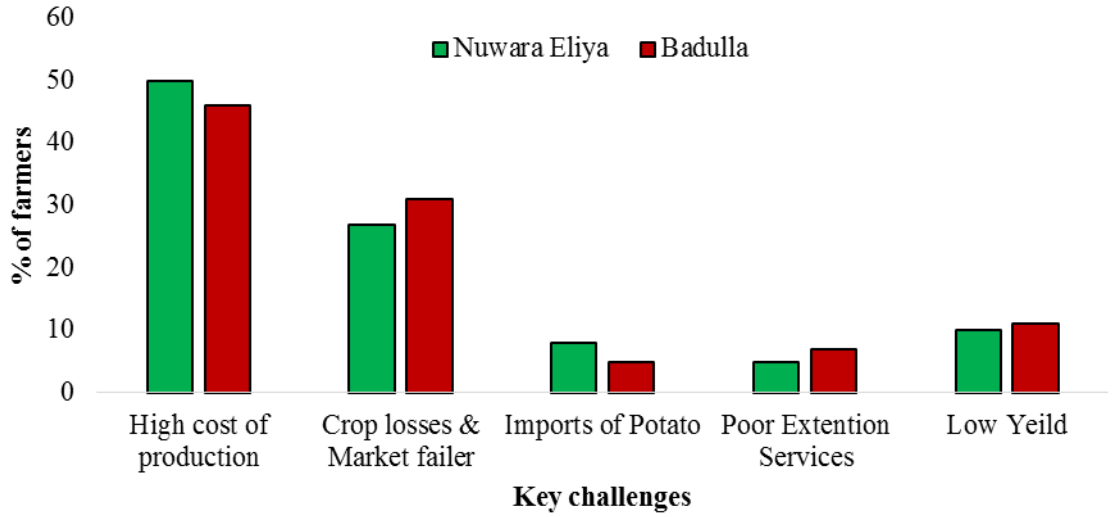


**Figure 2: Farming practices of the potato cultivation in Nuwara Eliya and Badulla district**

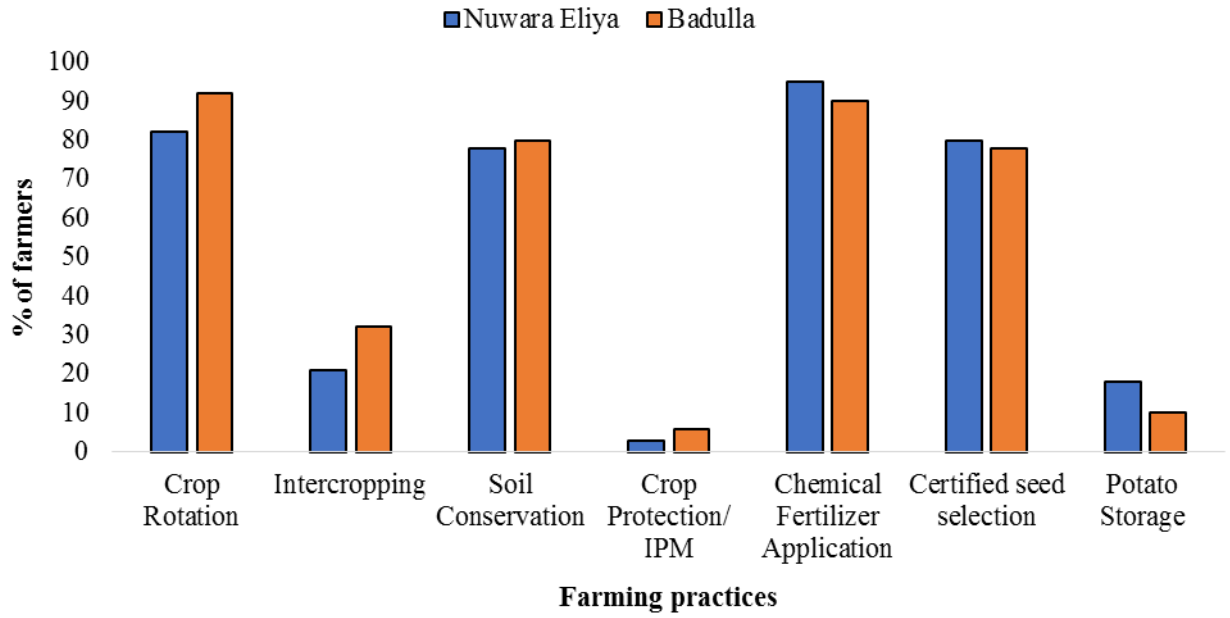


**Figure 3: Key challenges of the potato cultivation in Nuwara Eliya and Badulla districts**

were greater in Nuwara Eliya than that from the Badulla district. Therefore, 18% of farmers had stored potato harvest for off-season usage and seed potato production. Also, they take a high net return from off-season potato selling (Figure 2).

As shown in Figure 3, higher cost of production, crop losses and problems in marketing, potato imports, high cost of farm inputs, poor extension services and low yield are some major reasons for the reduction in potato production. According to the literature and findings, the cost of production per acre is estimated at around Rs. 292,000 and productivity is around 6000 kg (Wikrmaratna, 2010). In addition, when compared to the other countries, the cost of production of potatoes is relatively high, for example, the overall cost of production of potatoes in India was Rs. 7.95 per kg. But in Sri Lanka, the cost of production, estimated at around Rs 35.00 – 45.00 per kg and has remained extremely high and poor yield has eroded the profitability of this crop (Singh *et al.* 2014). The average cost of production of potatoes greatly varies due to the type of seeds and other agronomic practices (Struik, and Wiersema, 1999).

The annual seed potato requirement in Sri Lanka is about 900- 1200 kg per acre. However, most of the farmers are believed that imported seed potatoes have superior characteristics such as quality, yield per area, viability, seedling health and tolerance against pest and disease attacks, *etc*. Therefore, many farmers preferred imported seeds. Thus only 20% to 22% of the seed requirement fulfill by themselves and deficient amount were purchased from input suppliers (Hayleys, CIC, *etc*.) and research institutes (Seetha Eliya and Kahagolla). When considering the cost of production, the seed cost is Rs. 9000 (local seeds) to 17,000 (imported seeds) per 50 kg and it is also estimated that 2500 kg of seeds are required for one acre. This shows that the seeds themselves account for about 55-60% of the total cost of production.

The crop losses and market failures were other identified key challenges in the Badulla and Nuwara Eliya districts with the distribution of 31% and 27% respectively. Production losses, pest and disease attacks, environmental disorders, nutrient deficiencies, climatic disorders, post-harvest losses are some of the main reasons for crop losses and market failures. Further, most of the farmers do not have a proper method such as post-harvest handling practices, storage facilities

and transportation *etc*. to prevent or minimize market failures and crop losses. In addition to that, poor extension services and low yield were the challenges among farmers in the study areas. The farmers in Nuwara Eliya and Badulla district were stated that their crop yield was getting decreased due to the pest and disease attacks and nutrient deficiency. However, the crop yield is determined by irrigation, fertilizers, crop protection measures and cropping systems. Therefore, crop yield varies from field to field within the same area (Oerke, 2006). Also, farmers said that agricultural instructors have not visited their field frequently. Therefore, most of the time they have asked required clarification about management and cultivation practices from experienced farmers.

The importation of potatoes is also a major challenge to the farmers. However, in the survey, only 8% of farmers claimed that potato importation is a barrier to gaining high profits for their harvest. In 2020, the value of imports of commodity group "potatoes, fresh or chilled" has been $ 42 million with accounted for 0.273% of total import flow to Sri Lanka (total imports to Sri Lanka amounted to $ 15.6 billion in 2020). Mainly Sri Lanka has imported potatoes from Pakistan (53%), China (19.6%), Netherland (11.8%), India (10%), Bangladesh (1.67%), France (1.16%), Germany (1.09%), Turkey (0.84%), Iran (0.49%) and United Arab Emirates (0.34%). Out of the total potato imports, 93% of the potatoes (39 million US$) have been imported for ware consumption and the other 6.59% (2.81 million US$) are imported as seed potatoes (fresh/chilled) (Central Bank of Sri Lanka, 2020; Trend Economy, 2021).

However, in 2020, Sri Lanka has exported a total value of $ 33 thousand of potatoes as fresh or chilled to Canada (48%), the USA (38%), Maldives (6.83%), United Arab Emirates (5.12%) and France (1.43%) with sharing a 0.07% of total sales of the group in Sri Lanka (Cumulative exports of commodity group 0701 "potatoes, fresh or chilled" from Sri Lanka amounted $ in 2019). Out of that 99% (33 thousand US$) of potatoes exports for ware potatoes other than seed potatoes (fresh/chilled) and the rest 0.716% (242 US$) for seed potatoes (fresh/chilled) (Central Bank of Sri Lanka, 2020; Trend Economy, 2021).

**Farmers view on the Good Agricultural Practices**

The farmer awareness on GAPs such as land preparation by conserving the soil and minimizing soil erosion, application of organic fertilizers, quality seed selection which is free from pests and diseases, effective and efficient irrigation methods *etc*. was comparatively greater in Badulla (48%) district than Nuwara Eliya (45%). In addition to that, some farmers in Badulla (28%) and Nuwara Eliya (25%) district were moderately aware of GAPs such as the use of quality seed tubers, storing potatoes in a ventilating place by minimizing the post-harvest losses, sorting and grading before store and enter to the market, appropriate crop protection products (pesticides, fungicides *etc*.) to control the target pest or disease, synthetic fertilizer usage by appropriately and minimizing consequences on human health and the environment, *etc*. They used crop protection products which are recommended by some other farmers or agrochemical shop owners. Furthermore, the potato farmers in Badulla (20%) and Nuwara Eliya (26%) were highly aware of basic good agricultural practices such as different cropping systems (intercropping, mixed cropping), crop verity selection which is resistance to external damages and pest & diseases attacks (Granola, Lapala *etc*.), land preparation by conserving the soil and minimizing soil erosion, effective and efficient irrigation methods *etc*. consequences of synthetic chemicals and fertilizers for human health, environment and the quality of the potatoes, and out of them, six farmers were doing organic potato cultivation on small scale using the organic fertilizers and biopesticides. However, an averagely 4% of them do not have a clear idea of Good Agricultural Practices in potato cultivation.

When comparing the farmers' willingness to know GAPs, the majority of farmers expressed their willingness to know about

GAPs in potato cultivation respectively 80%, 82% in Badulla and Nuwara Eliya district. Moreover, farmers' willingness was categorized under several good agricultural practices and table 02 shows the distribution of components. 78% of farmers were willing to know about eco-friendly cropping systems like intercropping *etc*. However, the lack of knowledge and updated information on intercropping systems most of them presently practiced sole copping. Because of the knowledge gained from experience, farmers thought they can make the right decisions. Therefore, 16% were not willing to know about seed sowing requirements such as suitable date, depth, treatments, *etc*.

The majority of farmers (75%) were willing to know about organic fertilizers, biochemical usage to balance the inorganic fertilizer usage while reducing the cost of cultivation. However, some farmers were not willing to know chemical fertilizer and agrochemical usage due to the trust that more fertilizer can gain the highest yields. According to Laosutsan *et al.* (2019), the farmers who follow GAPs, cost of production were lower than non-followed farmers due to the smart use of chemicals and pesticides *etc*.; and to the higher prices commanded by the GAP vegetables relative to conventional vegetables. Moreover, most of the farmers (72%) were willing to know about pest and disease management practices such as integrated pest management. The majority, (97%) of potato farmers were willing to know at least one GAPs. Averagely, 3% of potato farmers were not willing to know about any farming practice according to the GAPs. They want to do what can make a high profit by increasing production.

**Farmer willingness to follow guidelines of the GAPs through mobile-based information system for potato production in Sri Lanka**

The majority of the farmers in Badulla (68%) and Nuwara Eliya (65%) district, expressed their willingness to follow GAPs based guidelines to improve their potato cultivation in Sri Lanka. Among them, 59 farmers were aged above 40 years and the majority had an education up to advanced level with more than 10 years cultivation experience in potato cultivation. 20% to 30% of farmers were quite willing to follow the guidelines based on good agricultural practices. This is due to the reluctance to follow certain practices such as the use of fertilizers and agrochemicals following the recommended level and methods. Only 08% of potato farmers were not willing to follow guidelines based on the

**Table 2: Distribution of components according to the willingness to know about GAPs**

| Good agricultural practices | Not willing | Somewhat willing | Willing |
|---|---|---|---|
| Crop type/verity selection | 18% | 35% | 47% |
| Cropping system/Intercropping | 3% | 19% | 78% |
| Land preparation | 27% | 32% | 41% |
| Spacing | 31% | 24% | 35% |
| Quality seeds selection | 3% | 18% | 79% |
| Seed sowing requirements (date, depth and treatments) | 16% | 28% | 56% |
| irrigation system | 35% | 26% | 39% |
| Mulching | 3% | 31% | 66% |
| Organic fertilizer requirement and usage | 2% | 23% | 75% |
| Chemical fertilizer requirement and usage | 33% | 25% | 42% |
| Agrochemical usage | 22% | 25% | 53% |
| Pest and Disease management practices | 11% | 17% | 72% |
| Storage | 12% | 20% | 68% |
| Package | 8% | 31% | 61% |
| Transportation | 9% | 43% | 48% |

**Table 3: Farmers view on good agricultural practices with coefficient values and significant values.**

| | Statements | r value | p value | Decision |
|---|---|---|---|---|
| 1 | Age will affect on the farmers awareness of GAPs | 0.536* | 0.000 | Reject the null hypothesis |
| 2 | Education Level will affect the farmers' awareness of GAPs | 0.350* | 0.014 | Reject the null hypothesis |
| 3 | Farmer's experience will affect the farmers' awareness of GAPs | 0.660* | 0.000 | Reject the null hypothesis |
| 4 | Age will affect the farmers' willingness to know GAPs | -0.226* | 0.001 | Reject the null hypothesis |
| 5 | Education Level will affect the farmers' willingness to know GAPs | 0.140* | 0.035 | Reject the null hypothesis |
| 6 | Farmer's experience will affect the farmers' willingness to know GAPs | 0.130 | 0.051 | Accept the null hypothesis |
| 7 | Age will affect the farmers' willingness to follow GAPs based guidelines through a mobile-based information system | -0.263* | 0.000 | Reject the null hypothesis |
| 8 | Education Level will affect the farmers' willingness to follow GAPs based guidelines through a mobile-based information system | 0.229* | 0.001 | Reject the null hypothesis |
| 9 | Farmers' experience will affect the farmers' willingness to follow GAPs based guidelines through a mobile-based information system | 0.176* | 0.008 | Reject the null hypothesis |
| 10 | Farmers' awareness will affect the farmers' willingness to follow GAPs based guidelines through a mobile-based information system | 0.067 | 0.319 | Accept the null hypothesis |
| 11 | Farmers' willingness to know GAPs will affect the farmers' willingness to follow GAPs based guidelines through a mobile-based information system | 0.632* | 0.000 | Reject the null hypothesis |

GAPs in both districts. They want to do what can make a high profit by increasing production. Interestingly, 92% of farmers preferred to follow GAPs based guidelines through mobile-based information systems for potato production in Sri Lanka.

Considering the desire to obtain certificates for cultivation, 96% of farmers expressed their willingness to take certificates for their farms and cultivation. All of them happy to take a certificate by following guidelines based on the Good Agriculture Practices. Due to the laziness to follow a guideline and reluctance to adapt to a new method, the other 4% of farmers were not like to take certificates by following any guidelines. Only 5 farmers had a certificate issued by the banks such as HNB, RDB, *etc*. However, it is also based on their debit instalments and financial state.

Furthermore, the study compared the relationship between the farmers' awareness of GAPs, willingness to know GAPs, willingness to follow GAPs based guidelines with the farmers' age, education level and farming experience in potato cultivation using

the Spearman's correlation coefficient. The results show that in Table 03. Farmers view good agricultural practices with coefficient values and significant values.

In this study, the correlation between farmers' age, education level and the experiences with farmers' awareness of GAPs, willingness to know GAPs and willingness to follow GAPs via a mobile application was analyzed and data is shown in table 3. Strong and positive relationships were observed for all variables analyzed except for the relationship between farmers' age with the willingness to know GAPs and willingness to follow GAPs through a mobile application implying the difficulties of introducing new technologies and knowledge to the senior farmers. Whereas except for the correlation between farmers' experience and willingness to know GAPs all other relationships are statistically significant. The results imply that farmers' age educational level and farming experiences are some factors that need to be considered in popularizing GAPs in potato cultivation in Sri Lanka through a mobile application. A positive and significant correlation between farmers' willingness to know GAPs and willingness to follow GAPs through a mobile app implies the importance of developing a guideline model.

Moreover, educated and experienced farmers on small scale are already following basic GAPs for their cultivation (Shanadi *et al.* 2020) and this can be positively expanded to medium and large-scale cultivations with proper guidelines and appropriate knowledge delivery methods.

**Proposed model to develop the guidelines based on Good Agricultural Practices (GAPs)**

An ICT-based knowledge dissemination method can be proposed to address some of the issues observed in this study such as usage of improper farming practices lack of vital information insufficient knowledge, crop losses & market failures *etc*., which will provide information and guidance on GAPs to farmers to make the right decisions at the right time for effective farming. Therefore, A mobile application will be a sound solution for delivering information and guidance on GAPs to farmers.

Based on the DSR research methodology, the GN-GAP (*Govi Nena* - Good Agricultural Practices) model (Figure 4) was proposed to develop the guideline based on GAPs for potato production in Sri Lanka through the "*Govi Nena*" mobile-based information system.

Initially, the factors/ problems (Environmental, Social and Economic) effect on potato crop cultivation and adoption of GAPs have been identified based on the findings of first and second objective's, literature survey, discussion with domain experts and field survey. Farmer's age, education level, framing experience in potato cultivation, awareness of GAPs, willingness to know GAPs, willingness to follow GAPs, cost of production per season, income per season and land ownership of the farmers are some factors, which will be affected on the adoption of the GAPs on potato cultivation in Sri Lanka (Senanayake*,* 2015).

Secondly, a guideline system has been designed based on the GAPs with the help of gathered information from research findings, discussion with domain experts and field survey, various reliable knowledge sources such as previous records (DOA, Faculty of agriculture-UOR, HARTI, HORDI, Hayleys, Seetha Eliya research center), thesis, research articles, and reliable web sources, *etc*. For that, collected GAPs have been grouped according to the stages of the crop life cycle such as Pre planting, Growing, Harvesting, and Post harvesting stages. Then identifies the differences among required information in different agro-ecological regions and design the guideline model for potato crops based on the identified gaps. The first stage of the potato farming life cycle is pre-planting and the guideline model in this stage provides information and guidance about various types of documents preparation (Site map, Record Book, Site History report *etc*.), Site Management, coordination of internal audit, Waste disposal and management, Soil and

substrate management, Chemical Fertilizer, Organic fertilizer, Pesticide selection, usage and storage arrangement, Safety, training and instructions, Selection of the planting materials (Seed Potatoes or Tubers) and land preparation *etc*., Information about the nutrient requirement, fertilizer management, irrigation and fertigation, crop protection have been given in the second stage which is named as the growing stage. Under the harvesting stage, equipment, tools and methods of harvesting information and

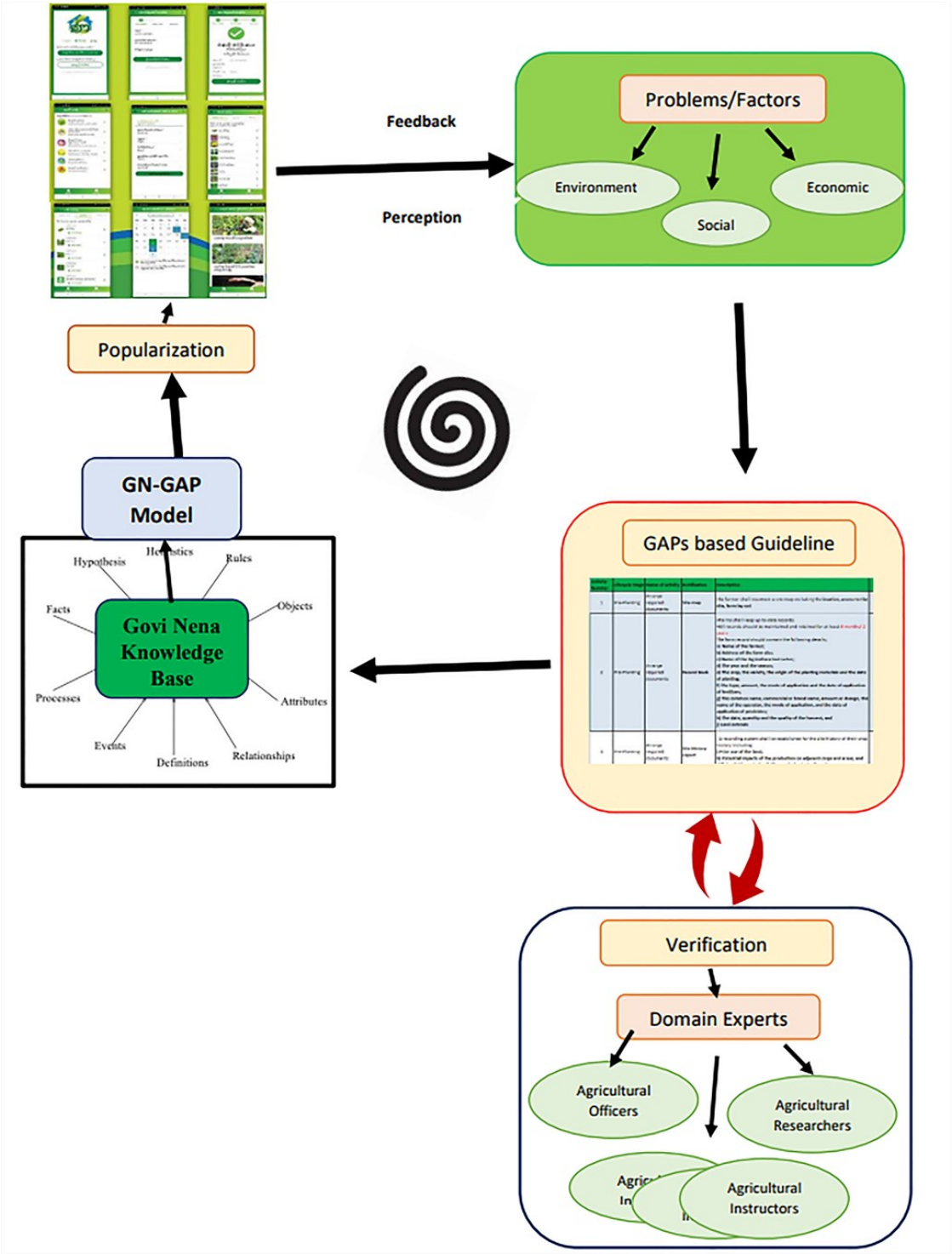


**Figure 4: Govi Nena - Good Agricultural Practices (GN-GAP) model**

guidance have been provided. In the final stage of the post-harvesting stage, post-harvest treatment, storage, packaging requirements and transport requirements information and guidance are given.

Then designed guideline system has been verified through domain experts such as agriculture instructors, agricultural researchers and extension officers, *etc*. A verified guidelines have been represented in the "*Govi Nena*" knowledge base and finally, the guideline model has been popularized and delivered through the "*Govi-Nena*" mobile application with the help of user-friendly interfaces (see Figure 05).

Most important information regarding good agricultural farming practices is available in different formats such as research articles, books, newspapers, magazines leaflets, audios and videos *etc*. However, it is difficult for the farmer to acquire knowledge and updated information from these sources. When comparing above delivery methods (articles, books, newspapers, magazines, leaflets, audios and videos), the mobile phone is familiar to everyone. Therefore, it makes easy to use the mobile applications and get updated information and knowledge with the help of user-friendly interfaces. Thus, user-friendly interfaces' play a major role in the knowledge sharing and guiding process (Shao *et al.* 2012). It will help farmers to get guidance, accurate knowledge and vital information easily at the right time.

Initially, the farmers who want to follow GAPs based guidelines should register the "*Govi Nena*" mobile-based application. GAPs based guideline was categorized based on the four stages in farming life and each stage contains the GAP activity that needs to be done at that time as mentioned above.

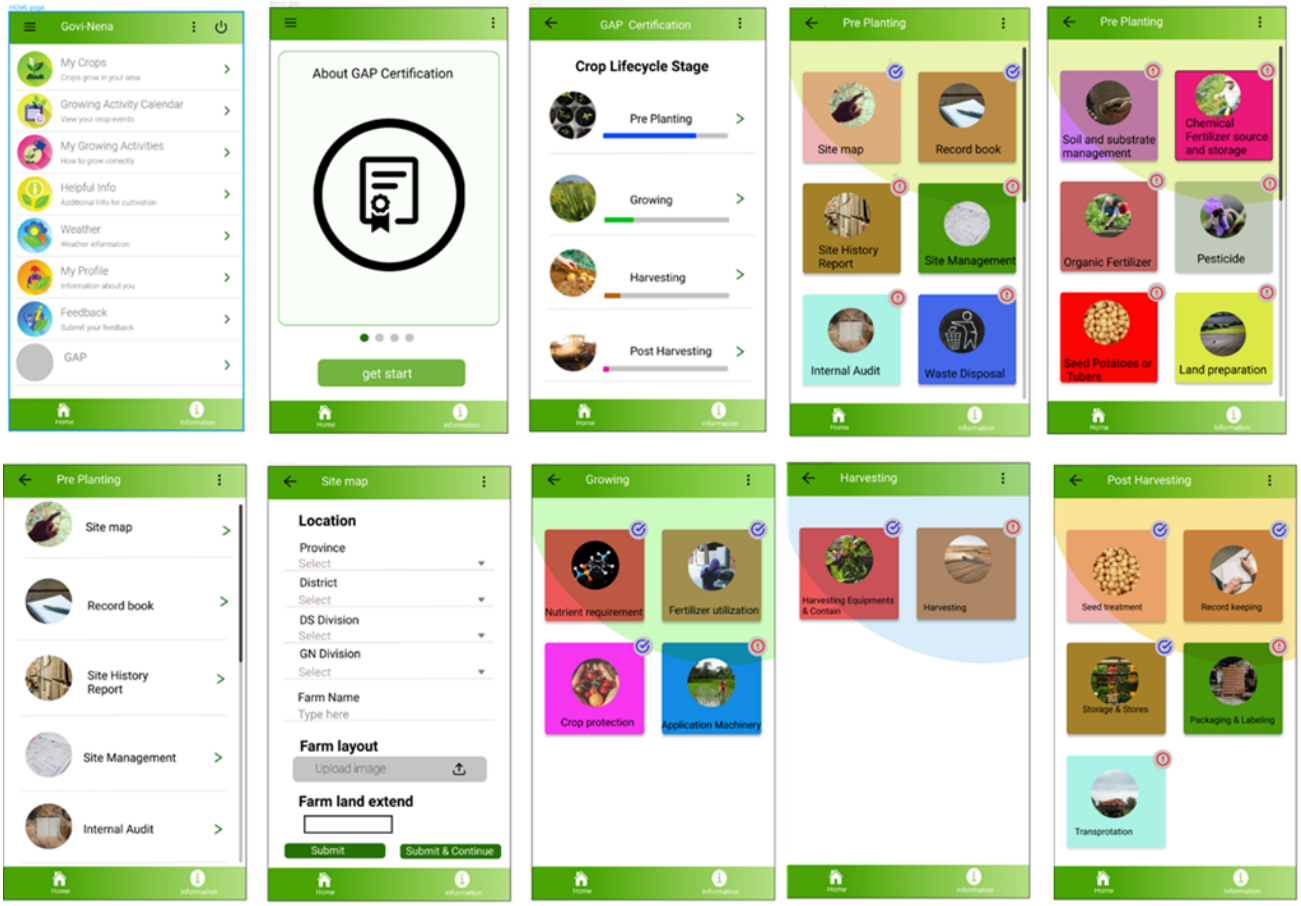


**Figure 5: User interfaces to disseminate GAPs based guidelines through "Govi-Nena" mobile application**

Moreover, farmers can select life cycle stages and complete GAPs activities one by one in a timely manner. Through the interfaces, we can visualize the percentage of completion for each GAP activity. In that way, four stages in the farming life cycle contain activities, information and guidance in detail. Finally, when all activities are completed, it shows the percentage of completion in stage vice (See Figure 5).

However, the change of perception and feedback among potato farmers on GAPs have been analyzed. Farmers perception and feedbacks have been collected using GAPs phototype version, structured questioner through face-to-face interviews and field visits. Further collected data will be analyzed using inferential statistical test method. According to perception, feedback and updated information, the guideline model and user interfaces of the GN-GAP model have been modified. This GN-GAP model can be a great opportunity to improve potato cultivation by reducing extreme synthetic chemical and fertilizer usage, bad crop management practices, post-harvest losses, and potato importation in Sri Lanka. Moreover, to address the language difficulty among farmers, GAPs based guideline model will be prepared in three languages (Sinhala, Tamil and English) used in Sri Lanka.

## CONCLUSION

The study focused on the development of mobile-based guideline model of Good Agriculture Practices (GAPs) for potato farmers in Sri Lanka, revealed that the majority of potato farmers were doing properly farming practices such as land preparation crop rotation, intercropping and soil conservation *etc*. However, farming practices like extreme usage of synthetic chemicals and realizers, improper soil fertility management, poor integrated pest management for crop protection, post-harvest handling practices, packaging, storage and transportation farmers were not properly practiced in potato cultivation. The key challenges faced by the farmers were observed as a high cost of production, crop losses & market failure, imports of potato, poor extension services and low yield *etc*. Further, study revealed that the potato farmers in Nuwara Eliya and Badulla district were highly willing to know and follow GAPs. Therefore, GAPs based guideline system will be a great solution to minimize and overcome these key challenges and improper farming practices. Moreover, the farmer experience, age, education level, awareness of GAPs, willingness to know GAPs and willingness to follow GAPs through a mobile-based application are the key components to be considered in promoting the designed "*Govi Nena* Good Agricultural Practices" (GN-GAP) model to deliver the information and guidance on GAPs through Mobile Base Information System. Further, the guidance of the GAPs will be implemented in three languages and delivered through the "*Govi Nena*" mobile application. This will be promised a better solution to minimize improper farming practices in potato production in Sri Lanka by disseminating the knowledge and guidance on GAPs.

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## AUTHOR CONTRIBUTION

SAT conceptualized and designed the study. SAT conducted the survey, collected the data, analyzed the data and wrote the manuscript. All authors discussed the results and commented on the manuscript and updated.

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