# AN ASSESSMENT OF ORGANIC AND CONVENTIONAL POTATO PRODUCTIONS IN WEST-CENTRAL BHUTAN

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**A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN AGRICULTURE, SCHOOL OF AGRICULTURAL TECHNOLOGY, KING MONGKUT'S INSTITUTE OF TECHNOLOGY LADKRABANG**

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## Abstract

Bhutan wishes to be an entirely organic nation; the country also prioritizes food self-sufficiency and improving farm household income. To achieve these goals, an assessment of the country's current organic agricultural performance is required. There have also been complaints of some conventional potato (*Solanum tuberosum* L.) growers in the country overusing chemical fertilizers. Following that, the key objectives of the study were to explore the productivity (tuber yield) and profitability, as well as soil properties and any correlations between them and crop productivity impacted by organic and conventional potato farming in West-Central Bhutan. Also, briefly identify key constraints for organic potato farmers in the region.

The studied areas were Gasa and Wangdue Phodrang, two neighboring representative districts with comparable agro-ecological characteristics. The study sample was chosen using multistage and purposive sampling approaches. A semi-structured questionnaire and face-to-face interviews collected primary data from 93 potato growers for the 2019 cropping cycle (43 organic farmers in Gasa and 50 conventional farmers in

Wangdue Phodrang districts). A total of 30 soil samples were collected within these farmers' fields, 15 samples each from the two selected districts using systematic sampling in August-September 2020. Descriptive statistics, cost and return analyses, and independent and one-sample t-tests were used to analyse productivity and profitability studies' data. For soil data analysis, independent sample t-tests and Pearson correlations were used.

According to the results, conventional potatoes were significantly more productive and profitable than organic potatoes. Organic and conventional potato productivities averaged 7.48 and 19.22 tonnes per hectare (MT/ha), respectively. The productivity of organic potatoes was likewise significantly lower than the national average. The organic potato had a benefit-cost ratio of 0.40, while conventional potato had 1.27. The break-even points of organic potatoes were 18.63 MT/ha (yield or productivity) and 45.58 Nu/kg (price), whereas the same for conventional potatoes was 15.12 MT/ha and 16.08 Nu/kg, respectively. The organic potato had a significantly higher labour cost, while the conventional potato had a significantly higher input cost. Organic potato producers faced constraints such as a lack of premium prices, pest and disease issues, low crop productivity, and climate change. In addition, the conventional farmers produced potatoes over a larger area than the organic growers.

The total nitrogen (N)%, exchangeable (Ex.) calcium and magnesium, cation exchange capacity (CEC), and base saturation (BS)% were significantly higher in the organic potato soils than the conventional potato soils. However, available phosphorus (P) was significantly higher in conventional potato soil. There was no significant difference in terms of available and Ex. potassium (K). The pH of conventionally farmed soil was significantly lower than that of organic soil. The organic matter% content, on the other hand, showed no significant difference. In addition, the carbon:nitrogen (C:N) ratio in organic soil was significantly lower than in conventional soil. The proportion of N accessible to potatoes in organic farming was relatively lower than in conventional agriculture. Furthermore, conventional potato growers added relatively more P in their fields than organic ones. Both the study areas had loam and silty clay loam soil texture.

The study showed that conventional potatoes are more productive and profitable under the current scenario than organic potatoes in West-Central Bhutan. On the other hand, organic potatoes were unprofitable due to lower crop productivity and low farm-gate prices. Therefore, realising a profitable venture for organic potato would entail increasing its crop productivity or farm-gate price higher than their respective break-evens. According to the findings, organic farming generated higher residual N, led to higher CEC, increased calcium and magnesium contents than conventional farming. It also reduced the soil's C:N ratio; however, conventional farming increased P build-up while decreasing pH. Although no correlations were found between soil parameters and crop productivity, reduced N and P nutrient availability and accessibility in organic agriculture and pest and disease difficulties possibly led to lower crop productivity.

Conventional farmers are recommended to apply dolomite ($CaMg(CO_3)_2$) to rectify their acidic soil. On the other hand, organic farmers need to further adhere to the principles of organic farming by incorporating green manure/leguminous crops in their cropping sequences. Additionally, long-term scientific field study on the viability of organic, conventional, and good agricultural practices (GAP) potatoes is required in Bhutan. Research and technology innovation to raise organic potato productivity considering varied constraints including inherent low soil fertility status and growing farm labour shortage problems in the country and market research to increase its profitability will be critical for organic potato development. The study's essential findings are anticipated to contribute towards Bhutan's aspiration for organic agriculture development.

**Keywords:** Productivity, Profitability, Constraints, Soil Properties, Organic and Conventional Potato, West-Central Bhutan.

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(Norden Lepcha)

## List of abbreviations

| | |
|---|---|
| AEZ | Agroecological Zone |
| ARDC | Agriculture Research and Development Centre |
| BAFRA | Bhutan Agriculture and Food Regulatory Authority |
| BCR | Benefit-cost ratio |
| B:C ratio | Benefit:Cost ratio |
| BS | Base saturation |
| Ca | Calcium |
| CEC | Cation Exchange Capacity |
| C:N ratio | Carbon:Nitrogen ratio |
| CoRRB | Council of Renewable Research of Bhutan |
| CRA | Cost and Return Analysis |
| DNT | Druk Nymarup Tshogpa |
| DoA | Department of Agriculture |
| Ex. | Exchangeable |
| FAO | Food and Agriculture of the United Nations |
| FYP | Five-year plan |
| FYM | Farmyard manure |
| Ha | Hectare |
| ICIMOD | Integrated Centre for Mountain Development |
| IFI | Individual farmer's interview |
| IFOAM | International Federation of Organic Agriculture Movement |
| IOC | Item Objective Congruence |
| K | Potassium |
| Kg | Kilogram |
| m.a.s.l | meters above mean sea level. |
| Me | Milliequivalent |
| Mg | Magnesium |
| Mg | Milligram |
| MoAF | Ministry of Agriculture and Forests |

| | |
|---|---|
| MT | Metric tonnes |
| N | Nitrogen |
| NSSC | National Soil Service Centre |
| Nu | Ngultrum |
| P | Phosphorous |
| PHCB | Population and Housing Census of Bhutan. |
| RGoB | Royal Government of Bhutan |
| ROI | Return on Investment. |
| SDGs | Sustainable Development Goals |
| SOC | Soil Organic Carbon |
| SOM | Soil Organic Matter |
| SPAL | Soil and Plant Analytical Laboratory |

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# Chapter 1

# Introduction

Chapter 1 (introduction) lays down a foundation for the study and prepares for the following four chapters (Chapter 2 - 5) comprehensively. It has ten sections; 1st section (1.1) discusses a Background, 2nd section (1.2) delves into a Research problem, 3rd section (1.3) puts forth Research questions, 4th section (1.4) provides Research objectives, 5th section (1.5) discusses on Expected outcomes, 6th section (1.6) provides a study area, 7th section (1.7) comprehensively discusses on Research framework, 8th section (1.8) delivers Scope and limitation of the study, which is further divided into four sub-sections namely; (1.8.1) Scope of the content, (1.8.2) Scope of the study area, (1.8.3) Scope of the data, and (1.8.4) Research limitation. The 9th section (1.9) provides various Definitions of research terms used in the study, and the last and final 10th section (1.10) offers the overall Organization of the study.

## 1.1 Background

Organic farming is seen as a feasible option for small farmers looking to enhance their long-term food security and farm revenue performance (Morshedi et al., 2017). It is also regarded as a sustainable agricultural practice that has been proved to aid in achieving the sustainable development goals (SDGs) (Willer & Lernoud, 2019). There has been a gradual increase in global organic area and other indicators (IFOAM, 2015b). Organic activities were carried out in 181 countries in 2017, with the organic market estimated at 90 billion euros. The global per-capita consumption of organic food was 10.8 Euros. Organic agricultural land covered 69.8 million hectares (ha), of which Asia had 6.1 million ha. The global share of organic farmland was 1.4%, and Asia had 0.4%. There were 2.9 million organic producers globally, Asia had 1.1 million producers and it accounts for 40% of organic growers worldwide (IFOAM, 2018). Organic agriculture (OA) makes agriculture more sustainable (Feuerbacher et al., 2018).

In pursuit of promoting sustainability and meeting its gross national happiness (GNH) goals, Bhutan pledged to be 100% organic by 2020 (McCrae-Hokenson, 2014). Bhutan has an ambitious target to become the first 100% organic country globally (Seldon, 2019). Bhutan, located on the southeast slope of the Himalayas, is a tiny and hilly nation bordered by India to the south and east and China to the north and west (D'Avanzo, 2008). The agriculture sector is an important primary sector in Bhutan, which supports the livelihood and provides employment to about 43.9% of the population (Population & Housing Census of Bhutan [PHCB], 2017). The National Statistical Bureau [NSB] (2017) reported that important crops grown are rice, maize, mandarin, apple, potato, other vegetables, cardamom, and other spices. Bhutan is characterized predominantly by smallholder farmers engaged to a large extent in subsistence farming, holding an average of 1.16 ha. The National Framework for Organic Farming (NFOF) in Bhutan published in 2006 envisioned that Bhutan would be fully organic by 2020 (Department of Agriculture [DoA], 2006). At Rio+20 on 19$^{th}$ June 2012, the then prime minister of Bhutan declared that Bhutan would go 100% organic in food production (Barclay, 2012). However, the current third democratically elected Government of Bhutan informed that the country's goal to become 100% organic by 2023 is quite vague (Seldon, 2019). Therefore, Bhutan will not achieve 100% organic by 2020. Nevertheless, the country has been pursuing its organic vision, as apparent by the initiation of one billion Ngultrum (Nu) (Bhutanese currency; 1 Nu=0.014 USD) worth National Organic Flagship Programme by the Royal Government of Bhutan (RGoB) in its 12th Five Year Plan (FYP) (2018 to 2023) (Seldon, 2019).

The National Organic Programme [NOP] (2017) reported that Bhutan has around 10,391.86 ha of land with a production of 2,599.7 metric tonnes (MT) under organic management in 2017, which includes areas under agriculture, livestock, and wild collections. The Department of Agriculture (DoA), Bhutan, has identified potato as one of the six prioritized commodities while organic farming is one of the thrust areas targeted in the 12th FYP (Department of Agriculture [DoA], 2018). Potato is one of the important cash crops for the farmers in Bhutan. This is one crop that has transformed traditional subsistence farming practices to a market-oriented production system (Council of Renewable Research of Bhutan [CoRRB], 2005)

Following rice, maize, and wheat, the potato is the fourth most important crop in terms of calories (Roder et al., 2008). According to Bajgai (2018), the potato is a widely produced, eaten, and traded horticulture crop in Bhutan, owing to the availability of favorable agroecological conditions for potato production. It is cultivated as non-cereal food and cash crop and a vegetable by around 22% of the rural households in the country. It is the most important crop for the farmers above 2,500 meters above mean sea level (m.a.s.l) and is usually cultivated at the altitude range of 2,000 and 3,500 m.a.s.l. It also hugely contributes to food security in the country through direct consumption. The Ministry of Agriculture and Forests [MoAF] (2019) recorded that potato is mainly exported to India, Bangladesh, and Nepal apart from the domestic market. Due to its combined superior qualities concerning its productivity, nutritional contents, and adaptability to the Bhutanese environmental conditions, the potato tops the list for any government's program on food security and nutrition (Roder et al., 2008).

The potato is one of Bhutan's most significant cash crops, mostly farmed using conventional agricultural methods (Lhamo, 2019). Conventional agrochemicals such as fertilizers and insecticides are used in minimal doses in Bhutan and are limited to essential cereals and cash crops (ICIMOD, 2018). On the other hand, conventional potato farmers supplement chemical fertilizers with farmyard manure (FYM) and other organic amendments. In addition to hand weeding, herbicides are used by conventional farmers to manage weeds in potatoes. In Bhutan, conventional farming is an integrated method as acceptable as good agricultural practices (GAP). The country's total potato production was 43,560 MT, with a total area of 4187 ha and average national productivity of 10.40 MT/ha in 2019 (Ministry of Agriculture and Forests (MoAF), 2020). The country's potato productivity is among the lowest in the South Asian region, but potato farming is profitable in Bhutan, with an average profit of 36.02% (BPV Consultancy & Research Services, 2018). In 2018, Bhutan exported 24,983.4 MT and made 511.06 million Nu. (Ministry of Agriculture and Forests [MoAF], 2019). Organic potato cultivation accounted for approximately 1.08% of the total potato acreage in the country in 2019, comprising 45.15 ha (Agriculture Research & Development Centre (ARDC)-Yusipang, 2019). Since 2016, a credible government organization in Bhutan has certified roughly 20.34 ha, or 0.50% potato acreage in the country, as organic in Gasa district. The government covered the entire cost of organic certification in Gasa (Agriculture Research & Development Centre (ARDC)-Yusipang, 2019). Certified organic farmers adhere to Bhutan organic standards, abstain from using chemical fertilizers and agrochemicals in their farms, and instead rely on locally available organic inputs such as FYM and bio-pesticides.

This study assessed the performance of organic and conventional potato farming in West-Central Bhutan regarding its productivity and profitability for the 2019 production cycle. However, the soil samplings and tests were carried out from these potato farms in 2020 to determine the long-term effects of organic and conventional potato farming on the soil properties in the region. In addition, constraints in organic potato production in the region were studied for a meaningful inference. Because different potato types might affect productivity and profitability, the research focused on *Desiree*, the most common potato variety in the country. The study also addresses the following United Nations SDGs: 1) no poverty, 2) zero hunger, and 3) decent work and economic growth (United Nations Development Program [UNDP], 2015).

**1.2 Research problems**

The Department of Agriculture (DoA) under the Royal Government of Bhutan (RGoB) has the national mandate to enhance food production to achieve household food security, alleviate poverty, substitute, or reduce imports through increased domestic production, generate a marketable surplus, enhance household income and employment opportunities (Ghimiray et al., 2019). Albeit the country is promoting organic agriculture, on the other hand, the Government also has a strong priority of increasing food self-sufficiency. Inappropriately, Bhutan’s pledge to go 100% organic by 2020 seems not to favor the increase of self-sufficiency and food security goal of the country (McCrae-Hokenson, 2014). Therefore, to meet the national mandate of food security and enhance farm household income, there is a necessity to see the performance of organic agriculture in the country.

One of the most significant challenges in organic agriculture's adoption is its productivity (Connor, 2008). Increased productivity is a vital prerequisite for achieving long-term food security in the face of increased farm products demand (Qaim Matin & Arjunan, 2010). Productivity is a performance indicator that measures the quantity of production generated from a current resource base; it can be a vital sign of long-term viability (FAO, 2018). According to Conway (1986), productivity measures yearly crop production per hectare of land. According to the FAO (2017), land productivity is the production generated by a given piece of land. A strong link exists between agricultural productivity and farm income, with implications for food security and rural incomes (FAO, 2018). Agricultural production needs to be increased by 70% and almost 100% in developing countries by 2050 to meet the increase in the world population by 40%. To achieve the food production, 90% in the developed world and 80% in the developing world the rise in crop production would be required by higher crop productivity and increased intensity, remaining will be from area expansion (Bruinsma, 2009). The FAO estimates that the productivity of food crop production must be increased by at least 43% by 2030 to meet the global food demand provided all other factors remain unaffected (Dasgupta & Roy, 2011).

On the other hand, profitability is considered an economic concept when analyzing the performance of the agricultural sector (Baležentis et al., 2019). Profit is defined as gross revenue minus total production expenses, whereas profitability is a word derived from it (Lipsey, 1975). If the difference is positive, the farmer gets a profit, but if it is negative, the farmer loses money (Kahan, 2013). Profitability performance is a measure of how effectively a farmer's resources are used to create income and profit (Kahan, 2010). The profitability analysis will be useful in determining the earnings of organic and conventional potato growers. Similar research was carried out by (Adamtey et al., 2016; Bajracharya & Sapkota, 2017; Lyngbaek & Muschler, 2001; Suwanmaneepong et al., 2020; Tashi & Wangchuk, 2016). As a result, using economic indicators to assess the effectiveness of organic potato production is critical.

The local leaders and agriculture officials in Gangtey and Phobjikha *Gewogs* (block; a group of villages in Bhutan) are concerned about the increasing trend of usage of chemical fertilizers in potato cultivation. Phobjikha *Gewog* is a research site for conventional potato production in the study. It has been observed that the farmers are competing to use more chemical fertilizers every year for potato farming in these *Gewogs* (Lhamo, 2019). Potato is one of the cash crops in Bhutan, where farmers use relatively higher quantities of agrochemicals.

According to Liebig's rule of the minimum, in steady-state conditions, plant growth is limited by the critical nutrient or component in the soil that is available in the least quantity proportional to the species' requirement (Randolph, 2004). Inadequate crop productivity has been linked to a variety of reasons, including low soil fertility and long-term soil deterioration such as loss of soil organic matter, acidification, compaction and nitrogen deficiency (Folberth et al., 2014). Organic systems have higher organic matter content and biological activity than conventional methods (Condron et al., 2000). Organic farming increased the amount of nutrients in sandy loam soil, such as N, P, and K, boosting crop production. Before and after harvest, the physical properties of the soil, such as field capacity, wilting point, and moisture content, increased more than the control plot (Jeyaseeli et al., 2021).

Hence, there is also a need to analyze any adverse or good effect of long-term conventional and organic potato farming on the soil properties in West-Central Bhutan. Therefore, the research is timely and pertinent to Bhutan and globally. Similar assessments on organic vis-à-vis conventional farming concerning its productivity, profitability, and soil properties have been carried out, among others by (Adamtey et al., 2016; Mendoza, 2004; Tashi & Wangchuk, 2016).

**1.3 Research questions**

1) Which farming system (organic or conventional) has higher productivity (land productivity/yield) on potato farming in West-Central Bhutan, addressing food security goals?

2) Which farming system (organic or conventional) is more profitable on potato farming in West-Central Bhutan, addressing higher farm household income goals?

3) Which farming system (organic or conventional) is better in improving the soil properties on long-term potato farming in West-Central Bhutan that can address higher sustained productivity?

## 1.4 Research objectives

1) To investigate the farm and farmers' socio-demographic characteristics and production aspects of organic and conventional potato farmers in West-Central Bhutan.

2) To compare productivity and profitability of organic and conventional potato productions in West-Central Bhutan. Also, concisely determine the marketing aspects and constraints of organic potato farmers in the region.

3) To compare the soil properties impacted due to organic and conventional potato productions in West-Central Bhutan. Additionally, determine any relationships between the soil properties and the potato productivity.

## 1.5 Expected outcomes

1) Performance of organic and conventional potato studied in West-Central Bhutan for crop productivity, profitability, and impact of these farming systems on soil properties by generating empirical data. Such critical findings will serve as a guide to policy makers, agriculture officials, and farmers. In addition, the results through the empirical data will contribute to the national and global agriculture research and development, and such studies will be helpful to the national and international researchers and academicians, especially from developing countries.

2) The socio-demographic characteristics of organic and conventional farmers in West-Central Bhutan determined. Furthermore, the constraints of the organic potato farmers studied, with meaningful inferences and suitable recommendations. Also, the

marketing channels of organic and conventional potatoes briefly analysed in West-Central Bhutan.

### 1.6 Study area

The research data were gathered from Bhutan, the West-Central region of the country, specifically from two representatives, potato producing and neighboring districts, namely Gasa and Wangdue Phodrang districts, as shown in Figure 1.1. Both Gasa and Wangdue Phodrang districts in the West-Central region of the country share similar agroecological characteristics, with both located above 1800 m.a.s.l and predominantly having a temperate climate. The West-Central part of Bhutan is one of the four regions, and it comprises five districts, namely Gasa, Wangdue Phodrang, Punakha, Dagana, and Tsirang (ARDC-Bajo, 2020). The region is the largest producer of potatoes in the country and produced 16,478 MT in 2019, comprising 38% of the total potato production (MoAF, 2020). The region was selected due to the availability of both commercial organic and conventional potato farmers. The soil type in the region is *ferralsols*, which is distinguished by low fertility, macro and micronutrient inadequacies, soil acidity, and low Phosphorus (Tashi & Wangchuk, 2016). The country as a whole saw near-normal temperatures and rainfall in 2019 (National Center for Hydrology and Meteorology, 2020). The annual national maximum and lowest temperatures were 22.4°C and 11.8°C, respectively, with 1825.2 millimeters of precipitation.

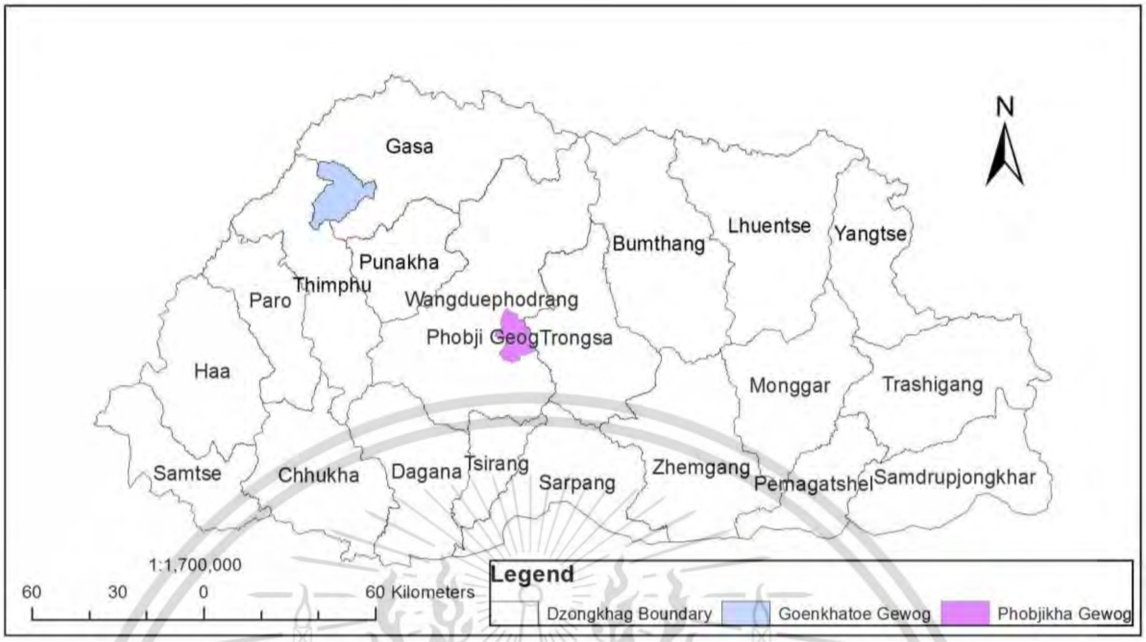


**Figure 1.1** The map of Bhutan showing study areas.

**Source:** National Soil Service Centre (2020).

Gasa district was selected for the research since the district was declared an organic area in 2004 by its local government. Gasa district has a potato area of 30.08 ha and produces 185.24 MT per year (MoAF, 2020). Goenkhatoe *Gewog* under Gasa district, situated at 27°50′N 89°38′E, with an elevation range from 2,100 to 2,800 m.a.s.l., was chosen as a study site for the organic potato assessment. The Goenkhatoe *Gewog* was mainly selected since the *Gewog* has organic farmers' group *Rangshin Sonam Detshen* which has produced certified organic potatoes since 2016. The *Rangshin Sonam Detshen* is also the first organic group to certify organic potatoes, garlic, and carrot with the Bhutan Agriculture and Food Regulatory Authority (BAFRA) on 10th October 2016. The organic farmers in Goenkhatoe *Gewog* are certified organic both under the National Organic Certification System through the BAFRA and under the local organic assurance system

(LOAS) by the National Organic Programme (NOP). The group was awarded the best organic farmer award-2019 by the National Organic Programme (NOP) under the Local Organic Assurance System (LOAS) (Agriculture Research & Development Centre (ARDC)-Yusipang, 2019). Potato is a significant cash crop grown in Goenkhatoe *Gewog,* vital for the farmers' livelihood. The crop is also widely consumed as an essential vegetable in their daily food consumption. According to the National Soil Service Centre (NSSC), Thimphu, 2020, the soil textures in the *Gewog* include loam and silty clay loam.

Wangdue Phodrang district was selected as the conventional potato production counterpart since the district is one of the region's top potato growers, and in the country. The district has an area of 357.33 ha and an annual production of 15,569.87 MT under potatoes (MoAF, 2020). The potatoes in the district are produced mainly through conventional farming practices. Phobjikha *Gewog* was chosen as a study area for conventional potato assessment in Wangdue Phodrang district located at 27°30′N 90°10′E, with altitudes varying from 2,300 to 4,000 m.a.s.l. It was selected because the farmers have been cultivating conventional potato for decades, and the potato is the main cash crop grown commercially. It shares similar agroecological characteristics to the organic site. According to the NSSC, 2020, the *Gewog's* soil textures are identical to Goenkhatoed *Gewog*.

**1.7 Research framework**

The general research framework of the study is given in Figure 1.2. It describes the research methodologies pictorially, which begins with the problem statement/research gap in the study and ends with the research outcomes in various steps. Key research gaps listed are the country's food self-sufficiency/security goal, more agronomic/economic studies that need to be taken up, and the lack of study on potatoes in these two farming systems. It provides three objectives to address these critical research gaps: objective 1 studies the farm and farmers' characteristics; objective 2 on the productivity and profitability differences, marketing aspects between these farming systems, and production constraints of organic potato growers. Objective 3 determined the soil properties impacted by these two farming systems and examined correlations with the second objective on the potato's productivity. Subsequently, various methodologies to achieve these objectives are provided; Objectives 1 and 2 were acquired by collecting the primary data using the pre-tested and reliability tested questionnaires through purposive samplings, face-to-face, and individual farmer's interviews. Objective 3 was pursued through systematic samplings, soil samplings and laboratory analysis. Then it provides various data analysis tools under each objective; objective 1 was analysed using descriptive statistics; objective 2 used cost and return, profitability analysis, and other inferential statistics (t-tests); objective 3 was examined using inferential statistics such as t-test and Pearson correlations. Any correlations between objectives 3 and 2 were investigated using Pearson correlations. Finally, the investigations of these three objectives culminate in the research outcomes and recommendations.

Following essential recommendations were made based on the critical findings of the study covering farmers, related organizations, policy implications and further studies. Farmer's recommendations were soil's dolomite application, adherence to IFOAM's principles, decision-making opportunities, more nitrogen (N) and phosphorus (P) application, and encouraging soil tests. Related organizations could address the various organic potato production constraints by collaborating with the National Plant Protection Centre, National Soil Service Centre, National Potato Programme, Department of Agricultural Marketing and Cooperatives, and awareness creation. Policy implications mention how it can guide policy makers, improve organic inputs availability and human resource development, address farm labour shortages, and prioritize climate-smart agriculture policies. Further studies recommend the intake of larger soil samples, other long-term studies, and research and technological innovation to boost organic potato productivity.

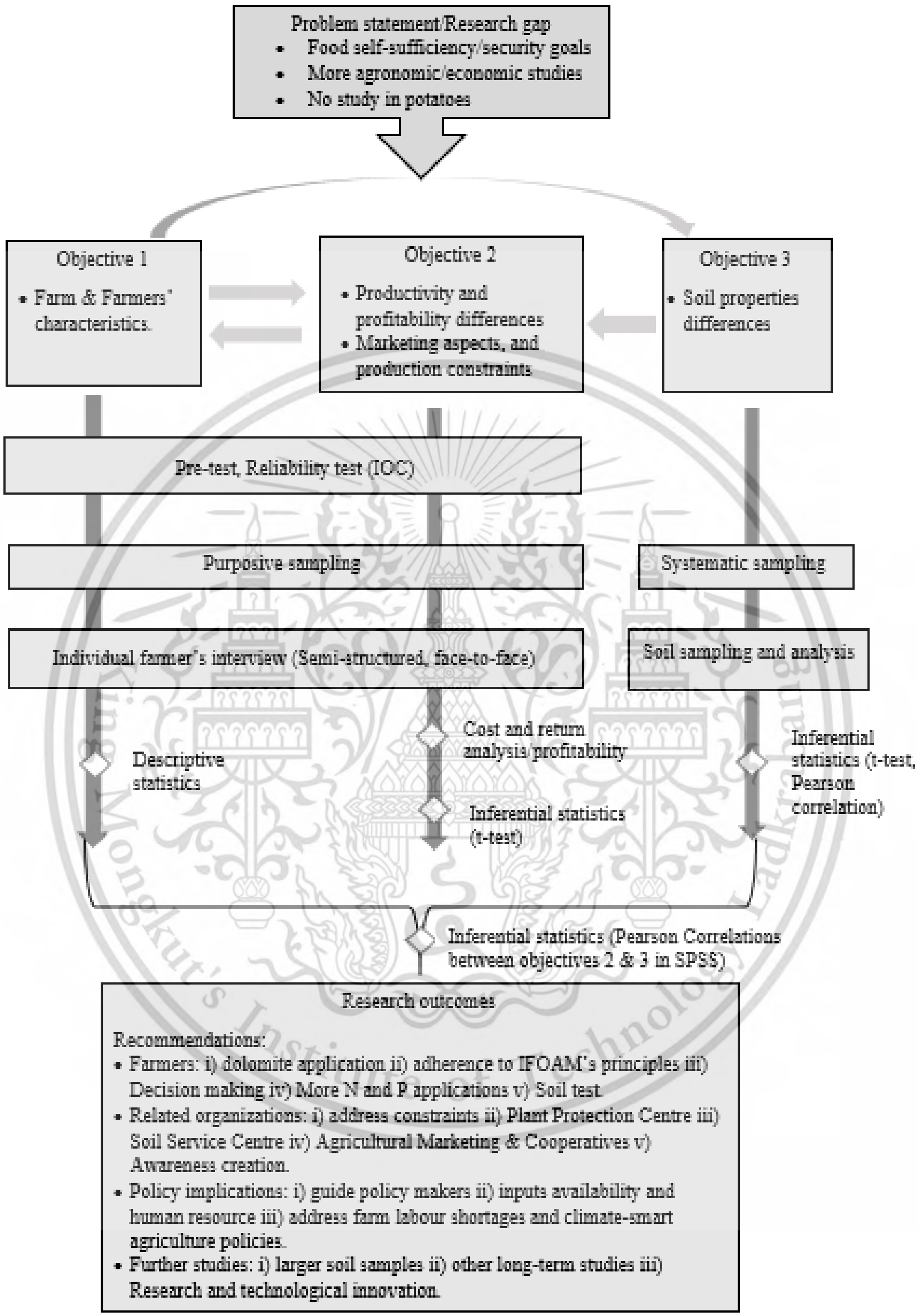


**Figure 1.2** A research framework

## 1.8 Scope and limitation

### 1.8.1 Scope of the content

The study broadly discusses farm and farmers' characteristics, productivity and profitability of organic and conventional potato production in West-Central Bhutan, constraints in the organic potato production, soil properties influenced by these farming systems on potato production in the region. It further discusses prominent relationships between farm and farmers' characteristics with other observations such as productivity, profitability, and soil properties. It provides suitable recommendation(s) on whether organic or conventional potato farming would be a more productive and profitable venture in West-Central Bhutan. The study also succinctly discusses measures to increase the productivity and profitability of potato production in the region. Suitable recommendation(s) whether organic or conventional farming would be better for improving the soil properties in West-Central Bhutan discussed. Finally, it briefly provides appropriate recommendations to improve the soil properties for potato production in the region.

### 1.8.2 Scope of the study area

This study is undertaken in two neighbouring representative districts under West-Central Bhutan, namely Gasa and Wangdue Phodrang districts. Gasa district has been the first organic district in Bhutan since 2004, and it has certified organic potato growers. In contrast, Wangdue Phodrang district is a leading conventional potato-producing district in the region and country.

### 1.8.3 Scope of data

The study provides empirical data on farm and farmers' characteristics of organic and conventional potato farmers in West-Central Bhutan. The research generates empirical data on the differences in the productivity and profitability of organic and conventional potato productions in West-Central Bhutan. The study also delivers empirical data on the differences in the soil properties due to organic and conventional potato production in West-Central Bhutan.

### 1.8.4 Research limitation.

Although the study has selected two representative districts in West-Central Bhutan and each representative *Gewog* within these selected districts, more *Gewogs* could be brought under the survey, especially in the conventional potato's site in Wangdue Phodrang district. Ideally, we could collect conventional potatoes data from the other three districts under West-Central Bhutan. The soil samples in the study were collected from 15 households, each from organic and conventional potato farmers, but if more samples could be gathered in the future, spread across more *Gewogs,* especially for the conventional potatoes. The data were collected for one cropping cycle, but it would have yielded more reliable findings if it had been collected for more years.

The opportunity and storage costs which are a part of fixed cost in the total cost of production, were not computed in the study. Similarly, in their studies, the opportunity and storage cost were not calculated (Adamtey et al., 2016; Chidiebere-Mark et al., 2019; Tashi & Wangchuk, 2016). The opportunity cost is part of the implicit/imputed cost, which is an indirect cost that does not entail a cash expenditure (Dwivedi, 2002). The economic resources foregone as a result of selecting one choice over another are referred to as opportunity costs (Rajasekaran, 2010). In Bhutan, most potato farmers store their potatoes in their houses, and the use of cold storage is scarce; this was prevalent at least during the study period of the author.

### 1.9 Definition of research term

To clarify research terminologies used in the research, it is essential to define them clearly and concisely to avoid ambiguous interpretations (Table 1.1). The definitions are standard definitions from reliable sources/authors, befitting the current research work.

**Table 1.1** Definition of research term

| Research term | Definition |
|---|---|
| Assessment | "Assessment measures are designed to provide a systematic method of collecting information to describe a client's circumstances concerning specific issues, concerns, problems, strengths, and resources " (Lichtenberg, 2010) |
| Organic agriculture (OA) | "Organic agriculture is a production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved" (The International Federation of Organic Agriculture Movement (IFOAM). |
| Conventional agriculture (CA) | The CA is synonymous with the Green revolution. The new technology termed the 'Green Revolution' prevailed in the late 1960s. It made use of new, high-yielding crop varieties cultivated using chemical fertilizers and agrochemicals, new methods of irrigation and cultivation, including the use of farm machinery. The new package of practices was to be adopted as a whole and superseded traditional technology (Farmer, 1986).<br><br>The CA in Bhutan is an integrated farming approach that advocates Integrated Nutrient Management (INM) and Integrated Pest Management (IPM), and not pure chemical farming (Council of Renewable Research of Bhutan [CoRRB], 2005).<br><br>Chemical fertilizers and organic manure were applied in the conventional system, whereas the organic methods were used with only organic inputs (Adamtey et al., 2016). |
| Productivity (yield) | "Productivity is the net increment in valued product per unit of resource (land, labour, energy, or capital). It is commonly measured as annual |

| Research term | Definition |
| --- | --- |
| | yield or net income per hectare or man-hour or unit of energy or investment." (Conway, 1986) |
| Cost and return analysis (CRA) | It is a form of economic assessment that considers both implicit and explicit expenses borne by farmers (Ciaian et al., 2013; Netayarak P, 2007) |
| Profitability | "Profitability is a relative term derived from profit, where profit is total farm profits (gross revenue) minus total production costs." (Lipsey et al., 1995). |
| Benefit: cost ratio (BCR) | The BCR was calculated by the following formula: $BCR = TRi/TCi$ where TRi was the total revenue and TCi was the total cost incurred by the farmers partaking in different supply chains (Naseer et al., 2019). |
| Return on investment (ROI) | The ROI is stated as a percentage and is the ratio of the money earned each year to the amount invested in a specific project or business (Drucker, 1999). |
| Physicochemical properties | "These are the major components that express the physicochemical properties of the soil like soil temperature, soil moisture, water holding capacity, aeration and infiuence the physical, chemical, and biological processes" (Vaishnav & Choudhary, 2021).<br><br>The chemical properties analysis of the sited soils included organic carbon (SOC), organic matter (SOM), cation exchange capacity (CEC) at pH 7.0, base saturation, soil EC, nitrogen, phosphorous, potassium, and sulphur, and soil pH. In addition, regarding the physical properties analysis, particle size analysis, soil structure, water holding capacity (WHC), bulk density (BD), and total porosity (PT) were determined (Hossain & Salam, 2019). |

## 1.10 Organization of the study

The organization of the study is structured in a traditional five-chapter layout. The study is introduced in Chapter 1 (introduction) by highlighting research problems, research objectives, and expected outcomes. Chapter 2 (literature review) presents a comprehensive review of the literature that supports the need for the research. It encompasses various theories, global and local scenarios, and related research. Chapter 3 (methodology) brings forth the study’s methodologies, including population and sample size, data collection methods, and data analysis methods. Chapter 4 (results) provides the research's vast array of results and findings in detail, ranging from productivity and profitability to soil properties results. Chapter 5 (discussion and conclusions) deliberates on various results and links them with other related studies.

Finally, the study ends with a conclusion that summarises the study's findings and significance, and provides further recommendations for improving current observations and future research.

# Chapter 2

# Literature Review

This chapter explores various theories and related research on the study. The review was essential to analyse the research gaps and ultimately identify the research topic. It has four sections; the 1st section (2.1) is a Theory part, which comprises literature reviews on three sub-sections, namely, (2.1.1) agricultural productivity theory; (2.1.2) cost and return, and profitability theories; and (2.1.3) theories on physicochemical properties of soil. The 2nd section (2.2) contains the global and local scenarios comprised of three sub-sections, namely, (2.2.1) global organic agriculture scenario; (2.2.2) agriculture and organic agriculture in Bhutan; and (2.2.3) potato cultivation in Bhutan and organic potato status in the study area. The 3rd section (2.3) is about related research, and it comprises four sub-sections, namely, (2.3.1) productivity of crops due to organic and conventional farming; (2.3.2) profitability due to organic and conventional farming; (2.3.3) effect(s) on soil physicochemical properties due to organic and conventional farming; and (2.3.4) organic marketing and premium price. Further, the last 4th section (2.4) consists of research gaps. A brief introduction and summary of the chapter are also provided.

## 2.1 Theory reviews

### 2.1.1 Agricultural productivity theory

"Productivity is commonly defined as a ratio of a volume measure of output to a volume measure of input use" (Organisation for Economic Co-operation and Development [OECD], 2001). Conway (1986) defines productivity as: "Productivity is the net increment in valued product per unit of resource (land, labour, energy or capital). It is commonly measured as annual yield or net income per hectare or man-hour or unit of energy or investment". Productivity can be measured as production per unit land area. It is the output (commercially marketable yield) per land area (Adamtey et al., 2016). Productivity is a performance indicator. It is the ratio of an economic entity's output(s) to input(s), such as agricultural holdings. The higher the values of this ratio, the better the performance. Productivity output can be expressed in physical quantities or volumes and in commodities or services. Agricultural productivity is stated as a ratio of outputs to inputs in either physical quantities (kg, tons) or volumes

The following formula (equation 2.1) may express agricultural productivity for any period (t) (FAO, 2018):

$$\text{Prod}_t = \frac{O_t}{X_t} \text{------------(2.1)}$$

Where:

$\text{Prod}_t$ is agricultural productivity

$O_t$ is output for any period *t*

$X_t$ is input for any period *t*

The amount of production generated by a given piece of land is measured as land productivity. A broad measure of productivity is the ratio of the value of all agriculture crops to the total land utilized. Land productivity is calculated by dividing agricultural production by the planted land area, and the size of the land area is stated in a unit area, such as hectares or acres. Land productivity is related to agricultural yields when expressed in physical units, such as tonnes of corn. It may be computed using equation 2.2 as indicated in the following (FAO, 2017):

$$\text{Land productivity} = \frac{Volume\ of\ output}{Planted\ Area} \quad \text{---------------} \ (2.2)$$

The production volume was measured in metric tonnes (MT) and the planted area in hectares (ha).

Crop production in quantities and values is essential for measuring land productivity. The total area of land cultivated under each crop is required as input data. Environmental and production circumstances data should be made available in addition. Land productivity/yields result from the production process and are hugely influenced by the quantity and quality of various farm inputs. High agricultural productivity/yields are associated with effective farming operations, highly skilled labour, efficient machinery, and other capital goods. Higher production per unit of land and higher farm revenue is synonymous with increased land productivity or yields, assuming all other elements remain constant, particularly climatic circumstances (FAO, 2017).

Policymakers and analysts are interested in agricultural productivity concerns because higher productivity allows farms to allocate scarce resources to other productive activities better. A strong link exists between farm productivity and farm income, impacting food security and rural incomes. Productivity indicators are classified into partial factor productivity and multifactor factor productivity. A single productivity indicator contains only one input, whereas multifactor productivity includes all key production factors and intermediate inputs. Single-factor productivity, for example, evaluates the output created by a single input, such as land productivity or output per unit planted area. Because both the numerator and denominator of single-factor productivity can be represented in physical units, it is simple to calculate, understand, and analyze. It may be derived directly from a single source of data, such as a farm or household survey, and does not require any additional secondary information, which may be more challenging to get when compared to physical quantity (FAO, 2018).

Considering Conway (1986)'s definition that productivity is also a measure of annual crop yield per hectare of land, FAO (2017) defines land productivity as the quantity of output produced by a given portion of land. Therefore, and also, taking into account the FAO (2018)'s single-factor productivity, i.e., land productivity, this research will exclusively focus on productivity which entails collecting the data on annual crop yield per hectare of land.

**2.1.2 Cost and return, and profitability theories**

Cost and return analysis (CRA) is a type of economic evaluation that considers both implicit and explicit expenditures incurred by farmers (Ciaian et al., 2013; Netayarak P, 2007). Actual expenses are categorised as explicit costs, but imputed or implied costs are classified as implicit costs because they are not related to actual expenditure payments (Ciaian et al., 2013). As a result, the costs may be divided into two categories: explicit costs and implicit costs, which are cash and non-cash expenses, respectively (Mendoza, 2004; Suwanmaneepong et al., 2020). Using Microsoft Excel, the CRA was calculated.

1) Total cost (TC) was computed as a sum of total variable cost (TVC) and total fixed cost (TFC) (Chidiebere-Mark et al., 2019; Suwanmaneepong et al., 2020) as indicated in equation 2.3:

$$\text{TC} = TVC + TFC \text{ ------------- } (2.3)$$

Where:

TC is total cost

TVC is total variable costs

TFC is total fixed costs

1.1) Variable costs (VCs) are dependent on the production levels.

1.2) Fixed costs (FCs) are non-dependent on the production levels.

These FC and VC can be categorized into explicit and implicit costs: cash and non-cash costs, respectively. Actual expenses incurred fall under the explicit cost while imputed or implied costs such as depreciation and opportunity costs are not related to the actual expenditure payments fall under Implicit costs.

1.1) Variable costs (VCs)

According to Delaney and Whittington (2011), variable costs (VCs) are sustained by variable inputs such as raw materials, labour, and other variable overhead charges. The VCs vary with respect to the number of systems or output of the system (Parnell et al., 2011). It can be categorized as explicit and implicit costs, where the explicit costs are the actual expenses incurred pertaining to the cash expenditures while the implicit costs are not the actual expenditure payments about non-cash expenditures (Suwanmaneepong et al., 2020). Therefore, it is critical to collect information from all VCs on the farm, regardless of their acquisition source (FAO, 2018).

1.2) Fixed costs (FCs)

According to Thorpe and Thorpe (2011), fixed costs are those costs of production that do not vary with the quantity produced. FCs are expenses that are unchanged by changes in output level, such as land rent, land tax, opportunity cost, and depreciation cost. These FC and VC may be divided into explicit and implicit costs, which are cash and non-cash expenses, respectively. Actual expenses spent are under the category of Explicit costs, while imputed or implied costs unrelated to actual expenditure payments belong under implicit costs (Suwanmaneepong et al., 2020). Depreciation is the reduction in the cost of machinery and equipment due to their progressive wear and tear over the years of use (Charantimath, 2005). The straight-line approach is used to determine depreciation costs, which are the diminishing values of farm assets (Suwanmaneepong et al., 2020).

1.2.1) The straight-line technique yields the same amount of depreciation cost in each period; the depreciable cost, which is calculated by removing an estimated salvage cost from the overall cost, is divided by the asset's projected useful life (Robinson et al., 2012). Equation 2.4 provides how to calculate an annual depreciation expense. Suwanmaneepong et al. (2020) applied similar formula in their study:

$$\text{Annual depreciation expense} = \frac{Asset\ cost - Salvage\ value}{Useful\ life\ of\ the\ asset} \text{---------(2.4)}$$

1.3) The gross return can be calculated using equation 2.5 as follows. Similar formula were used by (Adhikari, 2011; Tashi & Wangchuk, 2016):

$$\text{Gross Return (GR)} = Q \; x \; P \text{ ------------- (2.5)}$$

Where:

GR is gross return

Q is productivity (tuber yield)

P is farm-gate price

1.4) According to Lipsey (1975), profit is defined as gross revenue less total production expenses, whereas profitability is a relative word derived from profit. The gross margin or Profit can be computed using equation 2.6 as follows. Similar formula was applied by (Adhikari, 2011; Lyngbaek & Muschler, 2001; Tashi & Wangchuk, 2016)

$$\text{Profit or GM} = GR - TC \text{ ---------------- (2.6)}$$

Where:

GM is gross margin

GR is gross return

TC is total cost

1.5) The benefit: cost (B:C) ratio was computed using the following equation 2.7. Adhikari (2011) and Tashi and Wangchuk (2016) also applied similar formula in their studies:

$$\text{B:C ratio} = \frac{GR}{TC} \text{ -------------- (2.7)}$$

Where:

B:C ratio is benefit:cost ratio

GR is gross return

TC is total cost

If the B:C ratio is above 1, the farm enterprise/business is profitable (Adhikari, 2011). If the B:C ratio is more than one, the benefits exceed the costs; if it is less than one, the costs exceed the benefits, and the operation is unprofitable (Hay, 1982).

1.6) Return on investment (ROI)

The Return on Investment (ROI) was calculated using equation 2.8 as follows. Similar formula was used by (Chidiebere-Mark et al., 2019) in their study.

$$\text{ROI} = \frac{GM}{TC} \text{x}100 \text{ --------------(2.8)}$$

Where,

*GM* is gross margin (profit)

*TC* is total cost

The return on investment (ROI) is a vital indicator for determining a company's profitability. It is expressed in percentage (Rosenbaum et al., 2013; Tiffany & Peterson, 2011).

1.7) Break-even price and break-even yield (productivity) analysis using break-even analysis

A break-even analysis for the price (P) and yield (productivity) (Y) was done in addition to other considerations, as given in the equations below, based on (Dillon, 1992): Price (P): At what market price would there be a break-even point, i.e., when costs equal income with given yield (productivity) and cost. Equation 2.9 shows how to compute break-even Price (P).

Yield (productivity) (Y): in which yield (productivity) level the break-even would be realized, i.e., when costs equal income with given price and cost. Equation 2.10 shows how to compute break-even Yield (productivity) (Y).

$$\text{Output Price (Pi)} = \frac{VC_i+FC_i+\pi_i}{Y_i} \text{ -------------- (2.9)}$$

$$\text{Yield (productivity) (Yi)} = \frac{VC_i+ FC_i+ \pi_i}{P_i} \text{ ------------------- (2.10)}$$

Where:

$P_i$ is commodity i's output price.

$Y_i$ is output i's yield (productivity)

$VC_i$ commodity i's variable costs.

$FC_i$ commodity i's fixed costs.

Break-even price or yield (productivity) considerations in just covering costs can be investigated by setting profits ($\pi_i$) equal to zero.

**2.1.3 Theories on physicochemical properties of soil**

"The soil is a thin covering over the land consisting of a mixture of minerals, organic material, living organisms, air, and water, that together support the growth of plant life" (Bharucha, 2005). Soils provide a variety of ecosystem services that are critical to human well-being and survival on Earth, including food, clean water, and climate regulation (Montanarella et al., 2015). Soil health comprises physical and chemical qualities, organic matter, and biological activity in the soil. These elements also influence its complexity, fertility, and productivity, which are critical for sustained agricultural output (FAO, 2009).

Soil has the following physical and chemical (physicochemical) properties: soil texture refers to the size and proportion of soil particles, such as sand, silt, and clay, which impact the soil's ability to retain water and nutrients. The process through which soil mineral particles cluster together, giving rise to soil aggregates, is known as soil structure. It is principally impacted by the activities of soil organisms and decomposing organic matter in the soil. The soil structure determines aeration, water flow, heat conduction, erosion resistance, and crop root development. The ability of soil to keep together and resist fragmentation is known as soil consistency. It is used to anticipate cultivation issues, identify wetness and waterlogged conditions, and qualitatively analyse soils' organic matter, salt, and carbonate levels. Soil colour is typically determined by the amount of organic matter in the soil, the amount of drainage, and the degree of oxidation. Another essential physical attribute is soil porosity, controlled by the number and size of pores that impact water and air circulation inside the soil. It affects the soil's capacity to provide oxygen to organisms, which decomposes organic matter and plant roots and allows for the storage and flow of water and nutrients.

The soil reaction or measure of acidity or alkalinity is measured in terms of pH for the chemical characteristics of the soil. With variations in soil pH, some ions become accessible or unavailable in the soil based on their solubility at particular pH levels. Toxic quantities of aluminium and manganese, for example, tend to occur in soils with pH (measured in water) around 5.5, whereas soils tend to scatter owing to high levels of sodium with pH>8.5. Figure 2.1 shows different soil pH, classification, and corresponding availability of some essential nutrients to the plants. Because soil organisms are hampered by excessive acidity, most crops grow best in mineral soils with a pH of 6.5.

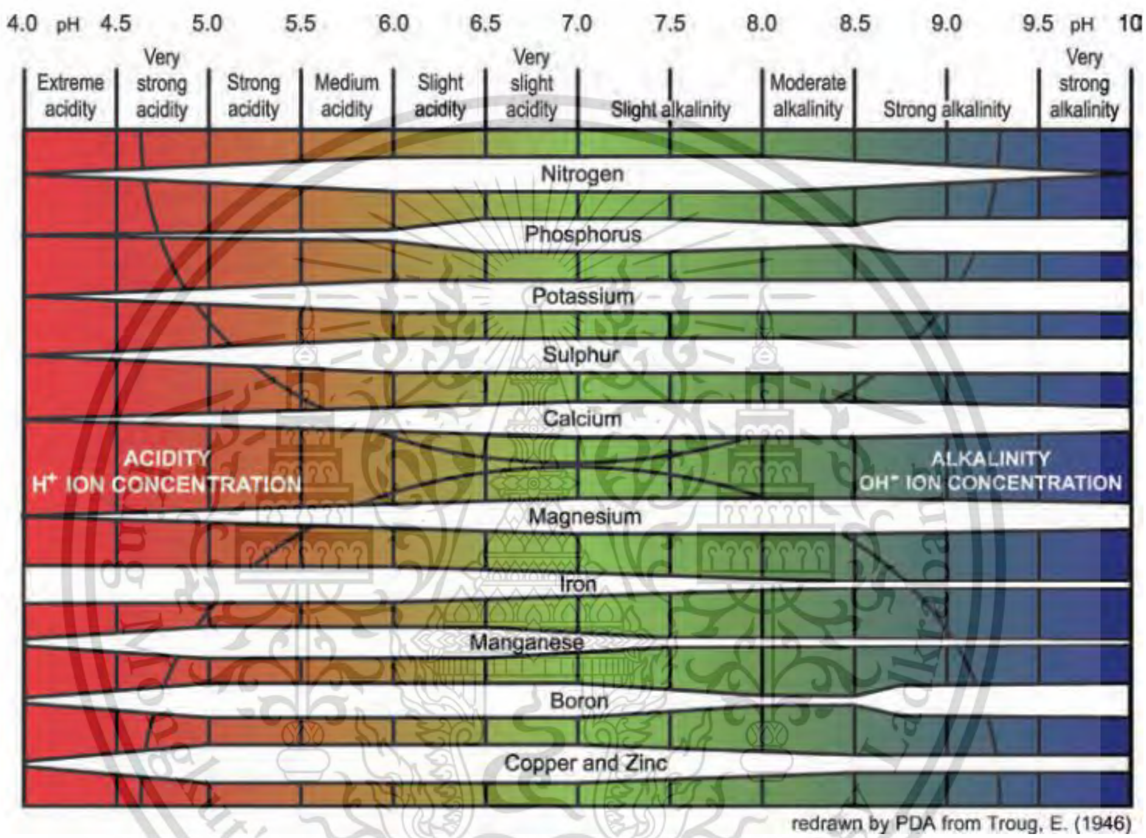


**Figure 2.1** Soil pH and its interpretation with nutrients availability. The more favourable the conditions of supply of a nutrient, the wider the white band.

**Source:** Adapted from (Botta, 2015).

The cation-exchange capacity (CEC) is the maximum quantity of total cations that a soil can keep and exchange with the soil solution at a particular pH value. It is used to measure nutrient retention capacity, soil fertility, and the ability to avoid cation pollution of ground water. The soil contains sixteen important elements that promote plant development and the survival of soil-dwelling creatures. The essential nutrients for plant growth are known as macronutrients, and they include nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), carbon (C), oxygen (O), and hydrogen (H). Plants require some elements in lesser amounts, referred to as micronutrients. These nutrients include zinc (Zn), manganese (Mn), boron (B), iron (Fe), molybdenum (Mo), chlorine (Cl), and copper (Cu). However, recent findings indicate seventeen essential elements, with the discovery of Nickel, which is one of the micronutrients required by plants. Mahler (2004) reported that in 1991, nickel was added to the list of essential elements. Plants require no more than one part per billion Ni. It is believed that the Nickel plays a vital role in plants' iron metabolism.

Soil salinity occurs owing to an excess of Na, Ca, Mg, K, Cl, S, and carbonates, whereas soil sodicity arises due to an excess of exchangeable sodium (FAO, 2016). The most significant factor in soil health and productivity is organic matter. It is made up of both living and non-living elements. Since the top 20 cm of soil typically includes more soil organisms and higher levels of biological activity than soil below in the profile, your management activities can have a significant influence on them. Majority of them rely on organic matter for energy and release a huge reservoir of plant-available nutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and trace elements during the decomposition process in aerobic environments. Organic matter may contain large amounts of these nutrients because it has a large surface area and both negative and positive charges. The glues and slimes produced by soil organisms during the decomposition process aid in the aggregation of soil mineral particles. This better soil structure results in increased water-holding capacity, drainage, aeration and root penetration, as well as a lower incidence of erosion and nutrient leaching (Botta, 2015).

Randolph (2004) mentioned that according to Liebig's law of the minimum that under steady-state environments, an organism's (including plants') development is restricted by the critical nutrient or component in the soil accessible in the least quantity relative to the species' demands. Hossain and Salam (2019) analysis of the chemical properties of the sited soils included soil organic carbon (SOC), soil organic matter (SOM), cation exchange capacity (CEC), base saturation, soil electrical conductivity (EC), N, P, K and S, and soil pH. For the investigation of soil physical attributes, particle size analysis, soil structure, water holding capacity (WHC), bulk density (BD), and total porosity (PT) were determined.

## 2.2 Global and local scenarios

### 2.2.1 Global organic agriculture scenario.

According to the IFOAM Annual Report-2018, there were 181 countries engaged in organic activities in 2017, with an organic market worth of 90 billion euros, a global per capita consumption of organic food of 10.8 euros, and organic agricultural land covering 69.8 million hectares, with Asia accounting for 6.1 million ha. China possessed the most organic land in Asia, at three million acres. The global percentage of organic agricultural land was 1.4%, with Asia accounting for 0.4%. Timor-Leste has the biggest proportion of organic land in Asia, accounting for 8.2%. There were 2.9 million organic growers worldwide, with Asia accounting for 1.1 million, with India accounting for the most with 835,000 growers (IFOAM, 2018). Global organic area and other parameters have gradually increased throughout the years. In 2014, the worldwide percentage of organic in total agricultural land was 0.99 percent, with 2.3 million farmers, both of which rose by 0.41% and 0.6 million in 2017. In Asia, there were 3.4 million hectares of organic land in 2014, which rose to 6.1 million ha in 2017, a 74% growth (IFOAM, 2015b).

Agricultural approaches based on organic farming principles are gaining popularity as a potential key contributor to achieving food and nutrition security and fighting poverty (IFOAM, 2015a). Nonetheless, organic agriculture (OA) accounts for only a small portion of global agriculture, frequently seen as overly expensive and low productivity (IFOAM, 2017). To support the 40% rise in global population, agricultural production needs to be increased by 70%, and in developing countries, it must be increased by almost 100% by 2050. To attain food production of 90% in the developed world and 80% in the developing world, crop productivity and intensity would need to be enhanced, with the remainder coming from area expansion (Bruinsma, 2009). Global agriculture has been hampered by the depletion of resources such as water, land, soil, and energy due to a variety of reasons such as urbanization, industrialization, and competition from bio-energy crops. As a result, boosting crop productivity remains an essential option for meeting food supply needs. According to the FAO, food crop productivity must be raised by at least 43% by 2030 to fulfil world food demand if all other parameters stay constant (Dasgupta & Roy, 2011).

### 2.2.2 Agriculture and organic agriculture in Bhutan

Agriculture is an important primary sector in Bhutan, supporting livelihoods and employing around 43.9% of the population (Population & Housing Census of Bhutan [PHCB], 2017). However, only 7% of the country's land is arable due to overall geography, characterized by steep terrains. Druk Nyamrup Tshogpa (DNT) (2018) reported that just 2.9% of total arable land is farmed.

Rice, maize, mandarin, apple, potato, other vegetables, cardamom, and other spices are important crops farmed. Bhutan is characterized mainly by smallholder farmers who primarily participate in subsistence farming and own an average of 1.16 hectares (NSB, 2011). The Department of Agriculture (DoA) under the Ministry of Agriculture and Forests (MoAF), RGoB, has a vision of a self-reliant, resilient and sustainable agriculture food system and a Mission to achieve food and nutrition security, agricultural transformation through innovative and sustainable technologies, diversified and competitive economic/production options, inclusive and sustainable policies and programs. Among many objectives, two critical goals under the department are increasing crop production to enhance food self-sufficiency, income, and nutrition security and promoting organic farming for sustainable agriculture, safe food, and environmental conservation.

Some of the essential mandates are: i) ensure attainment of food self-sufficiency ii) generate appropriate agriculture technologies iii) promote income generation, employment opportunities, and enterprise development iv) delivery of essential agriculture inputs and services (farm infrastructure, technical, advisory, and administrative) v) provide support services on soil, plant protection, post-harvest and other agricultural services vi) facilitate value chain and marketing of agriculture produce vii) promote farm mechanization and labour-saving technologies (Department of Agriculture [DoA], 2018).

The DoA has a national mandate to increase food production to ensure household food security, alleviate poverty, substitute for or reduce imports through increased domestic production, generate a marketable surplus, increase household income, and create job opportunities. The DoA's Agriculture Research and Development Section envisions a dynamic, vibrant, and functioning research system for national food self-sufficiency, nutrition security, and self-reliance. The mission is to generate knowledge, information, and technology that solve emerging food self-sufficiency, nutrition security, rural income, and economic challenges (Ghimiray et al., 2019). The World Health Organization (WHO) has defined food security as "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life" (IFOAM, 2015c). The DoA, Bhutan, has identified potato as one of the six prioritized commodities in the 12th five-year plan (FYP). In addition, organic farming is one of the thrust areas and outcomes targeted by the DoA in the 12th FYP (Department of Agriculture [DoA], 2018).

The current Bhutan Government's (Druk Nymarup Tshogpa (DNT) (2018-2023) manifesto on agriculture states, "rural prosperity through the strategic marketing of agricultural produce, thereby, enriching families." Its agricultural pledges include 1) creating a network of farm marketing centers and 2) establishing cold storage and warehouses. 3) Make farming more accessible and affordable; 4) exempt farmers from paying taxes on revenue earned from primary agricultural products, and 5) promote agricultural employment. 6) Increase agricultural productivity, minimize imports, and 7) assure year-round irrigation. The government will consider allowing conversion of *chuzhing* (wet land) to *kamzhing* (dry land) where there is a lack of water source for irrigation, and 8) provide crop insurance (Druk Nyamrup Tshogpa (DNT), 2018).

The National Framework for Organic Farming in Bhutan (NFOFB) published in 2006 envisions that Bhutan will be fully organic by 2020 (Department of Agriculture [DoA], 2006). The then prime minister of Bhutan declared that Bhutan would go 100% organic in food production at Rio+20 on 19th June 2012. However, the current government of Bhutan has addressed in one of the country's mass media that the country's goal to become 100% organic by 2023 is quite vague (Seldon, 2019). Therefore, Bhutan will not be able to achieve 100% organic by 2020. Nevertheless, the country has been pursuing its organic vision, as apparent by the initiation of the National Organic Flagship Programme by the RGoB in its 12th five year plan (FYP) (2018 to 2023) (Agriculture Research & Development Centre (ARDC)-Yusipang, 2019). In 2017, the country had around 25,667.9 acres of land under organic management, with a production of 2,599.7 MT, which included areas under agriculture, livestock, and wild collections. About 5560 acres and 966 MT are under intentional organic agricultural production (National Organic Programme [NOP], 2017).

**2.2.3 Potato cultivation in Bhutan and organic potato status in the study area**

Potato farming is said to have begun some 8000 years ago in the South American highlands of Peru and Bolivia on the Andes Mountains (Sinha et al., 2010). In 2017, the total global potato area was 19,302,642 ha, with a total global production of 388,190,674 MT and global productivity of 20.11 MT/ha. The world's largest potato producer is China, with a total production of 99,205,580 MT in 2017. India is the second-largest producer, with 48,605,000 MT, followed by the Russian Federation produced 29,589,976 tons (FAOSTAT, 2017). Because of the importance of the potato crop in future food security and poverty reduction, the FAO announced 2008 to be the International Year of the Potato (Rana & Anwer, 2018).

The potato contributes to women's and children's nutritional balance and specified calories, protein, iron, and zinc requirements. Floury landraces and recent potato types supply critical nutrients throughout the year; hence their contribution to food security is significant (de Haan et al., 2019). After wheat, rice, and maize, the potato (*Solanum tuberosum* L.) is the fourth most significant crop. Aside from its adaptability, it can produce more nutritious food from less area in less time than other crops like wheat, maize, or rice. Due to the general presence of good agroecological conditions for potato development, potato is one of the most extensively farmed, consumed, and traded horticultural crops in Bhutan. It is grown as a non-cereal food, cash crop, and vegetable by around 22% of rural households. It is the most significant crop for farmers over 2,500 m.a.s.l. and is often grown between 2,000 and 3,500 m.a.s.l. in Bhutan (Bajgai et al., 2018). The first evidence of potato introduction in Bhutan goes back to 1,776 when it was mentioned in Bogle's visit to Bhutan. The potato is at the forefront of any government's food security and nutrition policy because of its superior productivity, nutritional value, and adaptability to Bhutanese environmental situations (Roder et al., 2008). Every Bhutanese consumes potato in cooked curry, boiled and fried, and all surpluses are sold to India and Bangladesh.

The introduced and widely grown varieties in Bhutan are 1) *Desiree* 2) *Kufri Jyoti* 3) *Yusikap* 4) *Khangma kewa kap* (Council of Renewable Research of Bhutan [CoRRB], 2005). The variety "Desiree" accounts for 90% of all potato cultivation in the country; better pricing, processing, storing/keeping, and palatability are all significant factors for this variety's popularity (Roder et al., 2008). Desiree is a prominent variety in Bhutan that is commonly used as a standard check during the standard assessment standards for potato germplasm (Bajgai, 2018). Some prominent potato varieties in Bhutan are provided in Figure 2.2.


**Figure 2.2** Some prominent potato varieties in Bhutan.

**Source:** National Potato Program, Bhutan (National Potato Programme, 2019). *Desiree's* picture was captured at Phobjikha, Bhutan, by the author.

Potato is an essential source of income for farmers in Bhutan. This crop has transitioned traditional subsistence farming into a market-oriented production (Council of

Renewable Research of Bhutan [CoRRB], 2005). Apart from the domestic market, it is mainly exported to India, Bangladesh, and Nepal (Ministry of Agriculture and Forests [MoAF], 2019). Figure 2.3 shows the export of potato and other vegetables from Bhutan for three years from 2016 to 2018; the export value of a potato is significantly higher than other vegetables combined for all three years. In 2018, potatoes earned 511.06 million Ngultrum (Nu) while other vegetables earned 43.98 million Nu. in the export market. This indicates that potato is one of the critical agricultural commodities for export and cash crop in Bhutan.

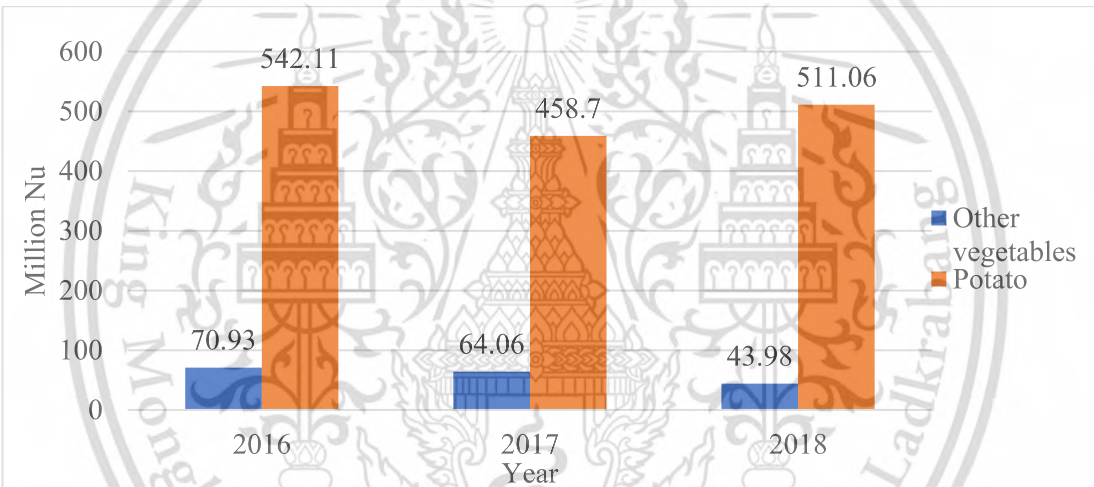


**Figure 2.3** Export of potato and other vegetables during 2016-2018 in Bhutan.

**Source:** Adapted from Bhutan RNR Statistics, 2018 Ministry of Agriculture and Forests [MoAF] (2019).

In 2019, total potato production was 43,560 tons (MT), with a total area of 4187 hectares (ha), and average national productivity of 10.40 (MT/ha) in the country (Ministry of Agriculture and Forests (MoAF), 2020). In Bhutan, about 20.34 hectares, or 0.5% of the total potato acreage, were certified organic in Gasa district by the relevant government institution (Agriculture Research & Development Centre (ARDC)-Yusipang, 2019).

The average productivity (yield) of potatoes in Bhutan for five years from 2012 to 2016 was 9.64 MT/ha. The country's potato productivity (yield) has been stagnant, and its productivity is among the lowest in the South Asian region (Bajgai et al., 2018; BPV Consultancy & Research Services, 2018). Seed potatoes are typically 35 to 65 g/tuber, with tuber diameters ranging from 25 to 50 mm. Bhutan's average potato seed rate is 800 to 1000 kg per acre or 1.98 to 2.47 MT/ha. However, if the tuber sizes are smaller than the above-recommended average, the seed rate will be lower, and if the tuber sizes are bigger than the average, the seed rate will be higher (Bajgai & Rai, 2020). In accordance to the National Potato Programme the potato productivity (yield) in Bhutan can be categorised into four groups, namely: i) <5 MT/ha (very low) ii) 5-10 MT/ha (Low) iii) 10-14 MT/ha (Moderate) and iv) >14 MT/ha (High) (National Potato Programme, 2019).

Gasa has been the first fully organic district in the country since 2004 (Wangmo & Iwai, 2018). *Rangshin Sonam Detshen* is also the first organic certified farmers' group in the country in Goenkhatoe *Gewog* (block/a group of villages in Bhutan) under Gasa district. The Bhutan Agriculture and Food Regulatory Authority (BAFRA) certified the organic group on 10th October 2016 following the Bhutan Organic Certification System (BOCS) Guidelines, 2013. The organic group has around 50 members with about 20.34 hectares of cultivable land with initial organic potato production of 25 MT. In 2016, for a promotional purpose, an organic group *Rangshin Sonam Detshen* from Goenkhatoe *Gewog*, Gasa, Bhutan, sold the first certified organic potatoes at a premium of around 25%

to the prevailing market price of local potatoes at the Centenary Farmers Market (CFM) in Thimphu, Bhutan. In the promotional sale, the organic group earned Nu. 67,655 by selling the organic potatoes at the Centenary Farmers Market (CFM), Thimphu, wholesale, and hotels at the selling price of Nu.50/kilogram (kg) for a retail price and Nu. 35/kg in wholesale. The retail price of Nu.50/kg was charged for selling directly to the hotels. Due to lack of actual cost of production, the selling price of organic potato then was fixed arbitrarily with the relative retail price of local conventional potatoes; therefore, there is still a need to assess the actual cost of production for organic potatoes (Department of Agricultural Marketing and Cooperatives [DAMC] & DAS Gasa, 2016).

Potato farming is the main source of income for almost all the households in Phobjikha and Gangtey *Gewogs* (block; a group of villages in Bhutan) in the Wangdue Phodrang district (Dorji, 2019). The local leaders and agriculture officials in Gangtey and Phobjikha *Gewogs* have been concerned over the increasing trend of usage of chemical fertilizers in potato cultivation. It has been observed that the farmers are competing to use more chemical fertilizers every year for potato farming in these *Gewogs* (Lhamo, 2019). Both Gasa and Wangdue Phodrang districts fall under the West-Central region of the country with predominantly temperate climates having similar agroecological characteristics, including altitude. Both the study place (Goenkhatoe *Gewog* under Gasa district and Phobjikha *Gewog* under Wangdue Phodrang district) fall under the temperate zone [Agroecological Zone (AEZ) 3] which is located above 1,800 meters above sea level (m.a.s.l) (Feuerbacher et al., 2018).

## 2.3. Related research

### 2.3.1. Productivity of crops due to organic and conventional farming.

Existing organic productivity may rise in Bhutan, but it may not be as high as conventional farming. Given this situation, the country's full conversion to organic agriculture may not result in greater farmer incomes (Neuhoff et al., 2014). The trend study from 2004 to 2016 in Gasa, Bhutan's sole organic district, revealed an increase in agricultural yield and variety (Wangmo & Iwai, 2018). According to a review of current on-farm data in Bhutan, organic crop yields were 24 percent lower on average than conventional yields (Feuerbacher et al., 2018). In all three Agroecological Zones (AEZs), no statistically significant differences in rice grain yields were observed between organic and conventional rice fields (Tashi & Wangchuk, 2016).

Org-High (organic-high) can contribute to sustainable agricultural production in Kenya, depending on the crops planted and geographical factors because it has proved that it is productive, economically viable, and resource-sustaining (Adamtey et al., 2016). For the three-year average in coffee, the organic farm's group had a 22% lower yield than the conventional farms (Lyngbaek et al., 2001). Rice yields from organic farms were somewhat lower than conventional farms (Mendoza, 2004). Since the results demonstrated that organic fertilization did not produce shortages in vegetable productivity and nutritional content compared to conventional fertilization, ecological management may be applied efficiently (Herencia & Maqueda, 2016). When agronomic management is adequately planned, there is little chance of crop productivity penalties from using alternative approaches (Norris & Congreves, 2018). In temperate locations, organic systems have yields that are 20 to 25% lower than conventional systems (Seufert et al., 2012). However, in the tropics and subtropics, organic treatment resulted in yields that were 26% greater than conventional management (Te Pas & Rees, 2014). Despite reduced yields, growing organic olive is a successful business (Sgroi et al., 2015).

**2.3.2 Profitability due to organic and conventional farming.**

In Bhutan, conventional rice had a significantly higher benefit-cost ratio (BCR) than organic rice (Tashi & Wangchuk, 2016). Sustainable agriculture in Bhutan refers to various farming methods, approaches, and systems that strive for profitability, stewardship, and quality of life following the principles of gross national happiness. Organic farming is the only method that achieves these objectives (Gyem, 2012).

Despite slightly lower yields in organic farms when compared to conventional farms, the net income in organic farms was higher (Mendoza, 2004). In a case study of black carrot (*Daucus carota* L.), organic farming required more labour than conventional farming, with benefit-cost ratios of 1.83 and 2.05 for conventional and organic farming systems, respectively (ÇelİK et al., 2010). Organic farming yielded higher profits for organic olive farms than conventional ones. This is primarily due to government subsidies and a higher market price for organic olive oil, which was 21% higher than conventional olive oil (Sgroi et al., 2015). Organic-High attracted a price premium of 20 to 50% from the fifth year, making it 1.3 to 4.1 times more lucrative than conventional-high when sold on local and regional markets (Adamtey et al., 2016). In accordance with Adhikari (2011), the costs of poultry manure, human labour, and oil cake all contributed significantly to total revenue ($p<0.05$), and labour costs contributed the most to total production costs, with a benefit-cost ratio of 1.15 observed for organic rice production. In the tropics and subtropics, organic management resulted in gross margins that were 51% higher than conventional management (Te Pas & Rees, 2014).

### 2.3.3 Effect(s) on soil physicochemical properties due to organic and conventional farming.

The soil organic matter (SOM) and available P were the soil parameters that consistently and significantly increased in the organic rice farms in both years (Tashi & Wangchuk, 2016). Low crop productivity has been attributed to several factors, including low soil fertility and long-term soil degradation such as acidification, compaction, loss of soil organic matter, and nitrogen (Folberth et al., 2014). Soil organic matter content and biological activity are generally higher in organic systems than conventional methods. Organic systems' sustainability may be adversely affected if natural trace element deficiencies are not resolved (Condron et al., 2000).

Soil chemical and nutrient indicators of healthy soil, such as carbon levels and nitrogen reserves, generally improved after soil amendments were applied. With the incorporation of cover crops into vegetable crop rotations, the risk of nitrate leaching was reduced, soil carbon levels were increased, and weeds were reduced (Norris & Congreves, 2018). Approximately 75% of allotment plot holders questioned used organic-based fertilizers and commercial composts, which explains higher soil organic carbon, C:N ratios, total nitrogen, and lower bulk density than arable soils, all of which are important for soil health (Edmondson et al., 2014). The results in the tropics and subtropics revealed that organic management increased soil organic carbon by 53% on average compared to conventional management (Te Pas & Rees, 2014). Organic farming enhanced the quantity of nutrients in the sandy loam soil, such as N, P, and K, which would promote crop production. The soil's physical properties, such as field capacity, wilting point, and moisture content, rose more than the control plot before and after harvest (Jeyaseeli et al., 2021).

### 2.3.4 Organic marketing and premium price

When sold at local and regional markets, organic-high maize attracted a 20 to 50% price premium from the fifth year onwards, making it profitable 1.3 to 4.1 times more than conventional-high maize (Adamtey et al., 2016). On the other hand, farmers were selling their paddy rice at a 20-30% premium over conventional paddy rice at the farm gate. With an average of 25% higher organic rice prices, gross revenue increased by 25% (Mendoza, 2004). The average premium price received by ten organic coffee farms was 20%, excluding four farms that did not receive a premium. However, the premium for the six farms that received it was 40%. (Lyngbaek et al., 2001). The premium price for organic olive oil was higher by 21.1% than conventional, ensuring higher profitability in the organic system and compensating for lower yields than the conventional system (Sgroi et al., 2015).

## 2.4 Research gaps

Pondering Bhutan's pledge to be a 100% organic country by 2020, prominent national and international researchers have already initiated their research on this issue. Some researchers have collected primary data through interviews and questionnaires, while many have dependent on the published secondary data sources. Following their studies, they have laid down significant research gaps that need to be addressed in Bhutan. According to one of the researchers, the pledge of 100% organic farming does not seem to meet the country's objective of enhancing food self-sufficiency and food security. For a full review of 100% organic policy in Bhutan, further comparative research on the agronomic and economic aspects of organic and conventional systems are required.

More research into the benefits and drawbacks of organic agriculture is needed. In general, research into the comparative productivity of organic agriculture in developing countries, notably Bhutan, is scarce. Except for studies on organic and conventional rice, no other research has been undertaken up to this point in the country. The followings are detail significant research gaps that further led to the conduct of this study (Table 2.1)

**Table 2.1** Important research gaps

| **Author (year)** | **Title** | **Research method** | **Data collection instrument** | **Key finding(s)** | **Research gaps** |
|---|---|---|---|---|---|
| Neuhoff, D., Tashi, S., Rahmann, G., and Denich, M. J. O. a. (2014). | "Organic agriculture in Bhutan: potential and challenges." | 1.Farm inspections 2.Discussions with experts and local people. 3.Secondary data 4.Qualitative and Quantitative. | Secondary data collection, farm inspections, discussions with experts and local people. | Yields from organic farming may increase slightly above current yields, but they may not be on par with yields from agrochemical farming systems. In this regard, the potential for increasing farmer incomes through whole-country conversion is limited. | In Bhutan, more comparative studies on the agronomic and economic aspects of organic and conventional systems are needed for a comprehensive evaluation. |
| Wangmo and Iwai (2018) | "Performance of Organic Agriculture based on Emergent | 1.Secondary data sources 2.Quantitative | Secondary data sources (the yield and crop diversity statistics were obtained from | Looking at the trend analysis from 2004 to 2016, there was an increase in | Nonetheless, more study is needed in Bhutan to effectively assess the performance of organic agriculture in the field, |

| Author (year) | Title | Research method | Data collection instrument | Key finding(s) | Research gaps |
|---|---|---|---|---|---|
| | Properties of Agriculture System in Gasa, Bhutan." | | Bhutan's Agriculture Statistics 2004-2007, 2009-2012, and 2014-2016). | crop productivity and diversity. | identifying opportunities and challenges. |
| Feuerbacher, Arndt Boysen, Ole Zikeli, Sabine Grethe, Harald, (2018) | "Is Bhutan destined for 100% organic? Assessing the economy-wide effects of a large-scale conversion policy." | 1.Secondary data sources 2.Quantitative | Agricultural Sample Survey 2012, MoAF, Bhutan. | According to an analysis of recent on-farm data, organic crop yields were 24% lower than conventional crop yields in Bhutan. | At this point, it is unclear whether Bhutan's adoption of a 100% organic agriculture policy is the best option. In general, research on the comparative productivity of organic agriculture is limited in developing countries, particularly in Bhutan. Until now, no other study has been conducted except for research on organic and conventional rice assessing rice grain productivity across all three AEZs undertaken in 2012 and 2013. |
| Duba, S., Ghimiray, M., and Gurung, T. R. (2008). | "Promoting organic farming in Bhutan: A review of policy, implementation, and constraints." | 1.Secondary data sources 2.Qualitative and Quantitative. | Government documents, conference paper and working paper of FAO, and workshop output report. | The study examines Bhutan's organic farming promotion policy, implementation, and constraints. | The Renewable Natural Resources-Research Centres (RNR-RC) would have the following roles: i) Generations of relevant organic farming technology ii) Research comparing conventional and organic farming iii) Technical know-how iv) Increasing or sustaining the productivity of organic farming. |
| McCrae-Hokenson, Mark, (2014). | "Organic Agriculture in Bhutan: Barriers Going to 100%." | 1.In-depth interviews of farmers, scholars, and Govt. officials 2.Qualitative and Quantitative. | Use of questionnaire for farmers and semi-structured interview for scholars, researchers, and | In Bhutan, we investigated the obstacles to converting to 100% organic farming. In addition, the programs and | Bhutan has pledged to become 100% organic by 2020 to promote sustainability and achieve its Gross National Happiness' (GNH) goals. The pledge, however, does |

| Author (year) | Title | Research method | Data collection instrument | Key finding(s) | Research gaps |
|---|---|---|---|---|---|
| | | | government officials. | initiatives in place to address these barriers and the future path of least resistance were investigated. | not appear to support the country's goal of increasing self-sufficiency and food security. |
| Eliza Barclay (2012) | "Bhutan bets organic agriculture is the road to happiness." | 1.Interviews 2.Secondary data sources 3.Quantitative | Interview, secondary data collection (World Food Program (WFP), information from other media such as Bhutan Observer, etc.) | Converting to 100% organic is an ambitious goal for any country. However, impoverished farmers want to use agrochemicals to increase crop yield and control pests and diseases. | Mr.Leu, President of IFOAM, is optimistic that the growing research centers in organic agriculture in Bhutan will eventually be able to find organic technologies to increase organic crop productivity. |

The literature reviews were undertaken to understand various theories, studies, and research gaps related to the study's topic. It comprehensively covers different crop productivity and profitability theories, global and Bhutanese agriculture and its organic agriculture scenarios, potato farming and organic potato's status in the country, various related research concerning productivity, profitability, physicochemical properties, and marketing of organic and conventional crops. It also brings forth several research gaps in the study. For instance, some studies are in agreement (Lyngbaek et al., 2001; Mendoza, 2004; Seufert et al., 2012; Sgroi et al., 2015) found organic crop productivity was lower than the conventional crops. However, literature reviews also indicate conflicting findings. For example, a review of current on-farm data revealed that organic crop yields were 24 percent lower on average than conventional yields in Bhutan (Feuerbacher et al., 2018). In contrast (Tashi & Wangchuk, 2016), in all three Agroecological Zones (AEZs), no statistically significant differences in rice grain yields were observed between organic and conventional rice fields in Bhutan.

Significant research gaps that support this study were (Neuhoff et al., 2014), which states that more comparative research on the agronomic and economic fields of organic and conventional systems is required for a comprehensive assessment in Bhutan. In addition, Wangmo and Iwai (2018) recommend that more study is needed to effectively evaluate the performance of organic agriculture in the field, finding opportunities and challenges in Bhutan. Similarly, (Barclay, 2012; Duba et al., 2008; Feuerbacher et al., 2018; McCrae-Hokenson, 2014) also indicate research gaps relevant to this study.

# Chapter 3

# Methodology

The 3rd chapter provides different methodological tools employed in the study. It is an integral part of the study, and the methodology was determined upon relevant literature reviews, careful discussion, and approval from relevant authorities. Both qualitative and quantitative research methodologies were employed in the study; the qualitative methods included in-depth farmers' interviews, whereas the quantitative method involved using a semi-structured questionnaire that also used Likert scales, soil samplings and subsequent statistical data analysis. It has five sections; 1st section (3.1) discusses how population and sample size were determined, 2nd section (3.2) informs on different data collection methods, 3rd section (3.3) confers on the implementation of methodological quality tools, 4th section (3.4) brings forth data analysis tools, 5th section (3.5) provides hypothesis testing. A brief introduction and summary of the chapter are also provided.

**3.1 Population and sample size**

The research data were gathered from West-Central Bhutan. There was around a total population of 50 households under the certified potato production in Goenkhatoed *Gewog*, under Gasa district. The sample size selected initially for the study was 44 farmers complying with the standard reference/chart developed by Krejcie and Morgan (1970). However, the data were gathered from available 43 farmers at Goenkhatoe *Gewog* in Gasa district, spread across 17 villages, during the data collection period. Subsequently, fifty (50) numbers of conventional potato farmers were purposively and randomly selected from a nearby place, Phobjikha *Gewog,* Wangdue Phodrang district, spread across 13 villages.

Such methodology was adopted from Lyngbaek et al. (2001), who applied a similar approach to organic versus conventional coffee study. Therefore, a total of 93 farmers were selected for the data collection in the study: Both organic and conventional potato farmers were practising their farming for at least three years. Likewise, organic coffee farms with at least three years under organic management were one of their research's selection criteria (Lyngbaek et al., 2001). For the sample size and other details, please refer the Table 3.1:

**Table 3.1** Study location and sample size

| **District** | **Gewog** | **Total farmers** | **Area (ha)** | **Main crop** | **Altitude (m.a.s.l)** | **Agroecological zone** |
|---|---|---|---|---|---|---|
| Gasa | Goenkhatoe | 43 | 20.34 | Potato | Above 1800 | Temperate |
| Wangdue Phodrang | Phobjikha | 50 | 38.15 | Potato | Above 1800 | Temperate |
| | Total | 93 | 58.49 | | | |

## 3.2 Data collection methods

Data collection methods following the research objectives:

**Objective 1:** To investigate the farm and farmers' socio-demographic characteristics and production aspects of organic and conventional potato farmers in West-Central Bhutan.

### 3.2.1 Purposive sampling

Potato farmers at Goenkhatoe *Gewog*, Gasa district, Bhutan, were purposively selected because they have been doing organic farming for a long time (more than three years). The group is also a certified organic potato grower. Similarly, conventional potato farmers were selected from Phobjikha *Gewog*, Wangdue Phodrang district because they have been into conventional potato farming for a long time (more than three years).

Purposive sampling is more suitable when there is a small population and its known characteristics to be studied thoroughly (Kothari, 2004). Adhikari (2011); Poungsuk et al. (2018) used purposive sampling techniques in their studies on organic rice and facilitation on organic agriculture learning, respectively.

### 3.2.2 Semi-structured questionnaire

Face-to-face interviews with individual farmers were used to acquire primary data. During each farmer's interview, the head of the family or any family member actively engaged in potato farming was interviewed. The data from farmers were collected using the semi-structured questionnaire. A similar method was implemented by (Bajgai & Sangchyoswat, 2018) in a study on soil fertility knowledge in Bhutan. Farmers' information was gathered through a semi-structured questionnaire. To obtain qualitative data of some type, the semi-structured interview has become the most popular tool among researchers because of its flexibility (Nunan & David, 1992). A sample of the questionnaire used in the study is annexed in an Appendix (Annexure 1).

Lyngbaek et al. (2001) and Kalra and Thanavisuth (2018) used semi-structured interviews in their studies on organic and conventional coffee and an attitude on English accent, respectively. It was divided into three sections: the first contained farm and farmer information such as socio-demographic data, the second gathered productivity and profitability data, and the third contained constraints. Suwanmaneepong et al. (2020) applied similar sections in a questionnaire in their study on organic and conventional rice.

Farmers' opinions on constraints were collected using a five-point Likert scale ranging from strongly disagree = 1 to strongly agree = 5 (Likert, 1932). The use of such methodology (scale) was adapted from similar research on the barriers of transitioning to organic farming by (Sharifi et al., 2010). Chidiebere-Mark et al. (2019) similarly collected data on farmers' various production constraints in their studies in rice.

### 3.2.3 In-depth farmers' interview by Individual farmer's interview (IFI)

The required data for the research were collected through face-to-face Individual Farmers interviews (IFI). The IFI was used by (Mendoza, 2004; Suwanmaneepong et al., 2020) in their studies on organic and conventional rice.

### 3.2.4 Pre-testing of a questionnaire

The questionnaire prepared for each farmer's interview was pre-tested with at least 30 farmers who did not belong to the sample study farmers. The pre-testing took place in Geney *Gewog*, Thimphu district, Bhutan, during the first week of September 2020. Similar pre-testing of questionnaires before final data collection was also implemented by (Adhikari, 2011; Mankeb et al., 2014; Mendoza, 2004; Nmadu & Simpa, 2014; Suanthaisong et al., 2016). Necessary improvements in the questionnaire were accordingly made before interviewing the actual research sample farmers.

### 3.2.5 Primary and Secondary data gathering

Primary data were collected by direct face-to-face interviews with the farmers and soil samplings. Primary data can be gathered by experiment or survey (Kothari, 2004). Figures 3.1, 3.2, and 3.3 indicate primary data gathering in the study area, while Figure 3.4 shows a conventional potato farmer busy working on harvested potato tubers in Bhutan.

**Figure 3.1** Pre-testing the questionnaire at Geney *Gewog*, Thimphu district, Bhutan.

**Figure 3.2** Interviewing organic potato farmers in Goenkhatoed *Gewog*, Gasa district.

**Figure 3.3** Interviewing conventional potato farmers in Phobjikha *Gewog*, Wangdue Phodrang district.

**Figure 3.4** Conventional potato farmer working on harvested potato tubers in Phobjikha *Gewog*, Wangdue Phodrang district.

Few relevant secondary data from international and Government agencies were drawn for the study, wherever necessary. Other researchers gathered secondary data (Feuerbacher et al., 2018; Neuhoff et al., 2014; Wangmo & Iwai, 2018).

**Objective 2:** To determine the differences in the productivity and profitability due to organic and conventional farming of potatoes in West-Central Bhutan. Also, concisely determine the marketing aspects and constraints of organic potato farmers in the region.

*Data collection methods were like Objective 1, as stated above.* Additionally, Productivity and profitability data were calculated as follows:

**3.2.6 Productivity and profitability were computed using the following formula**

**3.2.6.1 Productivity computation**

Productivity was computed using the following formula (equation 3.1) provided by the Food and Agriculture Organization (FAO, 2017):

$$\text{Land productivity} = \frac{Volume\ of\ output}{Planted\ Area} \quad \text{-------------(3.1)}$$

The volume of potato output in metric tonnes (MT) and potato planted area in hectares (ha) were collected from each organic and conventional potato farmer in the study.

**3.2.6.2 Profitability computation**

Profitability was calculated using the following formulas (equations 3.2 to 3.9). Total cost was calculated as a sum of total variable cost and total fixed cost as shown in following formula (equation 3.2). It was also applied by (Chidiebere-Mark et al., 2019; Suwanmaneepong et al., 2020).

$$TC = TVC + TFC \text{-----------------(3.2)}$$

Where:

TC is total cost

TVC is total variable costs

TFC is total fixed costs

The variable costs (VCs) collected in the study from each farmer were:

1) *Input cost* in this study comprise of:

   1.1) Seed

   1.2) Farmyard manure (FYM) and other organic fertilizers/chemical fertilisers.

   1.3) Pesticides/bio-pesticides/adjuvants

   1.4) Fuel and rental

2) *Labour cost* (man-days/ha) in this study comprise of:

   2.1) Land preparation

   2.2) Composting/FYM application

   2.3) Planting

   2.4) Weeding and earthing up

   2.5) Bio-pesticides/pesticides applications

   2.6) Harvesting/curing

The non-cash expenses were calculated using current market pricing for agriculture commodities. Labour expenses for hired, exchanged, and family laborers were calculated (Kahan, 2013). The prevailing farm labour wage determined the cash costs of hired laborers, and the costs of exchange and family laborers were determined by the farmers' actual food and beverage expenses (Tashi & Wangchuk, 2016).

3) The fixed costs (FC) collected in the study from each farmer were:

3.1) Land tax

3.2) Land rent

3.3) Depreciation cost.

4) Annual depreciation expense:

Annual depreciation expense was calculated using the following formula (equation 3.3). This was similarly employed by Suwanmaneepong et al. (2020).

$$Annual\ depreciation\ expense = \frac{Asset\ cost - Salvage\ value}{Useful\ life\ of\ the\ asset} \text{---------(3.3).}$$

The depreciation values of farm machineries such as tractor/power tillers/spray machines were computed in the study from each farmer.

5) The gross return

The gross return was calculated using following formula (equation 3.4). It was also applied by (Adhikari, 2011; Tashi & Wangchuk, 2016).

$$\text{Gross Return (GR)} = Q\ x\ P \text{ -----------(3.4)}$$

Where:

GR is gross return

Q is productivity (tuber yield)

P is farm-gate price

P (farm-gate price) was collected in Bhutanese Currency “Ngultrum” (Nu) per kilogram (kg) of potato from each farmer in the study, where 1 Nu= 0.014 USD.

6) The gross margin or profit

The gross margin or profit was calculated using following formula (equation 3.5). This was also employed by (Adhikari, 2011; Lyngbaek & Muschler, 2001; Tashi & Wangchuk, 2016).

$$\text{Profit or GM} = GR - TC \text{----------(3.5)}$$

Where:

GM is gross margin

GR is gross return

TC is total cost

All gross margin (GM), gross return (GR) and total cost (TC) were measured in Nu/ha.

7) The benefit: cost (B:C) ratio

The benefit: cost (B:C) ratio was calculated using the following formula (equation 3.6). It was also applied by (Adhikari, 2011; Tashi & Wangchuk, 2016):

$$\text{B:C ratio} = \frac{GR}{TC} \text{------------(3.6)}$$

Where:

B:C ratio is benefit: cost ratio

GR is gross return

TC is total cost

8) Return on investment (ROI)

The Return on investment (ROI) was computed using following formula (equation 3.7). Chidiebere-Mark et al. (2019) also employed it in their studies.

$$ROI = \frac{GM}{TC} \text{ x100 -------------(3.7)}$$

Where,

*GM* is gross margin (profit)

*TC* is total cost

9) The break-even price (P) and break-even yield (productivity) (Y)

The break-even price (P) and break-even yield (productivity) (Y) were calculated using the following formula (equations 3.8 and 3.9, respectively). Suwanmaneepong et al. (2020) also employed it in their study.

$$\text{Output price } (P_i) = \frac{VC_i + FC_i + \pi_i}{Y_i} \text{ -----------(3.8)}$$

$$\text{Yield (productivity) (Yi)} = \frac{VC_i + FC_i + \pi_i}{P_i} \text{ ----------(3.9)}$$

Where:

$P_i$ is commodity i's output price.

$Y_i$ is output i's yield (productivity)

$VC_i$ commodity i's variable costs.

$FC_i$ commodity i's fixed costs.

Break-even price or yield (productivity) can be examined by adjusting profits ($\pi_i$) equal to zero.

In the study the break-even price was calculated in Nu/kg of potato, while the break-even yield (productivity) was calculated in MT/ha.

**Objective 3:** To determine the differences in the soil properties due to organic and conventional potato production in West-Central Bhutan and determine any relationship(s) between them and productivity.

The data on soil properties were collected through soil sampling and analysis as follows:

### 3.2.7 Soil sampling

The Goenkhatoed *Gewog*, one of four *Gewogs* in Gasa district, was purposefully chosen for the organic potato soil research because it has been an organic farmers' group producing certified organic potatoes since 2016 (Department of Agricultural Marketing and Cooperatives [DAMC] & DAS Gasa, 2016). Phobjikha *Gewog*, one of 15 *Gewogs* in Wangdue Phodrang district, on the other hand, was purposefully chosen for conventional potato soil research. Farmers in this *Gewog* have been farming conventional potatoes for many years. Their primary source of income is potato farming (Dorji, 2019).

Soil samplings were carried out in study areas in accordance with the standard procedure mentioned in the field crops soil sampling (Leaflet No.2) (NSSC, 2008). The National Soil Service Centre (NSSC) is a premium national institute in Bhutan with a Soil and Plant Analytical Laboratory (SPAL). Minimum samples for soil sampling taken were: 15 organic farmers and 15 conventional farmers. Using a systematic sampling technique, 30 soil samples were collected from the research sites. Similarly (Edmondson et al., 2014), in their study, took 16 arable and 12 pasture soil samples randomly from pre-identified agricultural areas. Systematic sampling necessitates some degree of randomness in that it starts at a random position in the list and then chooses every $n^{th}$ member until the desired number is reached (Kothari, 2004). In this study, every third farmer was chosen until 15 samples from each farming system were acquired. Soil samples were gathered from 15 farmers in Goenkhatoed *Gewog*, Gasa district, out of 43 organic potato farmers scattered over ten villages. Soil samples were obtained from 15 farmers in Phobjikha *Gewog*, Wangdue Phodrang district, out of 50 conventional potato farmers spread over 11 villages. Figure 3.5 shows the soil samplings sites in Gasa and Wangdue Phodrang districts, where the black dots on the right are likely to be soil sampling locations. The soil samples were gathered in August-September 2020, just after the potato harvest but before any fertilizers were applied. Similar agricultural studies undertaken through soil samplings were done by (Bajgai & Sangchyoswat, 2018; Edmondson et al., 2014; Herencia & Maqueda, 2016).

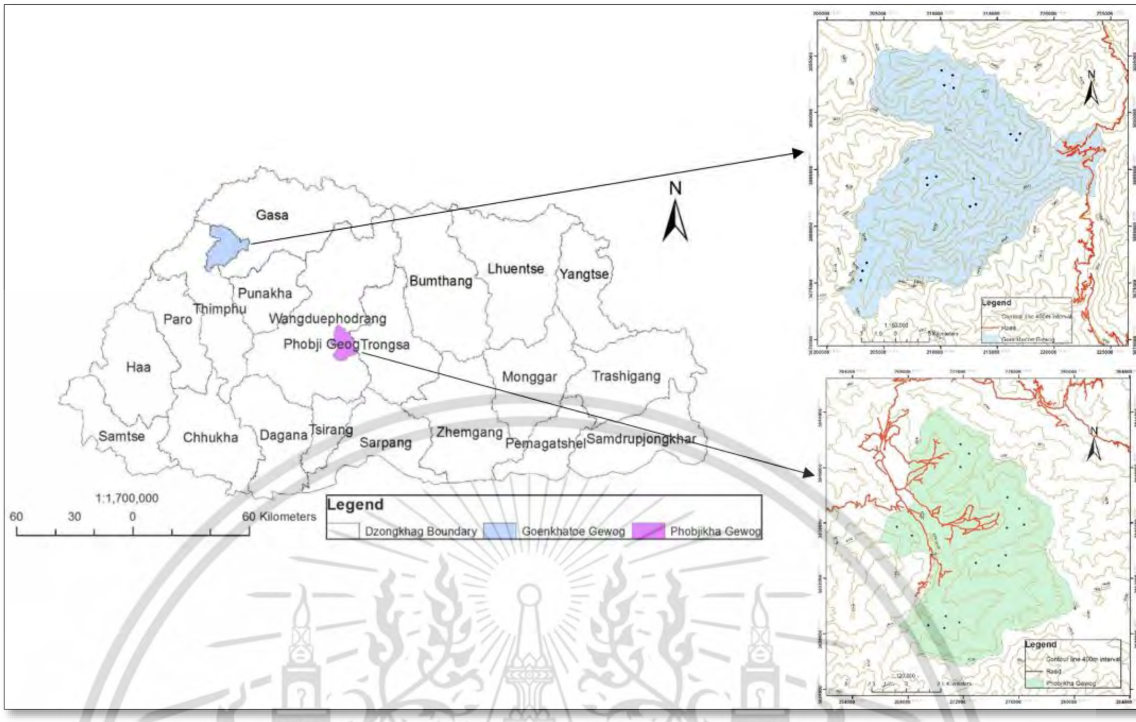


**Figure 3.5** Soil sampling in the districts of Gasa and Wangdue Phodrang.

**Source:** The National Soil Service Centre (NSSC) Bhutan, 2020.

1) **Procedures for soil sampling adopted from the National Soil Service Centre, Bhutan (NSSC, 2008). The same sampling procedure was applied for the collection of forest soils.**

1.1) The field was randomly divided into at least 8 to 10 parts to represent the area.

1.2) Any plant residues on the soil surface, such as grass, were scraped away.

1.3) For field crops, collected a soil sample to a depth of 20 cm using a soil auger and placed it in the tray.

1.4) We made a composite sample by taking and making identical samples from 8-10 additional points and arranging them in the tray. Then, all the samples were adequately mixed, and any stones or plant roots were removed from the tray.

1.5) A kilogram of the composite soil was placed in a plastic bag and properly labelled.

1.6) Filled soil analysis request form using soil information sheet from the center and attached it with the soil sample.

1.7) The prepared soil sample was subsequently delivered to the NSSC's Soil and Plant Analytical Laboratory (SPAL) for laboratory testing.

**3.2.8 Time of sampling**

Soil samples were taken in the field after harvesting the potato crop but before any new fertilizers were applied.

**1) Hints that helped take soil samples**

1.1) Each soil sample should only reflect one type or condition of soil.

1.2) When obtaining soil samples, avoid taking them on the borderline of two different soils.

1.3) A good soil sample adequately represents the area.

1.4) Take around 8-10 sub-samples of the area.

1.5) Soil samples should not be taken near fertilizer bands.

1.6) Avoid collecting samples from a tiny, unusual area.

1.7) A soil sample should be undertaken at the proper depth.

1.8) Unless otherwise indicated, soil samples for field crops must be obtained from a plough depth (15-20 cm). The pictorial soil sampling procedure has also been illustrated in Figures 3.6, 3.7, and 3.8.

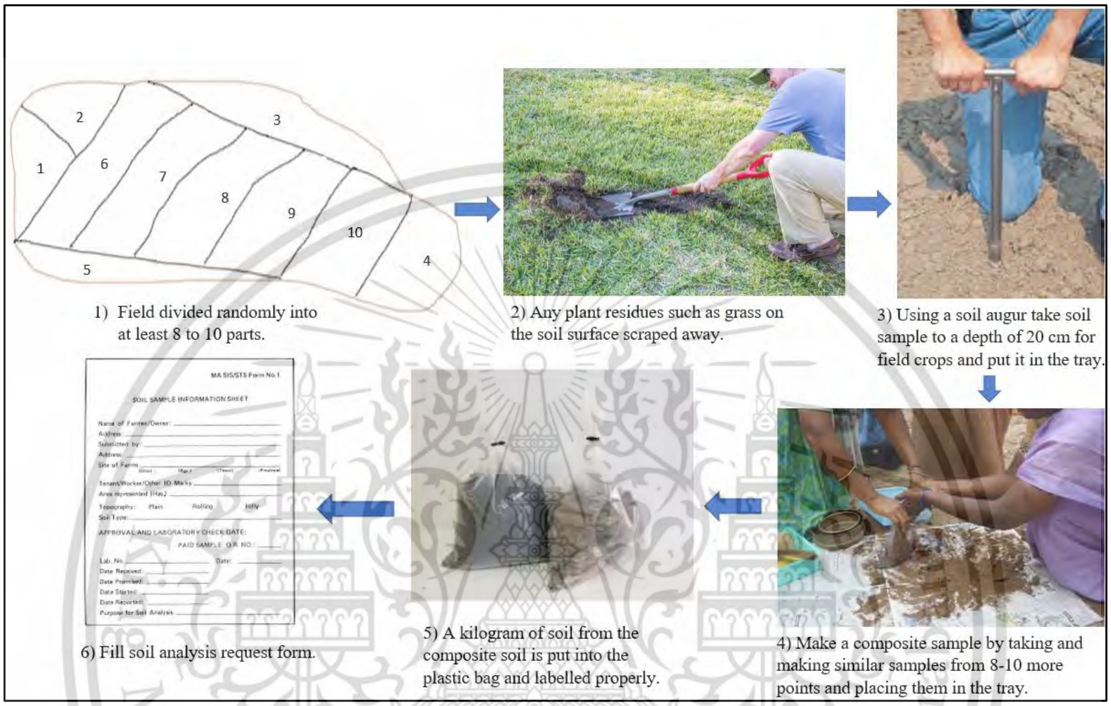


**Figure 3.6** Soil sampling procedure (NSSC, 2008)

**Figure 3.7** Soil samplings pictures in Bhutan in 2020.

**Figure 3.8** Soil sample submissions at the National Soil Service Centre (NSSC), Thimphu, Bhutan.

Soil properties of organic and conventional soil from the potato fields were analysed at the Soil and Plant Analytical Laboratory (SPAL), National Soil Service Center (NSSC), Thimphu, Bhutan. The SPAL is affiliated with the Netherlands University, and it is one of the members of the Southeast Asian Laboratory (SEAL).

Soil properties analysed at the SPAL located at the NSSC, Bhutan are: i) pH ii) total carbon iii) organic matter (OM) iv) total nitrogen v) available phosphorus vi) exchangeable potassium vii) exchangeable calcium viii) cation exchange capacity ix) texture [adopted from (Bajgai & Sangchyoswat, 2018; Tashi & Wangchuk, 2016). The details of soil tests methods and laboratory are provided in Table 3.2:

**Table 3.2** Soil properties, soil tests methods, and laboratory for the soil testing.

| Sl.no | Soil property | Soil tests methods | Laboratory |
|---|---|---|---|
| 1 | Total % carbon and % organic matter | Walkley-Black method following low-temperature oxidation with acidified $K_2Cr_2O_7$ and titration of the excess dichromate. | Plant and Soil Analytical Laboratory, National Soil Service Centre (NSSC), Thimphu, Bhutan. |
| 2 | Total N (%) | Micro-Kjedahl | |
| 3 | Available P | Bray II methods | |
| 4 | Exchangeable K, Ca, Mg, Na and CEC | 1 M ammonium acetate extraction at pH 7 | |
| 5 | Soil pH | Distilled water-soil suspension of 1 M KCL (both 1:2.5) using a PHM 83 automatic pH meter | |
| 6 | Soil texture | Feel method | |
| 7 | Base saturation (BS) % | Calculation method | |

Source: Adopted from (Tashi & Wangchuk, 2016).

### 3.3 Assessment of the methodological quality (Reliability and Validity, Pre-test)

A questionnaire was subjected to (1) first review by advisor, (2) test for validity and reliability, and (3) pre-testing to determine the methodological quality of this study.

### 3.3.1 First review by an advisor

The theoretical framework and literature reviews were used to develop the questionnaire. The adviser had gone through the questionnaire and evaluated it to verify that all pertinent information was included.

### 3.3.2 Validity and reliability test

Content validity: The item objective congruence (IOC) analysis was used to check the content validity of the questionnaire items (Rovinelli & Hambleton, 1977). The item objective congruence (IOC) was also determined in their research by (Kalra & Thanavisuth, 2018; Poungsuk et al., 2018). To ascertain that each questionnaire item captures the desired objectives, a draft semi-structured questionnaire was provided for review and comments from three experts relevant to the research topic. Each questionnaire item will be given a value based on congruence (+1 if an item clearly measures the construct, -1 if the item does not measure the construct, and 0 if the item is not obvious).

The (Martuza, 1977) formula was used to determine the IOC based on the expert evaluations as indicated below. The index has a value between -1.00 and +1.00. Table 3.3 shows the IOC rating, interpretation, and decision as suggested by Rovinelli and Hambleton (1977): $I_{ik} = (M - 1) S_k - S'_k / 2N (M - 1)$

Where:

$I_{ik}$ = the item-objective congruence index for item i and objective k

M = number(s) of objectives

N = number(s) of content specialists

$S_k$ = sum of the ratings assigned to objective k

$S'_k$ = sum of the ratings assigned to all objectives, except objective k

**Table 3.3** Interpretation and decision of obtained item objective congruence (IOC) values

| IOC RATING | INTERPRETATION | DECISION |
|---|---|---|
| 0.50 | Acceptable | Item to be retained |
| Less than 0.5 | Not acceptable | The item should be reviewed or removed |

## 3.4 Data analysis methods

Descriptive statistics, cost and return analysis, and inferential statistics (Independent sample t-test/Pearson correlations/one-sample t-test) were used for the research data analysis. The followings provide usage of specific data analysis tools under each objective.

**For objective 1.** To investigate the farm and farmers' characteristics and production aspects of organic and conventional potato in West-Central Bhutan.

Descriptive statistics such as percentages, frequencies, arithmetic means, and standard deviations were used to analyse the socio-demographic characteristics like sex, age, education level, etc. Suwanmaneepong et al. (2020) used descriptive statistics on organic and conventional rice studies. Poungsuk et al. (2018) and Suanthaisong et al. (2016) used descriptive and inferential statistics in their studies on the facilitation of organic agricultural learning and factors affecting rice seed production, respectively.

**For objective 2.** To determine the differences in the productivity and profitability of organic and conventional potato production in West-Central Bhutan. Also, concisely determine the marketing aspects and constraints of organic potato farmers in the region.

The cost and return analysis were applied to determine the profitability parameters using Microsoft Excel. Inferential statistics (Independent Sample t-test and one-sample t-test) were used to determine any significant differences in the productivity and profitability parameters. Juyjaeng and Suwanmaneepong (2017) used an independent sample t-test to study oil palm production in Thailand. Suwanmaneepong et al. (2020) used the CRA to study organic and conventional rice. Likewise, (Adhikari, 2011; Tashi & Wangchuk, 2016) used a similar approach on organic and conventional rice studies.

The constraints of organic potato farmers in the region opined by farmers were recorded using the five-point Likert scale, which ranged from strongly disagree = 1 to strongly agree = 5 (Likert, 1932). The descriptive analysis of the five-point Likert scale was used to analyze the constraints experienced by organic potato producers in the region. The constraints were ranked based on their mean values. The ranges of mean values were interpreted as follows: 1.00–1.80, Strongly disagree; 1.81–2.60, Disagree; 2.61–3.40, Undecided; 3.41–4.20, Agree; and 4.21–5.00, Strongly agree (Best & Kahn, 1998). It was adapted from similar research on the barriers of transitioning to organic farming (Sharifi et al., 2010).

**For objective 3.** To determine the differences in the soil properties of soils due to organic and conventional potato production in West-Central Bhutan.

An Independent Sample t-test was employed to observe any significant differences in the soil properties. Before statistical analysis, normal distribution and variance homogeneity conditions were validated. All tests were carried out at a 5% level of significance (Best & Kahn, 1998; Kothari, 2004). The t-test, which is based on the t-distribution, is an appropriate test for determining the significance of a difference between the means of two samples when the population variance is unknown in the case of a small sample(s) (Kothari, 2004). The independent sample t-test is one of the most often used statistical tests to determine any significant differences between the two samples (Grove & Cipher, 2019). Juyjaeng and Suwanmaneepong (2017) employed the independent sample t-test as the data analysis technique in their studies on oil palm production.

Relationships between productivity and soil properties were determined through Pearson correlations. For example, the Pearson correlations were used to determine correlations between the soil properties in organic and conventional rice in Bhutan (Tashi & Wangchuk, 2016). The most common approach for assessing the degree of a link between two variables is Karl Pearson's coefficient of correlation, commonly known as simple correlation (Kothari, 2004).

Karl Pearson's coefficient of correlation (or r) = $\frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{n \cdot \sigma_x \cdot \sigma_x}$

Where:

$X_i$ = $i^{th}$ value of X variable.

$\bar{X}$ = mean of X

$Y_i$ = $i^{th}$ value of Y variable

$\bar{Y}$ = Mean of Y

n = Numbers of pairs of observations of X and Y

$\sigma_x$ = Standard deviation of X

$\sigma_Y$ = Standard deviation of Y

### 3.5 Hypothesis testing for productivity, profitability, and soil properties

#### 3.5.1 Productivity (tuber yield) hypothesis

1) Null hypothesis ($H_o$): $H_o$: $\mu org = \mu conv$ (No significant differences in the productivity of organic and conventional potato in West-Central Bhutan).

2) Alternate hypothesis ($H_a$): $H_a$: $\mu conv > \mu org$ (The productivity of conventional potato is significantly higher than organic potato in West-Central Bhutan).

#### 3.5.2 Profitability hypothesis

1) Null hypothesis ($H_o$): $H_o$: $\mu org = \mu conv$ (No significant differences in the profitability of organic and conventional potato in West-Central Bhutan).

2) Alternate hypothesis ($H_a$): $H_a$: $\mu org > \mu conv$ (The profitability of organic potato is significantly higher than conventional potato in West-Central Bhutan).

#### 3.5.3 Soil properties hypothesis

1) Null hypothesis ($H_o$): $H_o$: $\mu org = \mu conv$ (No significant differences in soil properties under organic and conventional potato in West-Central Bhutan).

2) Alternate hypothesis ($H_a$): $H_a$: $\mu org$ (NPK, Ca, Mg, SOM, CEC, BS%, pH) $\neq$ $\mu conv$ (NPK, Ca, Mg, SOM, CEC, BS%, pH), i.e., the mean (NPK, Ca, Mg, SOM, CEC, BS%, pH) content of organic potato is significantly different from conventional potato in West-Central Bhutan.

The hypothesis-testing above was carried out after the data were subjected to various tests based on the nature and purpose of the research inquiry and by selecting a suitable level of significance (e.g., $\alpha = 5\%$ and $p<0.05$) (Kothari, 2004).

This chapter describes different methodological tools used while conducting the study. Multistage and purposive samplings were employed for selecting the study's sample size in West-Central Bhutan. A systematic sampling method was used for selecting soil sampling sites. The data on farm and farmers' characteristics, productivity and profitability, and constraints were gathered using a pre-tested semi-structured questionnaire. Face-to-face interviews of the head or experienced farmer from each household were conducted.

The advisor first reviewed the draft questionnaire and afterward sent it to three experts for their feedback. The item objective congruence (IOC) was implemented to validate that each question in a questionnaire captured the intended objective. The soil samplings were gathered following the standard protocol developed by the National Soil Service Centre (NSSC), Bhutan. The farm and farmer's characteristics data were analysed using the descriptive analysis.

The cost and return analysis were done using Microsoft Excel. The independent sample t-test was utilised to compare the means of different parameters under these farming systems. At the same time, a one-sample t-test compared the productivities of organic and conventional potatoes with the national average. The constraints of organic potato farmers were analysed using the mean analysis of the Likert Scale.

# Chapter 4

# Results

The 4th chapter presents different results of data analysis carried out according to the mentioned methodologies of the study. It has 13 sections and provide results on the: 1st section (4.1) farm and farmers' characteristics, 2nd section (4.2) different cropping sequences in the study area, 3rd section (4.3) marketing channels of organic and conventional potatoes, 4th section (4.4) productivity and profitability analysis of organic potatoes, 5th section (4.5) productivity and profitability analysis of conventional potatoes, 6th section (4.6) Comparison of mean differences of productivity and profitability parameters of organic and conventional potatoes, 7th section (4.7) constraints encountered by organic potato farmers, 8th section (4.8) Different types and average quantities of chemical and organic fertilizers used in 2019 agricultural cycle, section 9th (4.9) Comparison of different soil properties under organic and conventional potato farming, section 10th (4.10) Correlations between various soil properties under organic and conventional potato farming, section 11th (4.11) Correlations between the soil properties and productivity, section 12th (4.12) Comparison of different soil properties under organic potato fields and nearby forest soil, section 13th (4.13) Comparison of different soil properties under conventional potato fields and nearby forest soil. A brief introduction and summary of the chapter are also provided.

### 4.1 Socio-demographic profile of farmers and farm characteristics

Farmers' socio-demographic profiles and other farm characteristics are provided in Table 4.1. Organic potato farmers had a higher female (70%) than the male population

(30%), whereas conventional potato farmers had a roughly similar male (48%) and female population (52%). The average age of organic farmers was more than that of conventional farmers, at 52 and 43 years, respectively. Illiterate farmers were the highest in both the farming systems, with 63% and 52% of the organic and conventional farmers, respectively. Illiteracy was relatively higher in organic than conventional farmers. Following 21% and 34% of organic and conventional farmers attended primary schooling, indicating that most farmers who went to school pursued until primary school level. Furthermore, the average family labour of organic farms was lower than that of conventional farmers, with two and three numbers, respectively. Organic farmers had a higher average year of farming experience (31 years) than conventional farmers (26 years); additionally, 90% of conventional farmers had more than ten years of experience, whereas 79% of organic farmers had the same. Organic farmers received twice as much technical training as conventional farmers, with two sessions each year.

Most organic farmers (83.7%) relied only on farming for a livelihood, whereas 40% of conventional farmers earned money through off-farm income. The conventional farmers planted the potato across a larger area than the organic farmers, with a mean cultivated area of 1.08 ha against 0.11 ha, respectively. Organic farmers cultivated potatoes at a maximum of 0.92 ha and a minimum of 0.02 ha, whereas conventional farmers cultivated at a maximum of 2.12 ha and a minimum of 0.20 ha. Interestingly, organic farmers owned larger farm sizes (average 1.17 ha), whereas conventional farmers owned smaller farm sizes (average 0.84 ha). Conventional farmers cultivated potatoes in a larger area by leasing more land for potato farming.

**Table 4.1** Socio-demographic profile of the potato farmers.

| Items | Organic farmers (n=43) | | | | | | Conventional farmers (n=50) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | Mean | S.D | Min | Max | n | % | Mean | S.D | Min | Max |
| **Gender** | | | | | | | | | | | | |
| Male | 13 | 30.23 | | | | | 24 | 48.00 | | | | |
| Female | 30 | 69.77 | | | | | 26 | 52.00 | | | | |
| **Age** | | | 52.35 | 13.90 | 26 | 84 | | | 42.82 | 10.86 | 23 | 70 |
| <40 years | 10 | 23.26 | | | | | 23 | 46.00 | | | | |
| 40-50 years | 10 | 23.26 | | | | | 16 | 32.00 | | | | |
| 51-60 years | 13 | 30.23 | | | | | 7 | 14.00 | | | | |
| >60 years | 10 | 23.26 | | | | | 4 | 8.00 | | | | |
| **Education level** | | | | | | | | | | | | |
| None | 27 | 62.79 | | | | | 26 | 52.00 | | | | |
| Non-formal education | 4 | 9.30 | | | | | 4 | 8.00 | | | | |
| Primary School | 9 | 20.93 | | | | | 17 | 34.00 | | | | |
| Middle School | 1 | 2.33 | | | | | 2 | 4.00 | | | | |
| Lower secondary | 2 | 4.65 | | | | | 0 | 0.00 | | | | |
| Upper secondary | 0 | 0.00 | | | | | 1 | 2.00 | | | | |
| **Marital status** | | | | | | | | | | | | |
| Single | 0 | 0.00 | | | | | 1 | 2.00 | | | | |
| Married | 38 | 88.37 | | | | | 46 | 92.00 | | | | |
| **Household members** | | | 4.49 | 2.43 | 1 | 12 | | | 5.84 | 2.48 | 2 | 12 |
| ≤ 3 | 18 | 41.86 | | | | | 10 | 20.00 | | | | |
| 4-5 | 13 | 30.23 | | | | | 16 | 32.00 | | | | |
| ≥6 | 12 | 27.91 | | | | | 24 | 48.00 | | | | |
| **Family labour (nos)** | | | 1.98 | 0.91 | 1 | 5 | | | 2.96 | 1.26 | 1 | 7 |
| 1-2 | 35 | 81.40 | | | | | 22 | 44.00 | | | | |
| 3-4 | 7 | 16.28 | | | | | 21 | 42.00 | | | | |
| ≥5 | 1 | 2.33 | | | | | 7 | 14.00 | | | | |
| **Experience in farming (years)** | | | 31.05 | 19.81 | 5 | 70 | | | 26.40 | 11.66 | 8 | 56 |
| 1-10 years | 9 | 20.93 | | | | | 5 | 10.00 | | | | |
| 11-20 years | 9 | 20.93 | | | | | 12 | 24.00 | | | | |
| >20 years | 25 | 58.14 | | | | | 33 | 66.00 | | | | |
| **Attend farmers' training (nos/year)** | | | 1.65 | 0.92 | 0 | 3 | | | 0.80 | 0.81 | 0 | 2 |
| No training | 6 | 13.95 | | | | | 22 | 44.00 | | | | |
| 1-2 times per year | 30 | 69.77 | | | | | 28 | 56.00 | | | | |
| 3 times per year | 7 | 16.28 | | | | | 0 | 0.00 | | | | |
| **Off-farm income** | | | | | | | | | | | | |
| None | 36 | 83.7 | | | | | 30 | 60 | | | | |
| Yes | 7 | 16.3 | | | | | 20 | 40 | | | | |
| **Farm size (ha)** | | | 1.17 | 1.07 | 0.13 | 6.88 | | | 0.84 | 0.47 | 0.20 | 2.02 |
| **Potato cultivated area in 2019 (ha)** | | | 0.11 | 0.14 | 0.02 | 0.92 | | | 1.08 | 0.49 | 0.20 | 2.12 |

n=frequency, nos=numbers.

## 4.2 Cropping sequences in study areas

Table 4.2 depicts the yearly sequences of various crops planted on the same land in the research sites. Organic and conventional potato farmers' cropping sequences were equivalent, with the exception of some conventional farmers growing mustard following potato harvest. It was adapted from a similar potato production study (Bajracharya & Sapkota, 2017). Different cropping sequences/patterns implemented by the organic and conventional farmers were studied to verify that they cultivated potato as a primary crop and that other cultivated crops are comparable.

Due to shorter crop-growing seasons followed by freezing periods in both studied areas, farmers grew a maximum of two crops per year. At the beginning of the growing season, they cultivated potato, their primary cash crop, followed by sweet or bitter buckwheat or turnip. Sweet or bitter buckwheat was consumed as food or used in religious rituals, whereas turnips were fed to livestock. Organic farmers also grew garlic, a vital cash crop after potatoes. In both studied areas, farmers did not cultivate green manure crops or other leguminous crops to enhance soil fertility, especially in organic fields.

**Table 4.2** Cropping sequences in study areas

| | **Gasa (Goenkhatoe *Gewog*)** | **Wangdue phodrang (Phobjikha *Gewog*)** |
|---|---|---|
| 1. | Potato - Sweet or bitter buckwheat | Potato - Sweet or bitter buckwheat |
| 2. | Potato - Turnip | Potato - Turnip |
| 3. | Potato - Garlic | Potato - Mustard |

### 4.3 Marketing channels of organic and conventional potatoes

A distribution or marketing channel is a group of interdependent agencies involved in making a product or service available to be used or consumed (Gasc¢-Hernandez & Torres-Coronas, 2009; Verma, 2011). The organic potato farmers sell their potatoes directly from their farm or cold storage facility through four channels: 1) Local market, Gasa: sold in a local market in the Gasa district to the local community and civil servants by 21% of the farmers. 2) Capital city, Thimphu: around 7% of the farmers sell their organic potatoes directly to the capital city. 3) District Agriculture Sector, Gasa: Sometimes, their potatoes are collected by the District Agriculture Sector, Gasa, and then the sector sells them in the capital city, Thimphu. It is sold as a retail or wholesale in the restaurants/resorts in the capital city. The sector also sells it in other districts like Punakha and high-end resorts. Around 72% of the farmers supply to the District Agriculture Sector OR 4) Middle person/vendor: the organic farmers also sell directly to a middle person/vendor who comes to Gasa. The middle person sells it in the capital city. Similarly, around 72% of the farmers sell to the middle person/vendor when the District Agriculture Sector does not collect the organic potatoes.

The marketing channel of organic potato is given in Figure 4.1. The blue arrow indicates the supply of organic potatoes from farmers/producer to distributors/buyers/consumers; similarly, the green arrow shows the supply from the District Agriculture Sector, Gasa to consumers, and the red arrow from the middle person/vendor to consumers.

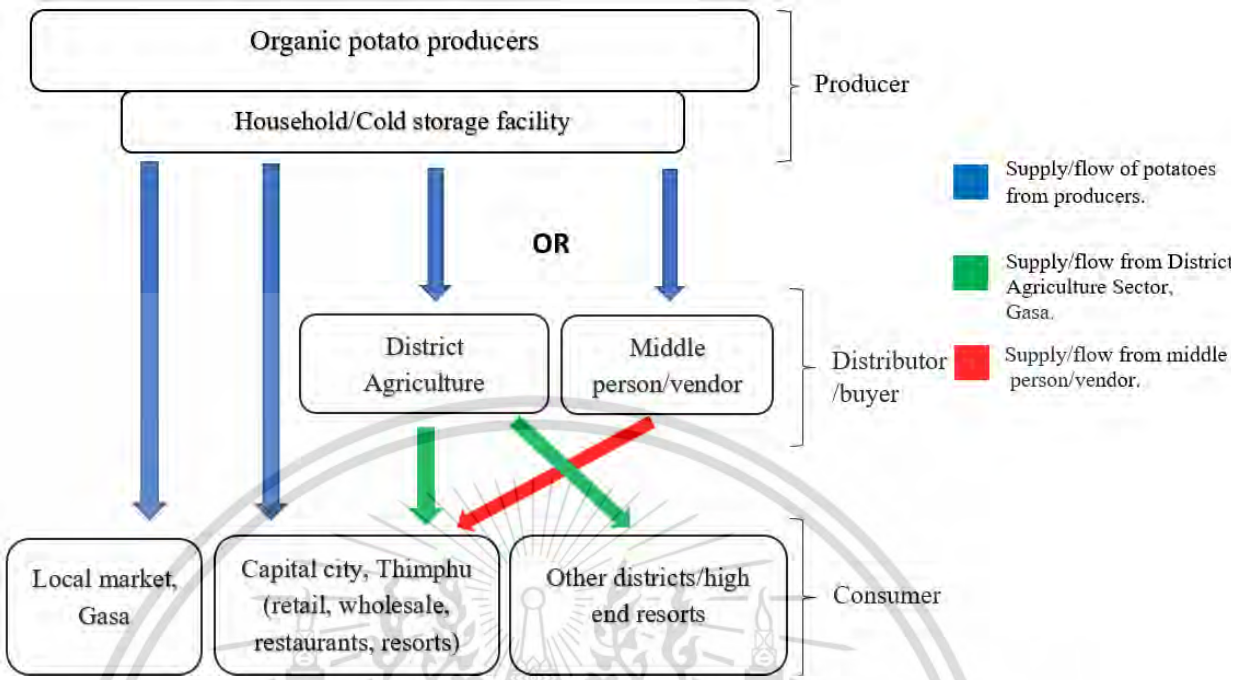


**Figure 4.1** Marketing channel of organic potato production.

Organic potato farmers in Goenkhatoe *Gewog*, Gasa district belonging to *Rangshin Sanam Detchen* are facilitated by Gasa's district Agriculture Sector for marketing their organic potatoes. In 2017 and 2018, the District Agriculture Sector bought organic potatoes from the group and distributed them to high-end hotels in the country. In 2020, the District Agriculture Sector purchased and distributed the organic potatoes in the neighbouring district of Punakha. However, in 2019, the organic potato was directly bought by Bhutan Smart Shop, a vegetable vendor enterprise based in the capital and distributed in the capital city of the country (Table 4.3). Organic potato farmers perse do not encounter market problems to sell their produce but certainly have issues getting premium price.

**Table 4.3** Marketing of organic potato (2017-2020)

| Year | Market | Facilitator/Distributor/Buyer |
|---|---|---|
| 2017 and 2018 | High-End Hotel | District Agriculture Sector, Gasa (bought and distributed) |
| 2019 | Thimphu | Bhutan Smart Shop (directly bought from the farmers) |
| 2020 | Punakha district | District Agriculture Sector, Gasa (bought and distributed) |

Conventional potato farmers (almost 100% farmers) sell their potatoes mainly through one channel, through the Food Corporation of Bhutan (FCB). The farmers either take their potatoes to the FCB, Phuntsholing, Bhutan, or the FCB purchases from their place. It is then exported to India, Bangladesh, and Nepal by the FCB and sold in domestic markets such as the capital city, Thimphu. Figure 4.2 shows the marketing channel of conventional potatoes. The concept of marketing channel, as discussed here, was adopted from (Laibuni & Omiti, 2014). The blue arrow indicates the supply of organic potatoes from farmers/producer to the Food Cooperation of Bhutan (FCB), Phuntsholing; similarly, the green arrow shows the supply from the FCB to export markets and consumers.

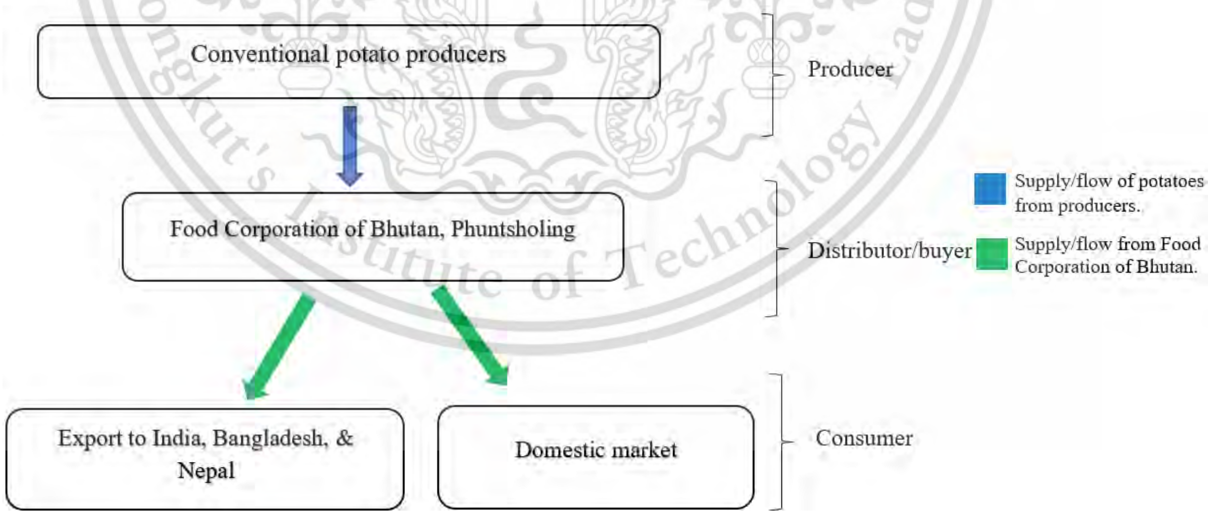


**Figure 4.2** Marketing channel of conventional potato production.

Potato planting, harvesting, and marketing calendar for the farmers at Goenkhatoe *Gewog*, Gasa district, and Phobjikha *Gewog* under Wangdue Phodrang district are comparable and fall under the same season. The details are given in Figure 4.3 below.

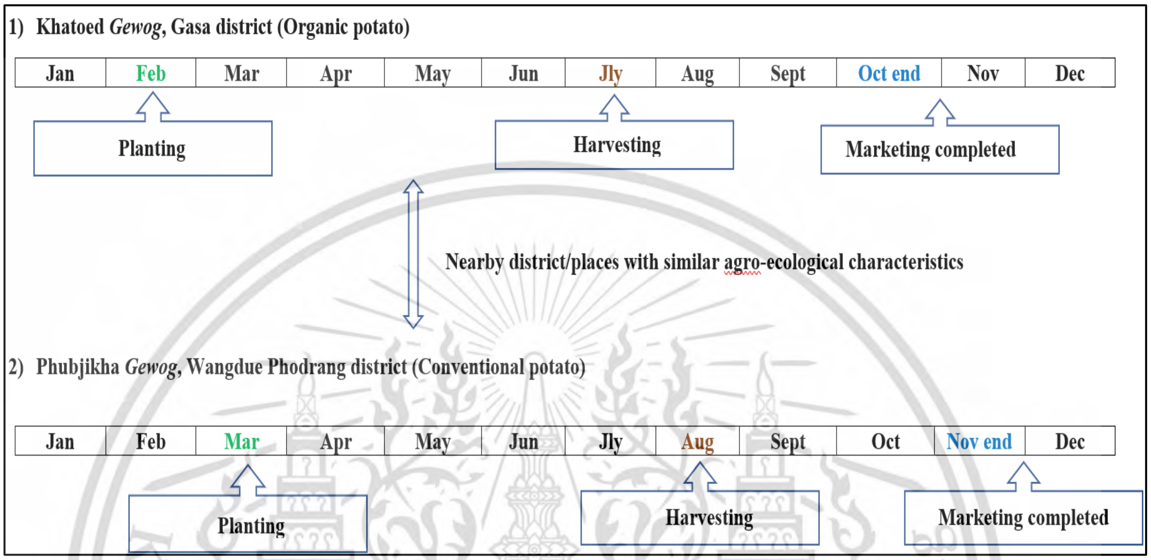


**Figure 4.3** Potato planting and harvesting calendar (including marketing month) at the research sites.

**4.4 Productivity and profitability analysis of organic potato production.**

Table 4.4 contains the results of the productivity and profitability study using the cost and return analysis (CRA). The average productivity of organic potatoes was 7.48 MT/ha; the maximum and minimum were 12.67 and 2.72 MT/ha, respectively, the standard deviation (*S.D*) was 2.81 for a total of 43 farmers. The total cost of producing organic potatoes was 340,771.17 Nu/ha, where the total variable cost accounted for 99.63%, while the total fixed cost incurred 0.75% of the total production cost. The total cash cost was 135,671.90 Nu/ha, while the total non-cash cost was 203,790.90 Nu/ha. The government gave input assistance in seeds and bio-pesticides worth an average of 1,308.37 Nu/ha. As a result, the actual cost of organic potato production to a farmer who received this input support was 339,462.80 Nu/ha. The labour cost was higher than the input cost under variable costs. The total input cost contributed about 41.96% of the total production cost. The highest input cost was incurred on acquiring potato seeds, accounting for 18.43%. In contrast, the lowest input cost was incurred on the usage of bio-pesticides, accounting for just 0.04% of the total production cost. The total labour cost contributed the most (57.67%) to the total production cost. The highest labour cost was spent in weeding and earthing up operations, accounting for 25.53% of the total production cost, while the lowest was incurred in applying biopesticides, accounting for barely 0.02% of the total production cost. Under fixed costs, depreciation contributed the most, accounting for 0.74% of the total production costs.

Farmers received an average farm-gate price of 18.29 Nu/kg, making a gross margin (GM) or profit of -202,708.47 Nu/ha. The gross margins over cash and variable costs were 1,082.43 Nu/ha and -201,457.56 Nu/ha, respectively. The break-even productivity and prices were 18.63 MT/ha and 45.58 Nu/kg, respectively, with a benefit-cost (B:C) ratio of 0.40 and a return on investment (ROI) of -59.71%. The seed rate used by organic potato farmers was 2.39 t/ha or 967 kg/ac.

**Table 4.4** Cost and return analysis of organic potato production.

| Item | Quantity | Cash (Nu) | Non-cash (Nu) | Total (Nu) | % |
|---|---|---|---|---|---|
| A) Variable costs (VCs) (Nu/ha) | | | | | |
| 1) Input cost | | | | | |
| i) Seed | 2.39 t | 9,321.90 | 53,243.60 | 62,565.50 | 18.43 |
| ii) Farmyard manure (FYM) and other organic fertilisers | 41.34 t | 1,550.39 | 56,792.70 | 58,343.09 | 17.19 |
| iii) Bio-pesticides | 0.002 Litre | 0 | 145.38 | 145.38 | 0.04 |
| iv) Fuel and rental | | 21,374.03 | 0 | 21,374.03 | 6.30 |
| **Total input cost** (Nu/ha) | | **32,246.32** | **110,181.68** | **142,427.99** | **41.96** |
| 2) Labour cost (man-days/ha) | | | | | |
| i) Land preparation | 133.42 | 8,681.41 | 14,998.68 | 23,680.09 | 6.98 |
| ii) Compost/FYM application | 46.89 | 6,570.37 | 6,801.57 | 13,371.94 | 3.94 |
| iii) Planting | 84.41 | 13,814.76 | 8,338.41 | 22,153.17 | 6.53 |
| iv) Weeding and earthing up | 297.17 | 43,861.92 | 42,793.78 | 86,655.70 | 25.53 |
| v) Bio-pesticides application | 1.01 | 0 | 83.73 | 83.73 | 0.02 |
| vi) Harvesting/curing | 196.93 | 30,466.60 | 19,372.67 | 49,839.27 | 14.68 |
| **Total labour cost** (Nu/ha) | | **103,395.05** | **92,388.84** | **195,783.89** | **57.67** |
| **Total variable cost (TVC)** (Nu/ha) | | **135,641.37** | **202,570.52** | **338,211.89** | **99.63** |
| B) Fixed Costs (FCs) (Nu/ha) | | | | | |
| 1) Land tax | | 30.53 | 0 | 30.53 | 0.01 |
| 2) Land rent | | 0 | 0 | 0 | 0.00 |
| 3) Depreciation cost | | 0 | 2,528.75 | 2,528.75 | 0.74 |
| **Total fixed cost (TFC)** (Nu/ha) | | **30.53** | **2,528.75** | **2,559.28** | **0.75** |
| **Total cost (TC) = (TVC + TFC)** (Nu/ha) | | **135,671.90** | **205,099.27** | **340,771.17** | |
| **Total cost with deductions of an average govt. support on seeds and bio-pesticides worth 1,308.37 Nu/ha** | | **135,671.90** | **203,790.90** | **339,462.80** | |
| Gross return (GR) (Nu/ha) (Q x P) | | | | 136,754.33 | |
| Productivity (kg/ha) (Q) | | | | 7,477 | |
| Farmgate price (Nu/kg) (P) | | | | 18.29 | |
| Gross margin (GM) (profit) (Nu/ha) (GR-TC) | | | | -202,708.47 | |
| Break-even productivity (kg/ha) | | | | 18,631.56 | |
| Break-even price (Nu/kg) | | | | 45.58 | |
| Benefit-cost ratio (B:C ratio) (GR/TC) | | | | 0.40 | |
| Return on investment (GM/TC x 100) (%) | | | | -59.71 | |
| Gross margin over cash cost (Nu/ha) (GR-Total cash cost) | | | | 1,082.43 | |
| Gross margin over variable cost (Nu/ha) (GR-TVC) | | | | -201,457.56 | |

Nu=Ngultrum (Bhutanese currency); 1 Nu= 0.014 USD

## 4.5 Productivity and profitability analysis of conventional potato production.

Table 4.5 shows the results of the CRA's productivity and profitability study. The average conventional potato productivity was 19.22 MT/ha, the maximum and minimum were 26.52 and 7.54 MT/ha, respectively, and *S.D* was 5.21 for a total of 50 growers. The total production cost of conventional potato was 309,012.30 Nu/ha, where the total variable and fixed costs accounted for 94.04% and 5.96%, respectively. The total cash cost per hectare was 108,133.20 Nu, whereas the total non-cash cost was 200,879.10 Nu. The total input cost equated to 60.10% of the total production cost. The cost of purchasing seeds was the highest input cost, accounting for 29.03% of the total production cost, while buying pesticides was the lowest, accounting for 0.01%. The total labour cost accounted for 33.94% of the total production cost. The largest labour cost was on harvesting/curing, accounting for 22.07%, while the lowest labour cost was on pesticide application, accounting for just 0.37% of the total production cost. The largest expense among the fixed costs was depreciation cost, which accounted for 3.79% of the total cost of production. Many conventional farmers rented land, accounting for 2.17% of the total production cost.

The average farm-gate price for conventional potato farmers was 20.44 Nu/kg, with a gross margin or profit of 83,832.85 Nu/ha. The gross margin over cash and variable costs was 284,711.95 and 102,253.36 Nu/ha, respectively. Its break-even productivity and prices were 15.12 t/ha and 16.08 Nu/kg, respectively, with a benefit-cost ratio (B:C ratio) of 1.27 and a return on investment (ROI) of 27.13%. Figure 4.4 shows the variable and fixed cost% of the total cost of production for both the farming systems. The conventional potato farmers used a seed rate of 3.06 t/ha or 1,239 kg/ac.

**Table 4.5** Cost and return analysis of conventional potato production.

| Item | Quantity | Cash (Nu) | Non-cash (Nu) | Total (Nu) | % |
|---|---|---|---|---|---|
| A) Variable costs (VCs) (Nu/ha) | | | | | |
| 1) Input cost | | | | | |
| i) Seed | 3.06 t | 2,198.25 | 87,522.03 | 89,720.28 | 29.03 |
| ii) Chemical fertilisers | 0.97 t | 32,458.18 | 0 | 32,458.18 | 10.50 |
| iii) Agro-chemicals | | | | | |
| a) Insecticide | 0.07 liter | 20.4 | 0 | 20.4 | 0.01 |
| b) Fungicide | 0.004 t | 1,050.75 | 0 | 1,050.75 | 0.34 |
| c) Herbicide | 0.0073 t | 5,785.26 | 0 | 5,785.26 | 1.87 |
| d) Sticker | 0.10 liter | 24.39 | 0 | 24.39 | 0.01 |
| iv) Farmyard manure (FYM) and other organic fertilisers | 16.08 t | 1,759.98 | 43,873.20 | 45,633.18 | 14.77 |
| v) Fuel and rental | | 11,024.77 | 0 | 11,024.77 | 3.57 |
| **Total input cost** (Nu/ha) | | **54,321.98** | **131,395.23** | **185,717.22** | **60.10** |
| 2) Labour cost (man-days/ha) | | | | | |
| i) Land preparation | 10.21 | 956.68 | 1,655.03 | 2,611.71 | 0.85 |
| ii) Compost/FYM application | 20.27 | 3,879.78 | 3,760.38 | 7,640.16 | 2.47 |
| iii) Planting/fertilizing | 42.35 | 8,106.79 | 7,893.78 | 16,000.57 | 5.18 |
| iv) Weeding and earthing up | 28.62 | 3,492.76 | 5,790.46 | 9,283.22 | 3.00 |
| v) Pesticide application | 5.15 | 575.78 | 569.74 | 1,145.52 | 0.37 |
| vi) Harvesting/curing | 195.70 | 30,075.72 | 38,117.67 | 68,193.40 | 22.07 |
| **Total labour cost** | | **47,087.52** | **57,787.05** | **104,874.58** | **33.94** |
| **Total variable cost (TVC)** (Nu/ha) | | **101,409.51** | **189,182.28** | **290,591.79** | **94.04** |
| B) Fixed Costs (FCs) (Nu/ha) | | | | | |
| 1) Land tax | | 21.11 | 0 | 21.11 | 0.01 |
| 2) Land rent | | 6,702.58 | 0 | 6,702.58 | 2.17 |
| 3) Depreciation cost | | 0 | 11,696.82 | 11,696.82 | 3.79 |
| **Total fixed cost (TFC)** (Nu/ha) | | **6,723.69** | **11,696.82** | **18,420.51** | **5.96** |
| **Total cost (TC) = (TVC + TFC)** (Nu/ha) | | **108,133.20** | **200,879.10** | **309,012.30** | |
| Gross return (GR) (Nu/ha) (Q x P) | | | | 392,845.15 | |
| Productivity (kg/ha) (Q) | | | | 19,220.00 | |
| Farm-gate price (Nu/kg) (P) | | | | 20.44 | |
| Gross margin (GM) (profit) (Nu/ha) (GR-TC) | | | | 83,832.85 | |
| Break-even productivity (yield)(kg/ha) | | | | 15,118.47 | |
| Break-even price (Nu/kg) | | | | 16.08 | |
| Benefit-cost ratio (B:C ratio) (GR/TC) | | | | 1.27 | |
| Return on investment (GM/TC x 100) (%) | | | | 27.13 | |
| Gross margin over cash cost (Nu/ha) (GR-Total cash cost) | | | | 284,711.95 | |
| Gross margin over variable cost (Nu/ha) (GR-TVC) | | | | 102,253.36 | |

Nu = Ngultrum (Bhutanese currency); 1 Nu= 0.014 USD

The following Figure depicts the variable and fixed cost % with respect to the total production cost of organic and conventional potato farming. The variable cost has been represented by the total input%, total labour% and total variable costs% of total cost of production. Conventional potato production has a higher input cost (60.1%) than organic production (41.8%). In contrast, organic potato production has a higher labour cost (57.45%) than conventional production (33.94%). Fixed costs are the least cost in both the farming systems, comprising 5.96% in the conventional production, which is higher than the organic production with 0.75%.

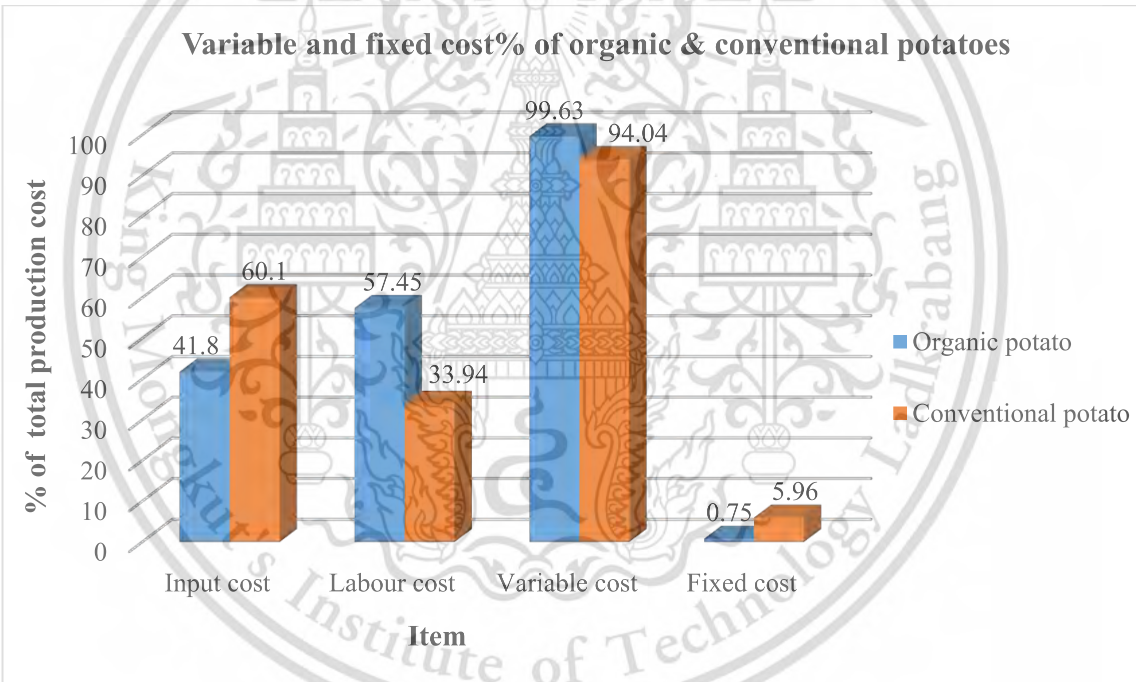


**Figure 4.4** Graphical representation for variable and fixed costs% of total production cost.

### 4.6 Comparison of productivity and profitability (mean difference)

Table 4.6 contains detailed results, including the p-value and significance level of mean differences. The independent sample t-tests revealed that the conventional potato had significantly higher productivity and profitability parameters values than the organic potato at $p<0.01$. Furthermore, the BCR in conventional potato farming was significantly greater than in organic farming. Figures 4.5, 4.6, and 4.7 further illustrates these findings graphically on productivity, profitability, and B:C ratio, respectively.

In terms of input costs, conventional potato production had significantly higher costs for seed, fertilizer and manure, pesticide/bio-pesticide, and total input cost than organic potato production. However, the cost of fuel and farm machinery rental was significantly higher in organic potato production. In addition, organic potato production had significantly higher labour costs in land preparation, compost/FYM application, weeding and earthing up, and total labour cost than conventional potato production. The labour cost for pesticide/bio-pesticide application, on the other hand, was significantly higher in conventional potato production.

In both farming systems, there were no significant differences in labour costs for planting and harvesting/curing operations. The total cost of production showed no significant differences in both farming systems. Further, the conventional potato farmers cultivated potatoes in significantly larger areas than the organic farmers.

**Table 4.6** Independent sample t-test results on productivity and profitability (N=93)

| Item | Organic | | Conventional | | d.f | t-test | *p*-value |
|---|---|---|---|---|---|---|---|
| | Mean | *S.D* | Mean | *S.D* | | | |
| **Productivity** (t/ha) | 7.48 | 2.81 | 19.22 | 5.21 | 77.40 | -13.767 | 0.000** |
| **Profit** (Nu/ha) | -202,708.47 | 227,746.91 | 86,031.02 | 102,760.39 | 56.51 | -7.669 | 0.000** |
| **Benefit Cost Ratio (BCR)** | 0.52 | 0.26 | 1.39 | 0.40 | 84.29 | 12.640 | 0.000** |
| **Input cost** (Nu/ha) | | | | | | | |
| Seed | 62,565.49 | 6,110.76 | 89,720.28 | 30,679.14 | 53.49 | 6.119 | 0.000** |
| Fertiliser/manure | 58,169.07 | 46,285.63 | 78,091.37 | 37,920.13 | 91 | -2.281 | 0.025* |
| Pesticide/bio-pesticide | 145.39 | 532.13 | 6,880.79 | 3,496.96 | 51.63 | -13.440 | 0.000** |
| Fuel and rental | 21,374.03 | 23,197.42 | 11,024.78 | 940.23 | 42.12 | 2.923 | 0.006** |
| Total input cost | 120,879.95 | 46,280.25 | 174,692.45 | 55,326.09 | 91 | -5.039 | 0.000** |
| **Labour cost** (Nu/ha) | | | | | | | |
| Land preparation | 23,680.09 | 26,293.12 | 2,611.71 | 2,688.77 | 42.76 | 5.231 | 0.000** |
| Compost/FYM application | 13,371.94 | 12,625.86 | 7,640.17 | 10,535.98 | 91 | 2.387 | 0.019* |
| Planting and fertilizing | 22,153.17 | 17,232.97 | 16,000.57 | 21,715.24 | 91 | 1.496 | 0.138 (ns) |
| Weeding and earthing up | 86,655.70 | 154,622.49 | 9,283.22 | 11,220.24 | 42.38 | 3.274 | 0.002** |
| Pesticide/bio-pesticide application | 83.73 | 348.05 | 1,145.52 | 2,096.31 | 52.13 | -3.525 | 0.001** |
| Harvesting/curing | 49,839.27 | 67,493.48 | 68,193.39 | 48,065.85 | 91 | -1.526 | 0.131 (ns) |
| Total labour cost | 146,141.55 | 167,061.46 | 89,428.34 | 69,706.95 | 54.47 | 2.076 | 0.043* |
| **Total production cost** (Nu/ha) | 339,462.79 | 227,746.91 | 306,814.13 | 102,760.39 | 56.51 | 0.867 | 0.390 (ns) |
| Potato area in 2019 (ha) | 0.11 | 0.14 | 1.08 | 0.49 | 57.69 | -13.365 | 0.000** |

N=sample size; organic farmers ($n_1$) =43; conventional farmers ($n_2$) = 50; *$p$<0.05; **$p$<0.01, ns (non-significant)

Organic potato productivity was likewise significantly lower than the national average (10.40 MT/ha), but conventional potato productivity was significantly higher both at $p<0.01$. It was compared statistically using one-sample t-tests; the t-test value between organic potato and the national average was -6.818 with d.f of 42; the t-test value between conventional potato and the national average was 11.961, with d.f of 49. The following figure shows the mean productivities (tuber yield) of organic and conventional potato farming. The error bars with a 95% confidence interval (CI) are depicted in the farming system's crop productivity. The potato productivity of conventional farming (19.22 MT/ha) is significantly higher than organic farming (7.48 MT/ha) at $p<0.01$, indicated by *** in the figure.

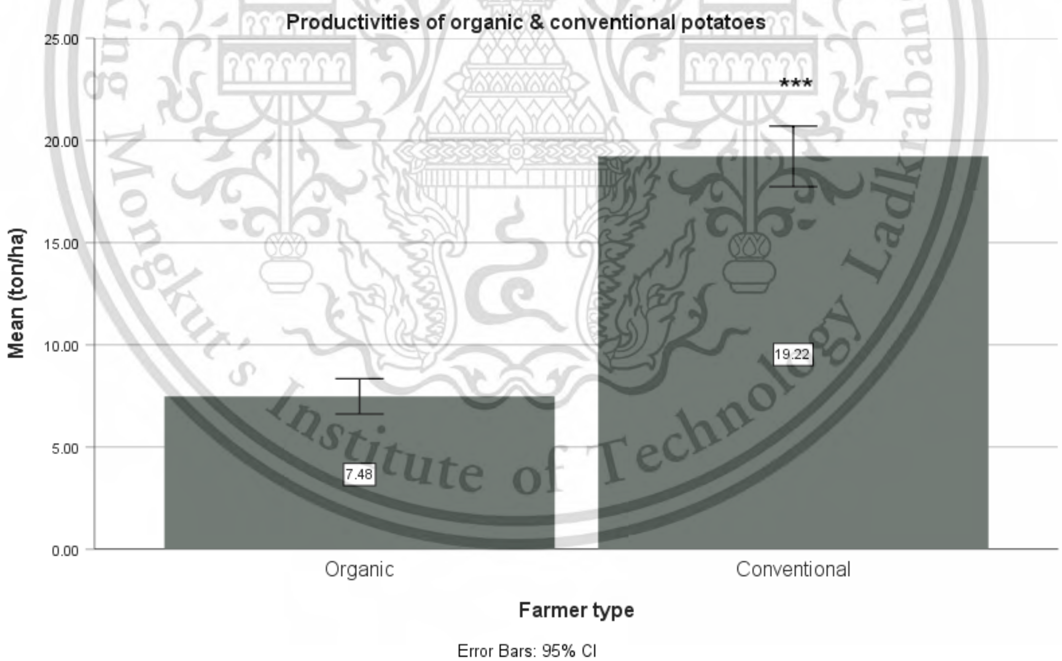


**Figure 4.5** Graphical representation of mean productivities (tuber yields).

The mean profits (Nu/ha) generated by organic and conventional potato farming are shown in the following figure. Error bars with a 95% confidence interval (CI) are shown for each profit for the respective farming system. The profit of conventional potato farming (86,031.02 Nu/ha) was significantly higher than organic farming (-202,708.47 Nu/ha) at p<0.01, shown by ***.

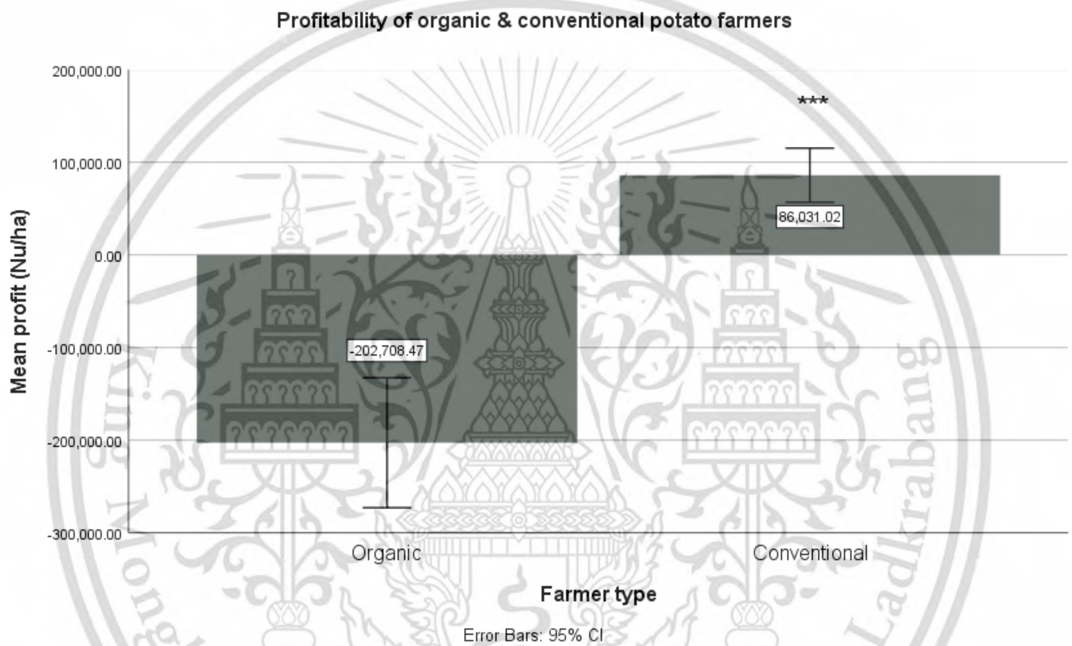


**Figure 4.6** Graphical representation of mean profit (gross margin).

The next figure depicts the Benefit-cost (B:C) ratios for organic and conventional potato farming. The error bars with a 95% confidence interval (CI) are displayed for each B:C ratio under the respective farming system. The B:C ratio of conventional potato farming (1.40) was significantly higher than that of organic farming (0.52) at p<0.01.

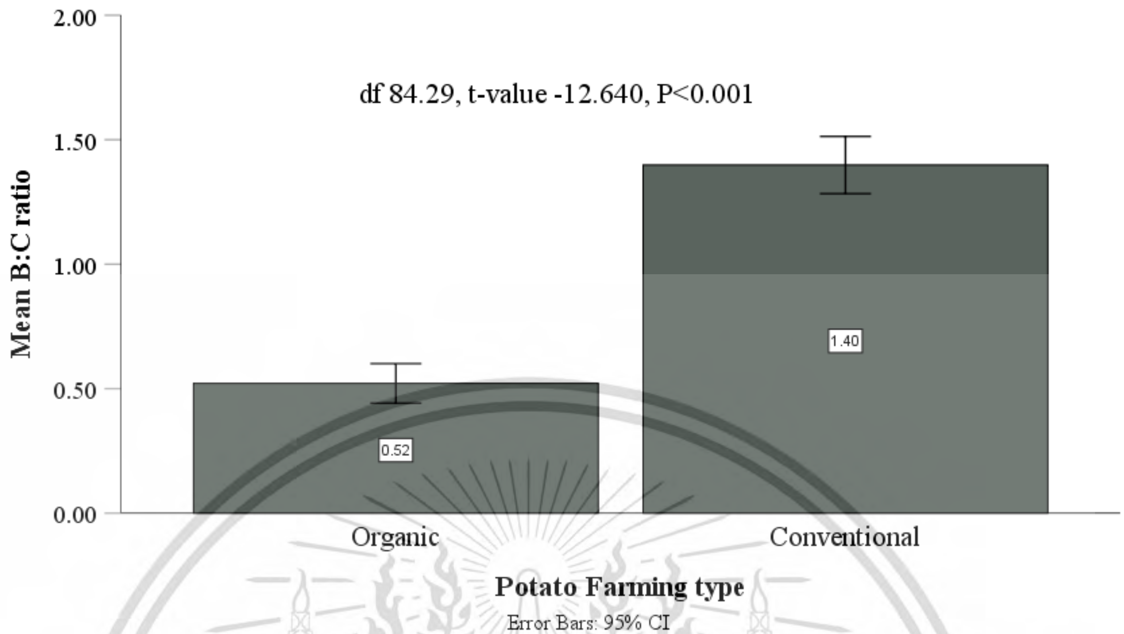


**Figure 4.7** Graphical representation on mean B:C ratios.

## 4.7 Constraints encountered by organic potato farmers

Table 4.7 depicts the constraints faced by organic potato farmers. According to the mean analysis, the first four constraints are significant: no price premium for organic produce, pest and disease issues, low crop productivity, and climate change impacts production. Other undecided constraints were a shortage of agricultural labour and an insufficient supply of bio-pesticides.

**Table 4.7** Constraints faced by organic potato farmers (N=43)

| Constraint | Mean | S.D | Interpretation |
|---|---|---|---|
| 1. No premium price for organic potato | 4.84 | 0.5 | Strongly agree |
| 2. Pest and disease problems | 4.02 | 1.2 | Agree |
| 3. Low potato productivity | 4.00 | 0.5 | Agree |
| 4. Climate change affects the production | 3.69 | 0.6 | Agree |
| 5. Labour unavailability | 3.14 | 1.2 | Undecided |
| 6. Bio-pesticide supply is inadequate | 2.65 | 0.6 | Undecided |
| 7. Bio-pesticides are not accessible on time | 2.50 | 0.9 | Disagree |
| 8. Imported potato competes with local | 2.09 | 0.6 | Disagree |
| 9. Organic fertiliser supply is inadequate | 2.02 | 0.6 | Disagree |
| 10. Inadequate knowledge of potato production | 2.02 | 0.3 | Disagree |
| 11. Damage of potato by wild animals | 1.77 | 1.2 | Strongly disagree |
| 12. Fertilisers are not accessible on time | 1.51 | 0.6 | Strongly disagree |
| 13. Seed supply is inadequate | 1.49 | 0.6 | Strongly disagree |
| 14. Seeds are not accessible on time | 1.39 | 0.5 | Strongly disagree |
| 15. Unavailability of farm machinery for hire | 1.07 | 0.3 | Strongly disagree |
| 16. Irrigation problem | 1.00 | 0.0 | Strongly disagree |

Means computed from five-point Likert scale (strongly disagree = 1 to strongly agree = 5 (Likert, 1932).

## 4.8 Different types and average quantity of chemical and organic fertilizers used in the 2019 agricultural cycle

In 2019, organic potato farmers applied around 41 MT/ha of FYM and other organic amendments, delivering approximately 450 kgs/ha of N, 225 kgs/ha of P, and 815 kgs/ha of K. It also added around 461 kg/ha of calcium, and 157 kg/ha of magnesium. In the same year, conventional potato farmers used around 16 MT/ha FYM and other organic amendments, 4 kg/ha urea (0:46:0), 740 kg/ha Suphala (15:15:15), and 230 kg/ha single super phosphate (SSP) (0:16:0). Consequently, it provided approximately 288 kg/ha of N, 235 kg/ha of P, and 428 kg/ha of K. It also added around 224 kg/ha of calcium, and 61 kg/ha of magnesium, and 26.5 kg of sulphur (Table 4.8 and Figure 4.8). The NPK content of FYM and organic fertilizers were calculated using (Chettri et al., 2003); according to the researchers, the FYM produced in Bhutan using a heap-storage technique has a dry matter content of roughly 68%, with dry matter nutrient values of 1.6% N, 0.8% P, and 2.9% K. Ca and S are estimated to be provided as supplemental nutrients while applying a macronutrient (P) in an SSP fertilizer that also includes 19.5% Ca and 11.5% S (IPNI, 2021). Additionally, the calcium content of 16.4 g/kg dry weight of FYM and similarly magnesium content of 5.6g/kg added through the application of FYM and other organic amendments were referred from (Subedi & Ma, 2009).

**Table 4.8** Different types and average quantities of fertilizers (chemical and organic fertilizers) used in potato production in 2019.

| Farming type in potato | Organic amendments (MT/ha) | Chemical fertilizers (kg/ha) | | |
|---|---|---|---|---|
| | FYM and others | Urea (0:46:0) | Suphala (15:15:15) | Single Super Phosphate (0:16:0) |
| Organic | 41.34 | - | - | - |
| Conventional | 16.08 | 4 | 740 | 230 |

Adapted from (Chettri et al., 2003) and (Subedi & Ma, 2009).

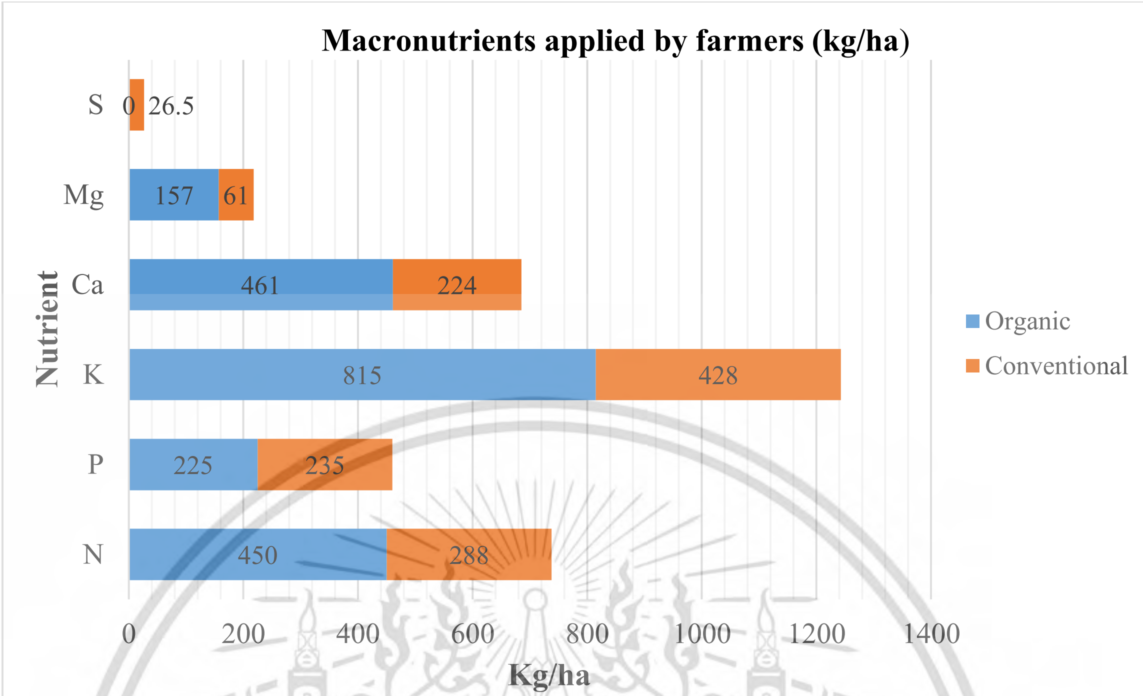


**Figure 4.8** Important macronutrients applied by potato farmers (kg/ha)

**4.9 Comparison of different soil properties of soils under organic and conventional potato farming**

Soil texture denotes relative proportions of sand, silt, and clay in the soil, and textural categories such as sandy loam, silty clay, and clay loam are used to describe the texture (Paul, 2014). The soil textures of both organic and conventional potato farms were loam and silty clay loam. According to the laboratory analysis, the organic field's soils were 73.3% loam and 26.7% silty clay loam. In conventional fields, silty clay loam made about 60% of the soil texture, while loam was 40% (Figure 4.9).

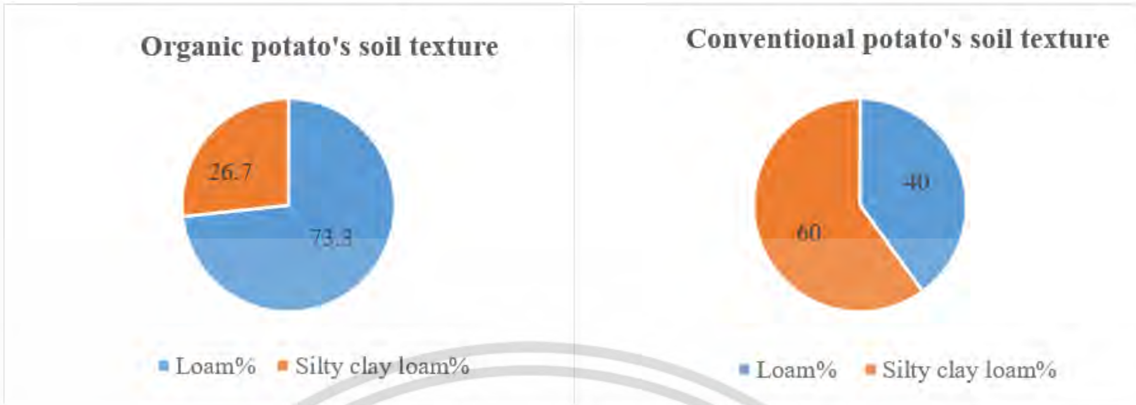


**Figure 4.9** Soil texture of organic and conventional potato field's soil

The pH ($H_2O$) of conventional soils (4.99) was significantly lower than that of organic soils (5.57) at $p<0.01$. In compliance with Botta (2015), the mean pH of conventional soil can be classified as strong acidity, while it is medium acidity for organic soil. At $p<0.05$, the available (Av.) P in conventional soils was significantly higher (8.87 mg/kg) than in organic soils (4.87 mg/kg). Organic matter (OM) content (%) did not differ significantly between organic and conventional soils. At $p<0.01$, total N% was significantly higher in organic soils (0.38%) than in conventional soils (0.26%). At $p<0.01$, the carbon: nitrogen (C: N) ratio in organic soils was significantly lower (9.99) than in conventional soils (11.52). Av. K did not significantly differ much across the two farming systems. The average Av. K for organic and conventional soils was 183.02 mg/kg and 143.47 mg/kg, respectively. Additionally, there were no significant differences in exchangeable (Ex.) K observed between the two farming systems.

Exchangeable calcium and magnesium (me/100g) were significantly high in the organic soils (5.73 and 0.87, respectively) than the conventional soils (2.69 and 0.51, respectively), both at $p<0.05$. The cation exchange capacity (CEC) (me/100g) and the base saturation (BS)% were significantly higher in the organic soils (22.26 and 31.15) than the conventional soils (19.45 and 19.96), both at $p<0.05$ (Table 4.9).

**Table 4.9** Comparison of means of different soil properties (independent sample t-test, N=30).

| Item | Mean | | d.f | t-test | p-value |
|---|---|---|---|---|---|
| | Organic | Conventional | | | |
| pH ($H_2O$) | 5.57 (M) | 4.99 (L) | 28 | 4.41 | 0.000** |
| Av. P (mg/kg) | 4.87 (vL) | 8.87 (L) | 28 | -2.392 | 0.024* |
| OM (%) | 5.87 | 5.10 | 28 | 1.700 | 0.100 (ns) |
| C% | 3.45 (H) | 3.00 (M) | 28 | 1.700 | 0.100 (ns) |
| Total N (%) | 0.38 (M) | 0.26 (M) | 28 | 3.848 | 0.001** |
| C:N ratio | 9.99 (vL) | 11.52 (L) | 28 | -3.304 | 0.003** |
| Av. K (mg/kg) | 183.02 (M) | 143.47 (M) | 28 | 1.214 | 0.235 (ns) |
| Ex. K (me/100g) | 0.84 (H) | 0.69 (H) | 28 | 1.001 | 0.626 (ns) |
| Ex. Ca (me/100g) | 5.73 (M) | 2.69 (L) | 21.37 | 3.060 | 0.006** |
| Ex. Mg (me/100g) | 0.87 (L) | 0.51 (vL) | 28 | 2.416 | 0.022* |
| CEC (me/100g) | 22.26 (M) | 19.45 (M) | 28 | 2.483 | 0.019* |
| Base saturation (%) | 31.15 (vL) | 19.96 (vL) | 28 | 2.704 | 0.012* |

N=Number of samples: organic soil (n1) = 15; conventional soil (n2) = 15. *$p<0.05$; **$p<0.01$; ns (non-significant) Av.:available, Ex: Exchangeable, vL (very low), L (Low), M (Medium), H (High), Source : SPAL, NSSC, Thimphu. Items arranged as per the soil analysis report.

### 4.10 Correlations between various soil properties under organic and conventional potato farming

The Pearson correlations among several soil properties in organic potato cultivation revealed that pH was correlated with Ex.Ca, Ex. Mg, and BS% at $p<0.05$. At $p<0.05$, available P was correlated with BS%, and at $p<0.05$, SOM was correlated with CEC and C:N ratio. At $p<0.05$, total N% was correlated to CEC. At $p<0.01$, available K was correlated with Ex.K. At $p<0.01$, Ex. Ca was shown to be correlated with Ex. Mg and BS%. At $p<0.05$, Ex. Mg had a correlation with Ex. K and BS% at $p<0.01$ (Table 4.10).

**Table 4.10** Correlations between various soil properties under organic potato farming (Pearson correlation)

| | pH | Av. P | OM % | Total N% | C:N ratio | Av. K | Ex. Ca | Ex. Mg | Ex. K | CEC | BS% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **pH** | | | | | | | 0.554* | 0.521* | | | 0.580* |
| **Av. P** | | | | | | | | | | | 0.591* |
| **OM%** | | | | | 0.534* | | | | | 0.517* | |
| **Total N%** | | | | | | | | | | 0.540* | |
| **Av. K** | | | | | | | | | 0.892** | | |
| **Ex. Ca** | | | | | | | | 0.842** | | | 0.900** |
| **Ex. Mg** | | | | | | | | | 0.535* | | 0.889** |

*. Correlation significant at the 0.05 level (2-tailed).

**. Correlation significant at the 0.01 level (2-tailed). Av.:available, Ex: Exchangeable.

Similarly, the Pearson correlations between several soil properties in conventional potato cultivation revealed that the pH was correlated with the Av. K at $p<0.05$, and with Ex.Ca, Ex.Mg, Ex. K, and BS% at $p<0.01$. At $p<0.01$, the SOM was correlated with total N%, Ex.Ca, and Ex. Mg, and at $p<0.05$ with CEC. At $p<0.01$, total N% was correlated with Ex.Ca and Ex. Mg, and at $p<0.05$ with CEC. At $p<0.01$, Av.K was correlated with Ex.K, and at $p<0.05$ with BS%. At $p<0.01$, Ex.Ca had a correlation with Ex. Mg and BS%, and with CEC at $p<0.05$. At $p<0.05$, Ex. Mg was correlated with Ex. K and CEC and BS% at $p<0.01$. At $p<0.01$, Ex.K correlated with BS% (Table 4.11).

**Table 4.11** Correlations between various soil parameters under conventional potato farming (Pearson correlation).

| | pH | Av. P | OM % | Total N% | C:N ratio | Av. K | Ex. Ca | Ex. Mg | Ex. K | CEC | BS% |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **pH** | | | | | | 0.612* | 0.666** | 0.668** | 0.719** | | 0.863** |
| **OM%** | | | | 0.883** | | | 0.715** | 0.734** | | 0.551* | |
| **Total N%** | | | | | | | 0.671** | 0.704** | | 0.610* | |
| **Av. K** | | | | | | | | | 0.950** | | 0.580* |
| **Ex. Ca** | | | | | | | | 0.890** | | 0.529* | 0.867** |
| **Ex. Mg** | | | | | | | | | 0.520* | 0.657** | 0.761** |
| **Ex. K** | | | | | | | | | | | 0.728** |

*. Correlation significant at the 0.05 level (2-tailed).

**. Correlation significant at the 0.01 level (2-tailed). Av.:available, Ex: Exchangeable.

## 4.11 Correlations between the soil properties and productivity

No correlations between the soil properties and the productivity of organic and conventional potatoes were observed (Table 4.12 and Table 4.13).

**Table 4.12** Correlations between soil properties and productivity for organic potato (n=15)

| Soil property | Productivity (MT/ha) | |
|---|---|---|
| pH_$H_2O$ | Pearson Correlation | .198 (ns) |
| | Sig. (2-tailed) | .479 (ns) |
| Available phosphorus | Pearson Correlation | -.063 (ns) |
| | Sig. (2-tailed) | .823 (ns) |
| Organic matter in the soil | Pearson Correlation | .101 (ns) |
| | Sig. (2-tailed) | .720 (ns) |
| Total nitrogen in % | Pearson Correlation | .044 (ns) |
| | Sig. (2-tailed) | .876 (ns) |
| Carbon: Nitrogen ratio of soil | Pearson Correlation | -.152 (ns) |
| | Sig. (2-tailed) | .588 (ns) |
| Available potassium (K) (mg/Kg) | Pearson Correlation | .120 (ns) |
| | Sig. (2-tailed) | .671 (ns) |
| Exchangeable calcium (me/100g) | Pearson Correlation | .124 (ns) |
| | Sig. (2-tailed) | .660 (ns) |
| Exchangeable magnesium (me/100g) | Pearson Correlation | .406 (ns) |
| | Sig. (2-tailed) | .133 (ns) |
| Cation exchange capacity | Pearson Correlation | .172 (ns) |
| | Sig. (2-tailed) | .540 (ns) |
| Base saturation % | Pearson Correlation | .188 (ns) |
| | Sig. (2-tailed) | .503 (ns) |

ns (non-significant)

As discussed before, the following table presents no correlations between various soil nutrients and properties with conventional potato productivity.

**Table 4.13** Correlations between soil properties and productivity for conventional potato (n=15)

| Soil property | Productivity (MT/ha) | |
|---|---|---|
| pH_$H_2O$ | Pearson Correlation | .013 (ns) |
| | Sig. (2-tailed) | .963 (ns) |
| Available phosphorus (mg/Kg) | Pearson Correlation | .153 (ns) |
| | Sig. (2-tailed) | .585 (ns) |
| Organic matter in the soil | Pearson Correlation | .150 (ns) |
| | Sig. (2-tailed) | .594 (ns) |
| Total nitrogen (%) | Pearson Correlation | .202 (ns) |
| | Sig. (2-tailed) | .470 (ns) |
| Carbon: Nitrogen ratio | Pearson Correlation | -.288 (ns) |
| | Sig. (2-tailed) | .298 (ns) |
| Available potassium (mg/Kg) | Pearson Correlation | .259 (ns) |
| | Sig. (2-tailed) | .351 (ns) |
| Exchangeable calcium (me/100g) | Pearson Correlation | .132 (ns) |
| | Sig. (2-tailed) | .640 (ns) |
| Exchangeable magnesium (me/100g) | Pearson Correlation | .158 (ns) |
| | Sig. (2-tailed) | .575 (ns) |
| Exchangeable potassium (me/100g) | Pearson Correlation | .114 (ns) |
| | Sig. (2-tailed) | .687 (ns) |
| Cation exchange capacity | Pearson Correlation | -.212 (ns) |
| | Sig. (2-tailed) | .447 (ns) |
| Base saturation % | Pearson Correlation | .098 (ns) |
| | Sig. (2-tailed) | .728 (ns) |

ns (non-significant)

## 4.12 Comparison of different soil properties under organic potato fields and nearby forest soil

No significant difference was observed between the pH of the organic potato fields (5.57) and nearby forest area soils (5.63). The soil texture of the nearby forest area was sandy loam. The Av. P of the organic soil (4.87 mg/kg) was significantly higher than the nearby forest soil (1.67 mg/kg), at $p<0.05$. The OM (%) of the organic soil (5.87%) was significantly higher than the nearby forest soil (3.40%), at $p<0.01$. The Total N% of the organic soil (0.38%) was significantly higher than the nearby forest soil (0.26%), at $p<0.01$.

The C:N ratio of the organic soil (9.99) was significantly higher than the nearby forest soil (7.83), at $p<0.01$. The Av. K of the organic soil (183.02 mg/kg) was significantly higher than the nearby forest soil (57 mg/kg), at $p<0.01$. The Ex. K of the organic soil (0.84 me/100g) was significantly higher than the nearby forest soil (0.21 me/100g), at $p<0.01$. No significant difference in Ex. Ca of the organic soil (5.73 me/100g) was found with the nearby forest soil (4 me/100g). The Ex. Mg of the organic soil (0.87 me/100g) was significantly higher than the nearby forest soil (0.29 me/100g), at $p<0.01$. The CEC of the organic soil (22.26 me/100g) was significantly higher than the nearby forest soil (17.56 me/100g), at $p<0.01$. There was no significant difference between the BS% between the organic soil (31.15%) and nearby forest soil (28.16%). The details are provided in Table 4.14.

**Table 4.14** Differences in soil properties between organic fields and a nearby forest area (one sample t-tests).

| Item | Mean | | d.f | t-test | p-value |
|---|---|---|---|---|---|
| | Organic | Test value (forest soil) | | | |
| pH ($H_2O$) | 5.57 | 5.63 | 14 | -0.777 | 0.450 (ns) |
| Av. P (mg/kg) | 4.87 | 1.67 | 14 | 3.10 | 0.008* |
| OM (%) | 5.87 | 3.40 | 14 | 9.29 | 0.000** |
| Total N (%) | 0.38 | 0.26 | 14 | 5.072 | 0.000** |
| C:N ratio | 9.99 | 7.83 | 14 | 6.98 | 0.000** |
| Av. K (mg/kg) | 183.02 | 57 | 14 | 5.49 | 0.000** |
| Ex. K (me/100g) | 0.84 | 0.21 | 14 | 6.079 | 0.000** |
| Ex. Ca (me/100g) | 5.73 | 4 | 14 | 1.972 | 0.069 (ns) |
| Ex. Mg (me/100g) | 0.87 | 0.29 | 14 | 4.71 | 0.000** |
| CEC (me/100g) | 22.26 | 17.56 | 14 | 6.411 | 0.000** |
| Base saturation (%) | 31.15 | 28.16 | 14 | 0.912 | 0.377 (ns) |

*$p<0.05$, **$p<0.01$, ns (non-significant); Av.:available, Ex: Exchangeable.

## 4.13 Comparison of different soil properties under conventional potato fields and nearby forest soil

The pH of the nearby forest area soil (5.33) was significantly higher than the conventional fields soils (4.99), at $p<0.05$. The soil texture of the nearby forest area was loamy sand. The Av. P of the conventional soil (8.87 mg/kg) was significantly higher than the nearby forest soil (0.22 mg/kg), at $p<0.01$. The OM% of the nearby forest soil (8.33%) was significantly higher than the conventional soil (5.10%), at $p<0.01$. The total N% of the nearby forest soil (0.44%) was significantly higher than the conventional soil (0.26%), at $p<0.01$. No significant difference in the C:N ratio was observed between the conventional soil (11.52) and the nearby forest soil (11.08). No significant difference in Av. K was observed between the conventional soil (143.47 mg/kg) and the nearby forest soil (121 mg/kg). No significant difference in Ex. K was seen between the conventional soil (0.69 me/100g) and nearby forest soil (0.55 me/100g).

The Ex. Ca was significantly higher in the conventional soil (2.69 me/100g) than nearby forest soil (1.41 me/100g), at $p<0.05$. No significant difference in Ex. Mg was observed between the conventional soil (0.51 me/100g) and nearby forest soil (0.41 me/100g). The CEC of the nearby forest soil (24.03 me/100g) was significantly higher than the conventional soil (19.45 me/100g), at $p<0.01$. The BS% was significantly higher in the conventional soil (19.96%) than nearby forest soil (9.96%), at $p<0.01$. The details are provided in Table 4.15.

**Table 4.15** Differences in soil properties between conventional fields and a nearby forest area (one sample t-tests).

| Item | Mean | | d.f | t-test | p-value |
|---|---|---|---|---|---|
| | Conventional | Test value (Forest soil) | | | |
| pH ($H_2O$) | 4.99 | 5.33 | 14 | -3.194 | 0.007* |
| Av. P (mg/kg) | 8.87 | 0.22 | 14 | 6.594 | 0.000** |
| OM (%) | 5.10 | 8.33 | 14 | -8.795 | 0.000** |
| Total N (%) | 0.26 | 0.44 | 14 | -9.406 | 0.000** |
| C:N ratio | 11.52 | 11.08 | 14 | 1.284 | 0.220 (ns) |
| Av. K (mg/kg) | 143.47 | 121 | 14 | 0.971 | 0.348 (ns) |
| Ex. K (me/100g) | 0.69 | 0.55 | 14 | 1.328 | 0.205 (ns) |
| Ex. Ca (me/100g) | 2.69 | 1.41 | 14 | 2.737 | 0.016* |
| Ex. Mg (me/100g) | 0.51 | 0.41 | 14 | 1.176 | 0.099 (ns) |
| CEC (me/100g) | 19.45 | 24.03 | 14 | -5.297 | 0.000** |
| Base saturation % | 19.96 | 9.96 | 14 | 3.954 | 0.001* |

*P<0.05, **P<0.01, ns (non-significant); Av.:available, Ex: Exchangeable.

This chapter provides the results of different analyses conducted on the study; the following are important summary results. Most organic farmers relied only on farming, whereas some conventional farmers had off-farm income. The conventional farmers planted the potato across a larger area than organic farmers. Cropping sequences were comparable in both farming systems, with potato as the main cash crop. The conventional potato farming had significantly higher productivity and profitability parameters than the organic potato farming. Conventional potato farming had significantly higher total input costs, whereas organic farming had significantly higher labour costs. The total cost of production showed no significant differences in both farming systems.

The constraints of organic potato farmers were no price premium for organic potato, pest and disease issues, low crop productivity, and climate change. Organic potato farmers only used organic fertilizers, while conventional farmers used both chemical and organic fertilizers. The soil textures of both organic and conventional potato farms were loam and silty clay loam.

Conventional potato soils' pH ($H_2O$) was significantly lower than organic soils. The available (Av.) P in conventional soils was significantly higher than in organic soils. Total N% was significantly higher in organic potato soils than in conventional soils. Exchangeable (Ex.) calcium and magnesium were significantly higher in organic potato soils than conventional soils. The CEC and the base saturation (BS)% were significantly higher in the organic potato soils. The Pearson correlations revealed that the OM% was correlated with CEC and C:N ratio in organic potato soil. Similarly, the OM% was correlated with total N% and CEC in conventional soil. No correlations between the soil properties and the productivity of organic and conventional potatoes were observed.

# Chapter 5

# Discussion and Conclusions

The 5th chapter is the last chapter of the study, and it discusses and concludes the essential findings of the study coherently. The chapter has two sections broadly; the 1st section (5.1) is the discussion part, and 2nd section (5.2) is the conclusion. The 2nd section conclusion has another sub-section (5.2.1), the recommendation part. The sub-section recommendation is further subdivided into 1) recommendations to farmers, 2) related organizations 3) policy implications, and 4) future studies. The discussion part is discussed in two parts for comprehensive discussion and clarity. The initial discussion is centred around objectives 1 and 2, which comprise farm and farmers' characteristics, productivity and profitability, production constraints, and marketing aspects. The 2nd part discusses the 3rd and last objective of the impact of these farming systems on soil nutrients and properties. The conclusion and recommendation part finally articulates the research work and provides a meaningful summation of the study.

## 5.1 Discussion

Organic farmers who got additional technical training than their conventional counterparts, farm input support, and free organic certification from the RGoB; showed the government's attempt to promote organic farming in Gasa district. Organic potato farmers had a higher female population, more aged farmers and, lesser family labour than the conventional farmers. Most farmers who went to school in both farming systems pursued until primary school; however, organic farmers had lesser educational attainment. According to the (Population & Housing Census of Bhutan [PHCB], 2017), Gasa district has the lowest literacy rate in the country with 59.8%, while the National literacy rate stood at 71.4%. Organic and conventional farmers had extensive working experience, with slightly higher average experience with organic potato farmers. Most organic farmers relied only on farming for a living, although some conventional farmers had off-farm earnings. Despite having a smaller farm size than organic farmers, conventional farmers grew potatoes in significantly bigger areas by leasing additional land.

The conventional potato farming was significantly more productive than the organic potato; it was 2.57 times more productive on average. Similar results have been reported by (Ierna & Parisi, 2014; Maggio et al., 2008) on organic potatoes. According to Seufert et al. (2012), their examination of available data revealed that, on average, organic yields are lower than conventional yields. This study contradicts (Tashi & Wangchuk, 2016), which found that rice grain yields in Bhutan were not significantly different between organic and conventional systems. Notably, organic potato productivity was significantly lower than the national average (10.40 MT/ha), but it was significantly higher for conventional potatoes for the same cropping year (i.e., 2019). The average organic productivity (7.48 MT/ha) can be categorised as low productivity (5-10 MT/ha), whereas the average for the conventional potatoes (19.22 MT/ha) as high productivity (>14 MT/ha) (National Potato Programme, 2019). Organic potato farming cost per hectare of land was not significantly different from the conventional one; however, this doesn’t include the organic certification cost, which the government separately bore. According to Lyngbaek et al. (2001), removing organic certification fees, mean variable costs in coffee were comparable for both organic and conventional groups. Therefore, if the certification cost is added, then the cost of production would be higher for organic farming. The actual data on the certification cost could not be assessed in the study. Cobanoglu et al. (2014)reported that the certification cost was one of the primary reasons for the higher cost in organic farming. On the other hand, Tashi and Wangchuk (2016) reported that the total cost of production for organic rice in Bhutan was significantly higher than conventional rice. The total labour cost in organic potato production was significantly higher than conventional potato production. The largest contributor to labour costs to organic potato farmers was weeding/earthing up operations. Organic farmers spent more on weeding and earthing-up because they needed more farm laborers (297.17 man-days/ha) to manage weeds without synthetic herbicides than conventional farmers (28.62 man-days/ha). In Bhutan, a man-day is measured as one adult person working the whole day from morning till evening to complete a work. Therefore, two persons working a whole day to complete work was considered two man-days in the study. These were ultimately converted per hectare basis. Mendoza (2004) and Tashi and Wangchuk (2016) found similar results in organic rice, while Adamtey et al. (2016) found similar results in organic maize. Uematsu and Mishra (2012) and Heinrichs et al. (2021) also concluded that organic systems require more labour than the conventional farming system.

On the contrary, the total input cost of conventional potato farming was significantly higher than that of organic potato farming. Organic farming reduces the expense of purchasing external inputs (Mendoza, 2004; Morshedi et al., 2017). In conventional potato farming, the input costs for seed, fertilizer/manure, and pesticide/bio-pesticide were also significantly higher. This finding is consistent with (Mendoza, 2004;

Tashi & Wangchuk, 2016). The seed cost was the highest among conventional potato farmers' input costs, accounting for 29.03% of the total production cost. The total fixed cost for conventional potato farmers was higher than that of the organic farmers; it was mainly due to paying rent on leased lands and the higher depreciation cost of agricultural machinery. The profitability of the conventional potato was significantly higher than that of the organic potato; it was higher by 286,541.32 Nu/ha on average than the organic potato. This finding is substantiated by conventional potatoes having significantly higher BCR. Coppola et al. (2020) and Tashi and Wangchuk (2016) found comparable results in hazelnut and rice, respectively. According to Froehlich et al. (2018), the profitability of organic producers is lower than those of conventional producers. It does, however, contradict the results of (Turhan et al., 2008) with organic tomatoes.

Organic production had a benefit-cost ratio (B:C ratio) of <1, and the return on investment (ROI) was negative, implying that organic potato production was not profitable. If the B:C ratio is more than one, the benefits exceed the costs; if it is less than one, the costs exceed the benefits, and the operation is unprofitable (Hay, 1982). The conventional potato had a B:C ratio >1, and a positive ROI, indicating that conventional potato production was profitable. This means that conventional potato farmers earned on average 1.27 Nu, while organic potato farmers lost 0.60 Nu. for every 1 Nu invested. The return on investment (ROI) is a vital indicator for determining a company's profitability (Rosenbaum et al., 2013; Tiffany & Peterson, 2011). Farm-gate price for conventional potato farmers was likewise 2.15 Nu/kg more than for organic farmers. According to several organic farmers, the poor appearance of organic potato tubers compared to conventional counterparts was a significant reason for receiving lower farm-gate or market pricing for organic potatoes. They noted that organic potato tubers are often small in size and that the tubers are not as smooth and appealing as conventional potatoes, which is partly due to insect and disease issues. Similarly, (Maggio et al., 2008) reported that organic farming resulted in a 25% decrease in marketable productivity, with conventional farming possessing a higher percentage of larger tubers. The seed rate used by the conventional potato farmers was relatively higher than the organic one; this partly agrees with the organic farmers' observation on organic potato's smaller tuber size.

Bhutanese traders and local consumers are prepared to pay more for larger and better-looking potato tubers, regardless of whether they were farmed organically or conventionally. They did, however, claim that there are a few educated clients in the market who are looking for organic potatoes. The organic potato was unprofitable due to low productivity and a lower farm-gate price. In the present productivity level, the organic potato's break-even price was 2.5 times higher than the farm-gate price; organic farmers would benefit if they receive higher and premium prices above the break-even point. Sgroi et al. (2015) found that organic lemon growing was more profitable due to premium pricing. The unprofitability of organic potato farming also explains why organic farmers planted the potato in a significantly smaller area in 2019, despite having more farmable land than conventional farmers. Farmers may opt to grow more of a specific crop because of the prospect for better profitability, according to (Kahan, 2013). The land is limited, and maximizing monetary returns per unit of land has by far the most significant in farmers' decision-making (Nwosisi, 2017). The research also found that organic potato growers undertook group marketing to sell their potatoes. Most of their potatoes were sold to a common middleman who bought directly from the farmers, but they were paid individually. The middleman's farm-gate price was not profitable for the organic growers. Similarly, (Tashi & Wangchuk, 2016) revealed no premium pricing for organic rice in Bhutan. Customers' limited market size and willingness to pay a price premium would influence the scope of organic agricultural adoption (Wheeler, 2008). As pricing differences arise across different business channels, better marketing channels should be investigated (Suwanmaneepong et al., 2020). In addition, farm commodities may now be marketed thanks globally to the global economy, providing farmers with more options to obtain profit (Kahan, 2013).

Farm production should be kept profitable by increasing marketability (Baležentis et al., 2019). Another critical constraint, the predominance of pest and disease issues, and following climate change constraints, may have decreased organic potato crop productivity. According to Wheeler (2008), the second most significant barrier to organic agricultural acceptance is production, and pest and disease challenges. Diseases and weather affect crop productivity (Kahan, 2013). Insufficient pest and disease control is the leading cause of productivity reduction in organic potato farming (Finckh et al., 2006). Late blight disease was one of the factors that contributed to the reduced potato productivity of organic agriculture compared to conventional farming (Ierna & Parisi, 2014). Much research has also observed a detrimental influence of climate change on potato production (Bhatnagar et al., 2018; Julio et al., 2018; Kimathi et al., 2020). Therefore, additional study is needed to address pest and disease difficulties, reduced crop productivity, and climate change challenges. Improving farming methods in-line with the International Federation of Organic Agriculture Movement (IFOAM) principles will increase organic potato productivity in the Gasa district; there is a need to have a green manure/leguminous crop in the cropping sequences of organic potato farmers to enhance the soil fertility. In addition, farm labour shortages might have resulted from fewer family laborers among organic growers. Since Himalayan soils in Bhutan are inherently low in soil nutrients and characterized by soil acidity, good soil fertility management will be critical to increase potato productivity. FAO (2009) mentions that maintaining high potato yields requires good soil health and fertility management. Bhutan's farm labour shortage is increasing due to increased rural-to-urban migration (Population & Housing Census of Bhutan [PHCB], 2017). In terms of insufficient bio-pesticide supply, many imported bio-pesticides in the nation have a limited shelf life, are pretty costly, and efficacy trials are still ongoing (DoA, 2015). Given the negative impact of pesticides on the environment and human health, the government has centralized the supply of pesticides and bio-pesticides, only available through a few government institutions.

**Discussion on soil properties**

Organic potato farmers used exclusively organic fertilizers in their fields for the annual potato cropping cycle, which included well-rotten FYM and other organic amendments. On the other hand, conventional potato farmers used both chemical fertilizers and small amounts of FYM and other organic amendments. The recommended rates of fertilizer application for potato production are 185 kg N/ha and 62 kg P/ha and 62 kg K/ha (Apnikheti, 2021). The estimated proportion of N accessible to the potato crop through the application of the FYM is 30% (BPDP, 2008); therefore, both organic and conventional potato farmers used N at lower rates than recommended. The N accessible to potatoes in organic farming is estimated to be 134 kg/ha using only organic fertilizers, but it is 165 kg/ha in conventional agriculture using a combination of chemical and organic fertilizers. As discussed above, in this study, higher potato tuber productivity in conventional farming could be explained with a relatively higher available and accessible N in the soil than organic potato farming. According to Mikkelsen (2006), appropriate N management is one of the most significant aspects necessary to achieve large yields of high-quality potatoes. Nitrogen fertilizer affected potato marketable yield (Maggio et al., 2008). Increased nitrogen levels in the soil are critical for productivity in plants (de Jesus Duarte et al., 2019). Conventional farmers also relatively applied higher quantities of Phosphorus for potato cultivation than the organic farmers and in more accessible forms through mineral fertilizers. Following N, P is frequently regarded as the second most crucial crop productivity limiting nutrient in Bhutan (Chettri et al., 2003). The soil textures in the study areas were comparable, with predominantly loam and silty clay loam, with some proportional differences.

The ideal soil pH is > than 5.5 ($H_2O$), and anything below is considered highly acidic, which increases the danger of aluminium toxicity. Plants in acidic soils with pH less than 4.8 ($CaCl_2$) or 5.5 ($H_2O$) may have reduced access to essential plant nutrients (Botta, 2015). The fact that conventional potato soil has a significantly lower pH than organic soil and below the ideal pH suggests that it is highly acidic. This observation contrasts the findings of (Tashi & Wangchuk, 2016); they found that soil pH in organic and conventional rice fields in Bhutan was not significantly different. Long-term soil pH changes were caused mainly through cation displacement or the addition of acidity sources such as H+ to soil exchange sites (Tisdale et al., 1993). Nitrate in soil solution is highly mobile, and if not absorbed by plants, it can leak off from the root zone, leaving behind hydrogen and aluminium ions and so increasing soil acidity (Botta, 2015). The widespread use of urea in Bhutan is expected to exacerbate the low soil pH problem. Liming to neutralizing acidic soils is not a regular practice in the country (Norbu & Floyd, 2004). The continuous use of chemical fertilizers such as urea and inadequate soil fertility management may have decreased the pH of the conventional soil. This is further supported with a significantly lower pH in conventional potato soil than the nearby forest area soil and no significant difference in the pH of organic soil with the nearby forest area soil. Since the conventional soil had a pH value lower than 5.2 and had low levels of both calcium and magnesium, they are recommended to apply dolomite ($CaMg(CO_3)_2$ in their soil. Dolomite application is suitable when both calcium and magnesium are low in the soil. Lime ($Ca(CO_3)_2$) is applied when pH is below 5.2 but when only calcium content is low in the soil.

A significant increase in available P in conventional soil compared to organic soil might be attributed to P build-up from long-term application of chemical P fertilizer in the form of Single Super Phosphate (SSP, 16% $P_2O_5$) in conjunction with organic fertilizers. Similar findings have been reported by (Bajgai et al., 2015; Grewal et al., 1981). Significantly higher available P with the conventional potato soil than the nearby forest area soil supports this view. Conversely, (Herencia & Maqueda, 2016; Tashi & Wangchuk, 2016) reported that available P was significantly higher in organically managed soils than conventionally managed soils. Soil samples with <5 mg P/kg and <15 mg P/kg are regarded to have very low and low P levels, respectively (Roder et al., 2008). This implies that the organic potato soil had a very low P level (4.87 mg P/kg), whereas the conventional soil had a low P level (8.87 mg P/kg). Plants require P for energy storage and transmission, early shoot and root growth, and legume nodulation (Botta, 2015). As a result, potato farmers are advised to apply extra P through rock phosphate additions in the case of organic potato farmers and synthetic P fertilizers in the case of conventional potato farmers. The absence of statistically significant differences in organic matter (OM)% content between organic and conventional soils might be attributed to conventional farmers' use of organic fertilizers such as the FYM in addition to chemical fertilizers. However, compared to the nearby area forest soil, the OM% was significantly lower in the conventional potato fields. In field trials employing integrated nutrient management strategies, the organic C pool of the soil increased (Choudhary et al., 2013). On the contrary, the organic rice farm in Bhutan had consistently and significantly higher soil organic matter (SOM) for two consecutive years (Tashi & Wangchuk, 2016).

Surprisingly, the total N% was significantly higher in organic soils than in conventional soils. N is an essential plant nutrient since it is necessary for the production of proteins and chlorophyll, as well as the conservation of photosynthetic efficiency, the leaf area increase, and, finally, the synthesizing of dry matter. It's also one of the world's most prominent yield-limiting nutrients (Muchow, 1998). Similar findings of higher N% available in organic plots than in conventional ones have been reported (Bajgai et al., 2015; Das et al., 2017; Tashi & Wangchuk, 2016). A conventional system's N mineralization rates are estimated to be 100% higher than an organic system's; hence, organic soil management approaches are expected to hold more N (Bajgai et al., 2015; Mallory & Griffin, 2007). This viewpoint is supported in conventional farming by a correlation between the SOM% and the total N% in conventional soils. However, no such direct correlations were observed in organic potato soils. Still, indirect associations were speculated, wherein the total N% was correlated with the cation exchange capacity (CEC), while the CEC was correlated with the SOM%. Jarvis et al. (1996) states that through breakdown and mineralization, plant nutrients held in SOM are released into the soil as inorganic forms. The N supply in these systems is typically constrained by mineralization and immobilization processes and can be unpredictable, resulting in excessive or inadequate asynchrony (Mallory & Griffin, 2007; Palmer et al., 2013). Organic potato farmers used 2.57 times more FYM and other organic fertilizers per hectare than conventional farmers. Nitrogen applied through urea and other chemical fertilizers is rapidly absorbed by the plants, with the remainder lost by leaching and volatilization. The losses such as denitrification and leaching may result from the use of readily accessible conventional fertilizers (Chien et al., 2009; Hirel et al., 2007).

Chemical fertilizers have a greater N utilization efficiency than organic fertilizers (Adamtey et al., 2016; Eghball & Power, 1999). The N management is a critical issue in most agricultural systems due to the excellent mobility and susceptibility for loss from the soil-plant system into the environment (Musyoka et al., 2017). Besides, the pH of the soil also influences N mineralization and thus plant availability. According to the results, the pH of conventional soil was significantly lower than that of organic soil. According to

Mallory and Griffin (2007), organic N mineralization decreases progressively when pH dips below 6. Similar reasons discussed above could have led to significantly higher total N% in nearby area forest soil than conventional potato soil. Similar carbon content but significantly higher N content of organic field soils than the conventional one resulted in a significantly lower C:N ratio in organic field soils than the conventional one. The N mineralization and immobilization pattern are represented by a C:N ratio (Reddy & DeLaune, 2008). The organic soils' lower C:N ratio might be attributed to the enormous volumes of cow dung manure added in FYM. Cow dung manure has a lower C:N ratio because of its high nitrogen content and is a good source of protein for microbes involved in the organic material breakdown (Adegunloye et al., 2007). Notably, there were no significant differences in available and exchangeable K between organic and conventional systems. Similar findings were obtained by (Herencia & Maqueda, 2016; Tashi & Wangchuk, 2016). Available K is part of the total quantity of K in the soil solution, available for uptake by the plant. On the other hand, the Exchangeable K test is a measure of readily available K only (Botta, 2015).

Plants require K to manage water and nutrient absorption, flowering and seed development, and resistance to environmental stresses and disease (Botta, 2015). Norbu and Floyd (2004) found that soil parent materials in Bhutan are typically rich in K, as shown by primarily moderate to high quantities of exchangeable K in their study on changing soil fertility management. No significant differences in Av.K and Ex.K between the conventional potato soil and nearby forest soil support this view.

Exchangeable calcium and magnesium (me/100g) were significantly high in organic than conventional soils. The lower calcium levels in conventional soils than organic soils might be attributed to the former's lower pH. While most neutral and alkaline soils contain enough Ca, acidic soils may be deficient in Ca. Soil Calcium levels are often raised to acceptable levels once low soil pH is corrected with lime (Subedi & Ma, 2009). Similar Ex. Ca in organic potato soil and nearby area forest soil with similar pH values also shows that the organic potato area in Gasa is inherently richer in Calcium than the conventional sites. Significantly higher Ex. Ca in conventional potato soil compared to the nearby area forest soil could be due to the addition of Calcium while applying the SSP, which also contains 19.5% Calcium (IPNI, 2021). Maintaining appropriate SOM in the soil through the use of agricultural manures and crop residues, on the other hand, assists in the maintenance of Ca and other nutrient levels. Ca is required by plants as an essential component of plant structure, such as a cell wall (Subedi & Ma, 2009). Organic farmers use organic fertilizers like FYM, and Adegunloye et al. (2007) reported that when cow dung manure is applied to the soil, it offers N, P, K, and calcium to crops.

Similarly, Herencia and Maqueda (2016) reported that available Mg levels in organic plots were significantly higher than in conventional sites. They showed that mineral fertilizers contain more K than Mg; therefore, K might replace Mg in the exchange sites and cause Mg loss by leaching, explaining the lower Mg levels in conventionally treated soils. Gliessman et al. (1996) also found enhanced Mg availability due to organic amendments. Significantly higher Ex. Mg in organic potato soil than the nearby forest soil with sandy loam texture supports this view. Magnesium is a chlorophyll molecule component that acts as an enzyme activator involved in glucose metabolism. The organic soils had significantly higher CEC and base saturation (BS)% than conventional soils. Bajgai et al. (2015); Sidhu et al. (2007) reported similar findings. Higher CEC in organic soils might be attributed to the use of more SOM in organic fertilizers than in conventional soils. The CEC and SOM were shown to be correlated in both farming system soils, indicating that the higher CEC in organic soils may be due to the use of more organic fertilizers. This is supported by significantly higher CEC in nearby forest soil than conventional potato soil; the former also has significantly higher OM% than the latter. Significantly higher CEC in organic potato soil than nearby forest soil with sandy loam texture; the former having significantly higher OM% than the latter further supports this view. The organic and conventional potato soils had very low average BS%, implying acidic soils. It is most likely acidic soil if the percentages of each exchangeable base cation are low (Botta, 2015). Low BS% also means that the soils in both farming systems can absorb more elements/fertilizers. There were no correlations between various soil properties and productivities of organic and conventional potato farming. This agrees with (Tashi & Wangchuk, 2016) in organic and conventional rice study in Bhutan.

**5.2 Conclusion**

According to the study, the organic potato growers had a greater female population, more elderly farmers, and less family labour than conventional farms. Most farmers in both farming systems who went to school completed primary school, but organic farmers had lower educational attainment. Organic and conventional potato farmers had considerable work experience, with organic growers having slightly more on average.

Most organic farmers relied only on farming for a living, but some conventional farmers also worked off-farm. Although with a smaller farm holding than organic farmers, conventional farmers cultivated potatoes in far larger areas by leasing extra acreage.

The conventional potatoes had significantly higher productivity and profitability than organic potatoes. It also revealed that the organic potatoes had significantly lower productivity than the national average. The total input cost was significantly greater in conventional potato farming, whereas the total labour cost was significantly higher in organic agriculture. The organic potato had a lower B:C ratio and an unfavourable ROI, implying that it was not profitable. The conventional potato had a higher B:C ratio and a favourable ROI, indicating a profitable enterprise. Organic potatoes' non-profitability was primarily due to lower crop productivity and lower farm-gate price. Organic potato farmers faced the following production constraints: lack of premium price, pest and disease challenges, low crop productivity, and climate change issues. They resorted to group marketing and sold to a pre-identified common middleman, which further sold/distributed in domestic markets. In contrast, the conventional potato growers sold to the Food Corporation of Bhutan (FCB), which further exported and also distributed in the domestic markets.

Organic potato farmers applied only organic fertilizers, but the conventional farmers applied both chemical and organic fertilizers; however, the latter applied lesser organic fertilizers per hectare than the former. Overall, organic potato farming in West-central Bhutan improved several essential soil properties for crop growth and productivity. Organic farming significantly increased Cation Exchange Capacity (CEC), base saturation percentage (BS%), exchangeable calcium and magnesium over conventional agriculture. Significantly higher residual Nitrogen was observed in organic farming fields, possibly due to the slow immobilization and mineralization process than the conventional system. Significantly lowered Carbon: Nitrogen (C:N) ratio was observed in organic potato fields, indicating its suitability for crop production. The conventional potato fields had significantly lowered pH compared to organic soil; this could be due to the use of inorganic fertilizers such as urea over a longer period. Conventional farming significantly increased the available P in the soil, possibly due to P build-up over a long period with the use of synthetic P fertilizers additionally with organic fertilizers; however, P levels were still low in both the farming systems' soils. There were no correlations between the soil properties and productivity; however, higher N and P availability and accessibility in the conventional fields, pest and disease, and climate change constraints with organic potato farmers possibly led to higher productivity in the conventional potato fields. Both the study areas had loam and silty clay loam soil textures.

### 5.2.1 Recommendations

Based on the study findings, the following recommendations are put forth, which are intended to benefit the farmers, related organizations, policy implications, and future studies.

**1) Farmers**

1.1) The study found that the mean pH of conventional soil was strong acidity, and it was medium acidity for organic soil. Further, the pH of the conventional potato soil was significantly lower than organic soil, deficient in both Ca and Mg. Therefore, conventional potato farmers are recommended to apply dolomite ($CaMg(CO_3)_2$) to increase the pH of their acidic soil.

1.2) In study areas, potato farmers did not grow green manure crops or other leguminous crops. This will be important to increase soil fertility critical in organic potato fields to increase nitrogen availability in the soil. Therefore, the organic potato farmers need to further adhere to the principles of organic farming laid down by the IFOAM, especially growing green manure/leguminous crops as part of the cropping pattern besides potatoes.

1.3) There are no other studies on organic and conventional potato production in Bhutan. Therefore, the critical findings in the study will assist farmers in decision making and adopting an appropriate potato farming technique in the country, specifically West-Central Bhutan.

1.4) P levels were still low in both the farming system's soils; therefore, the potato farmers are recommended to apply more P through additions of rock phosphates in case of organic potato farmers and synthetic P fertilizers for the conventional potato farmers.

1.5) Considering lower N application than the recommended dose and low BS% content in both the farming system's soils, the farmers are advised to apply more fertilizers to increase the availability of these critical nutrients (N, Ca, Mg) to increase the potato's productivity.

1.6) The potato farmers should be encouraged to undertake more soil tests, and the Government could train and supply them with field soil test kits.

**2) Related organizations**

2.1) The study found that organic potato farmers had several constraints: lack of price premium, pest and disease problems, low crop productivity, and climate change issues. However, the National Plant Protection Centre could closely coordinate with the National Potato Programme and Gasa district Agriculture Sector to address the pest and disease problems. As a result, pest and disease resistant and climate-resilient potato varieties with good market demand could be initiated.

2.2) The National Soil Service Centre, in collaboration with the National Potato Programme and Gasa district Agriculture Sector, could produce organic fertilizers with enriched NPK and micronutrients content.

2.3) The Department of Agricultural Marketing and Cooperatives could explore potential and reliable markets for organic potatoes in both domestic and export markets, where farmers could obtain premium prices. Additionally, Green market projects as practised in Thailand could be initiated, where organic potato farmers directly meet consumers, eliminating the need for a middleman and maximizing their profit.

2.4) The Royal Government of Bhutan needs to increase the demand for organic potatoes by awareness creations on the benefits of consuming organic products.

**3) Policy implications**

3.1) The researchers expect that the empirical data they presented will benefit policymakers towards the betterment of Bhutan's vision for organic agriculture development. This implies that the study's critical findings will contribute to Bhutan’s policy decision to pursue its 100% organic vision or adopt organic farming for niche markets.

3.2) Considering inherent low soil fertility status and pest and disease constraints, the Government should invest in making these inputs available to organic farmers, including quality organic seeds. These organic inputs could be manufactured within the country. Investment in human resource development in organic farming will be critical.

3.3) In light of growing farm labour shortages in the country and organic farming being more labour intensive than conventional farming, the Government policies should prioritize attracting youths to take up farming. In addition, other organic agriculture policies should be aligned with climate-smart agriculture.

**4) Future studies**

4.1) This study could only gather 30 soil samples (15 for each agricultural system); the authors recommend that a further study with a larger sample size be conducted, incorporating other additional physicochemical soil parameters.

4.2) Considering the recent emergence of an alternative farming system such as the Good Agriculture Practices (GAP) in Bhutan; additionally, a long-term scientific field study on the viability of organic, conventional, and GAP potatoes is required in Bhutan. Furthermore, such studies could also assess their adverse contributions to environmental contamination.

4.3) Since the labour requirement in weeding is significantly higher in organic potato farming than the conventional one, hugely contributing to the production cost, further research needs to develop labour saving and cheaper technologies for weed control.

# 6. References

Adamtey, N., Musyoka, M. W., Zundel, C., Cobo, J. G., Karanja, E., Fiaboe, K. K. M., . . . Foster, D. (2016). Productivity, profitability and partial nutrient balance in maize-based conventional and organic farming systems in Kenya. *Agriculture Ecosystems & Environment, 235*, 61-79. doi:10.1016/j.agee.2016.10.001

Adegunloye, D., Adetuyi, F., Akinyosoye, F., & Doyeni, M. (2007). Microbial analysis of compost using cowdung as booster. *Pakistan Journal of Nutrition, 6*(5), 506-510.

Adhikari, R. K. (2011). Economics of organic rice production. *Journal of Agriculture and Environment, 12*, 97-103.

Agriculture Research & Development Centre (ARDC)-Yusipang. (2019). *Annual report (2018-2019), ARDC-Yusipang, Royal Government of Bhutan*. Thimphu: Department of Agriculture

Apnikheti. (2021). Potato. Retrieved from https://www.apnikheti.com/en/pn/agriculture/horticulture/vegetable-crops/potato

ARDC-Bajo. (2020). About ARDC Bajo. Retrieved 1st January 2021, from Agriculture Research & Development Centre (ARDC)-Bajo, Wangduephodrang http://rcbajo.gov.bt/bsws/by-laws/

Bajgai, Y. (2018). Standard evaluation guideline for potato germplasm. In Lakey (Ed.), *Standard evaluation guidelines for field & horticultural crops* (pp. 27-39). Thimphu: Agriculture Research & Extension Division (Ared), Department Of Agriculture, Ministry of Agriculture & Forests, Thimphu.

Bajgai, Y., Dochen, T., Wangchuk, P., Kadian, S., Felde, T., Lefebvre, M., . . . Wangdi, N. (2018). Participatory varietal selection of potato and agronomic performance with farmers' feedback on new varieties.

Bajgai, Y., Kristiansen, P., Hulugalle, N., & McHenry, M. (2015). Comparison of organic and conventional managements on yields, nutrients and weeds in a corn-cabbage rotation. *Renewable Agriculture and Food Systems, 30*(2), 132-142. doi:10.1017/s1742170513000264

Bajgai, Y., & Rai, P. (2020). A Basic Guide On  Potato Farming In Bhutan In D. o. A. M. o. A. F. National Potato Programme (NPP), Bhutan (Ed.). Thimphu: National Potato Programme, Dept of Agriculture.

Bajgai, Y., & Sangchyoswat, C. (2018). Farmers knowledge of soil fertility in West-Central Bhutan. *Geoderma Regional, 14*, 8. doi:10.1016/j.geodrs.2018.e00188

Bajracharya, M., & Sapkota, M. (2017). Profitability and productivity of potato (Solanum tuberosum) in Baglung district, Nepal. *Agriculture & Food Security, 6*(1), 47. doi:10.1186/s40066-017-0125-5

Baležentis, T., Galnaitytė, A., Kriščiukaitienė, I., Namiotko, V., Novickytė, L., Streimikiene, D., & Melnikiene, R. (2019). Decomposing dynamics in the farm profitability: an application of index decomposition analysis to Lithuanian FADN sample. *Sustainability, 11*(10), 2861.

Barclay, E. (2012). Bhutan Bets Organic Agriculture Is The Road To Happiness. *National Public Radio*. Retrieved from https://www.npr.org/sections/thesalt/2012/07/31/157645902/bhutan-bets-organic-agriculture-is-the-road-to-happiness

Best, J. W., & Kahn, J. V. (1998). *Research in education* (8 ed. Vol. 8). Boston: Allyn and Bacon.

Bharucha, E. (2005). *Textbook of Environmental Studies for Undergraduate Courses*: Universities Press (India) Pvt. Limited.

Bhatnagar, A., Dua, V. K., & Chakrawarti, S. K. (2018). Scenario, implications and prospects of climate change on potato (Solanum tuberosum) insect pests: A review. *Indian Journal of Agricultural Sciences, 88*(9), 1331-1339. Retrieved from <Go to ISI>://WOS:000445542200002

Botta, C. (2015). *Understanding your soil test step by step* (J. Brookes Ed.): Shepparton.

BPDP. (2008). *Soil fertility management for sustained potato production in the mountain of Bhutan.* Thimphu: CIP/CFC/BPDP

BPV Consultancy & Research Services. (2018). *Lot 2: Potato Value Chain Analysis*. (EuropeAid/CMHR/IH/SER/BT). Thimphu, Bhutan: Bhutan Philanthropy Ventures Pvt. Ltd

Bruinsma, J. (2009). *The Resource Outlook To 2050: by how much do land, water and crop yields need to increase by 2050?* Paper presented at the Expert Meeting on How to Feed the World in 2050, Rome.

ÇelİK, Y., Peker, K., & Oguz, C. (2010). Comparative analysis of energy efficiency in organic and conventional farming systems: a case study of black carrot (Daucus carota L.) production in Turkey. *Philippine Agricultural Scientist, 93*(2), 224-231. Retrieved from http://www.pas-uplbca.edu.ph/932-11.php

Charantimath, P. M. (2005). *Entrepreneurship Development and Small Business Enterprise*: Pearson Education.

Chettri, G. B., Ghimiray, M., & Floyd, C. N. (2003). Effects of farmyard manure, fertilizers and green manuring in rice-wheat systems in Bhutan: Results from a long-term experiment. *Experimental Agriculture, 39*(2), 129-144. doi:10.1017/s0014479702001163

Chidiebere-Mark, N., Ohajianya, D., Obasi, P., & Onyeagocha, S. (2019). Profitability of rice production in different production systems in Ebonyi State, Nigeria. *Open Agriculture, 4*(1), 237-246. doi:10.1515/opag-2019-0022

Chien, S., Prochnow, L., & Cantarella, a. H. (2009). Recent developments of fertilizer production and use to improve nutrient efficiency and minimize environmental impacts. *Advances in agronomy, 102*, 267-322.

Choudhary, A. K., Thakur, S. K., & Suri, V. K. (2013). Technology Transfer Model on Integrated Nutrient Management Technology for Sustainable Crop Production in High-Value Cash Crops and Vegetables in Northwestern Himalayas. *Communications in Soil Science and Plant Analysis, 44*(11), 1684-1699. doi:10.1080/00103624.2013.783058

Ciaian, P., PALOMA, S., & Delincé, J. (2013). *Literature review on cost of production methodologies.* Paper presented at the The First Scientific Advisory Committee Meeting.

Cobanoglu, F., Kucukyilmaz, K., Cinar, M., Bozkurt, M., Catli, A. U., & Bintas, E. (2014). Comparing the Profitability of Organic and Conventional Broiler Production. *Brazilian Journal of Poultry Science, 16*(4), 403-409. doi:10.1590/1516-635x1604403-410

Condron, L., Cameron, K., Di, H., Clough, T., Forbes, E., McLaren, R., & Silva, R. (2000). A comparison of soil and environmental quality under organic and conventional farming systems in New Zealand. *New Zealand Journal of Agricultural Research, 43*(4), 443-466.

Connor, D. J. (2008). Organic agriculture cannot feed the world. *Field Crops Research, 106*(2), 187-190. doi:10.1016/j.fcr.2007.11.010

Conway, G. R. (1986). *Agroecosystem analysis for research and development*: Winrock International Institute for Agrcultural Development, Bangkok.

Coppola, G., Costantini, M., Orsi, L., Facchinetti, D., Santoro, F., Pessina, D., & Bacenetti, J. (2020). A Comparative Cost-Benefit Analysis of Conventional and Organic Hazelnuts Production Systems in Center Italy. *Agriculture-Basel, 10*(9), 16. doi:10.3390/agriculture10090409

Council of Renewable Research of Bhutan [CoRRB]. (2005). *Integrated Agriculture Technical Guide Book*. Thimphu: Ministry of Agriculture, Royal Government of Bhutan.

D'Avanzo, C. (2008). *Mosby's Pocket Guide to Cultural Health Assessment - E-Book*: Elsevier Health Sciences.

Das, A., Patel, D. P., Kumar, M., Ramkrushna, G. I., Mukherjee, A., Layek, J., . . . Buragohain, J. (2017). Impact of seven years of organic farming on soil and produce quality and crop yields in eastern Himalayas, India. *Agriculture Ecosystems & Environment, 236*, 142-153. doi:10.1016/j.agee.2016.09.007

Dasgupta, S., & Roy, I. (2011). *Good Agricultural Governance: A resource guide focused on smallholder crop production*. Bangkok: Food and Agriculture Organization of the United Nations.

de Haan, S., Burgos, G., Liria, R., Rodriguez, F., Creed-Kanashiro, H. M., & Bonierbale, M. (2019). The Nutritional Contribution of Potato Varietal Diversity in Andean Food Systems: a Case Study. *American Journal of Potato Research, 96*(2), 151-163. doi:10.1007/s12230-018-09707-2

de Jesus Duarte, S., Glaser, B., Paiva de Lima, R., & Pelegrino Cerri, C. E. (2019). Chemical, Physical, and Hydraulic Properties as affected by one year of Miscanthus Biochar Interaction with sandy and loamy Tropical soils. *Soil Systems, 3*(2), 24.

Delaney, P. R., & Whittington, O. R. (2011). *Wiley CPA Examination Review, Outlines and Study Guides*. New Jersey: Wiley.

Department of Agricultural Marketing and Cooperatives [DAMC] & DAS Gasa. (2016). Gasa Dzongkhag leading the way in organic crop production. Retrieved February 15, 2020, from MoAF http://www.moaf.gov.bt/gasa-dzongkhag-leading-the-way-in-organic-crop-production.

Department of Agriculture [DoA]. (2006). *National Framework for Organic Farming in Bhutan* Thimphu, Bhutan: Department of Agriculture, Royal Government of Bhutan (RGoB)

Department of Agriculture [DoA] (2018). Re: Harmonization of agency plans with Department's priorities (7th Programme Committee Coordination Meeting)

Dillon, C. R. (1992). Microeconomic effects of reduced yield variability cultivars of soybeans and wheat. *Journal of Agricultural and Applied Economics, 24*(1), 121-133.

DoA. (2015). *Implementation framework and guidelines for supply of bio-inputs in the country*. Thimphu, Bhutan: Department of Agriculture, Royal Government of Bhutan

Dorji, C. (2019, 16th Jan 2020.). Potato farmers of Gangteng and Phobji use more fertilisers for better yield. Retrieved from http://www.bbs.bt/news/?p=112250

Drucker, P. F. (1999). *Management* (abridged, reprint, reissue ed.): Taylor & Francis.

Druk Nyamrup Tshogpa (DNT). (2018). *Druk Nyamrup Tshogpa's Manifestos*. Thimphu: Election Commission of Bhutan (ECB). Royal Government of Bhutan

Duba, S., Ghimiray, M., & Gurung, T. R. (2008). Promoting organic farming in Bhutan: A review of policy, implementation and constraints. *Council for RNR Research of Bhutan, Ministry of Agriculture, Thimphu, Bhutan*.

Dwivedi, D. N. (2002). *Microeconomics: Theory And Applications*: Pearson Education India.

Edmondson, J. L., Davies, Z. G., Gaston, K. J., & Leake, J. R. (2014). Urban cultivation in allotments maintains soil qualities adversely affected by conventional agriculture. *Journal of Applied Ecology, 51*(4), 880-889. doi:10.1111/1365-2664.12254

Eghball, B., & Power, J. F. (1999). Composted and noncomposted manure application to conventional and no-tillage systems: Corn yield and nitrogen uptake. *Agronomy journal, 91*(5), 819-825.

FAO. (2009). *Sustainable Potato Production - Guidelines For Developing Countries*: Food and Agriculture Organization of the United Nations

FAO. (2016). Climate change and food security: risks and responses. *Food and Agriculture Organization of the United Nations (FAO) Report, 110*.

FAO. (2017). *Productivity and Efficiency Measurement in Agriculture - Literature Review and Gaps Analysis* Food and Agriculture Organization of the United Nations (FAO).

FAO. (2018). *Guidelines for the measurement of productivity and efficiency in agriculture* (S. Pasetto Ed.): Food and Agriculture Organization of the United Nations (FAO).

FAOSTAT. (2017). FAO, statistical databases. Retrieved 18th Jan 2020, from FAO http://www.fao.org/faostat/en/#data/QC.

Farmer, B. (1986). Perspectives on the 'Green Revolution'in South Asia. *Modern Asian Studies, 20*(1), 175-199.

Feuerbacher, A., Luckmann, J., Boysen, O., Zikeli, S., & Grethe, H. (2018). Is Bhutan destined for 100% organic? Assessing the economy-wide effects of a large-scale conversion policy. *PloS one, 13*(6), 24.

Finckh, M., Schulte-Geldermann, E., & Bruns, C. (2006). Challenges to organic potato farming: disease and nutrient management. *Potato Research, 49*(1), 27-42.

Folberth, C., Yang, H., Gaiser, T., Liu, J., Wang, X., Williams, J., & Schulin, R. (2014). Effects of ecological and conventional agricultural intensification practices on maize yields in sub-Saharan Africa under potential climate change. *Environmental Research Letters, 9*(4), 044004.

Froehlich, A. G., Melo, A. S., & Sampaio, B. (2018). Comparing the profitability of organic and conventional production in family farming: Empirical evidence from Brazil. *Ecological economics, 150*, 307-314.

Gasc¢-Hernandez, M., & Torres-Coronas, T. (2009). *Information Communication Technologies and City Marketing: Digital Opportunities for Cities Around the World: Digital Opportunities for Cities Around the World* (M. Gasc¢-Hernandez, Torres-Coronas, Teresa Ed.): IGI Global, 2009.

Ghimiray, M., Katwal, T. B., Tshering, K., Dorjee, Dukpa, W., Lakey, . . . Ngawang. (2019). *Agriculture Research Strategy 2018-2028*. Thimphu, Bhutan: Agriculture Research and Extension Division (ARED), Department of Agriculture.

Gliessman, S., Werner, M., Swezey, S., Caswell, E., Cochran, J., & Rosado-May, F. (1996). Conversion to organic strawberry management changes ecological processes. *California Agriculture, 50*(1), 24-31.

Grewal, J., Sharma, R. C., & Sud, K. (1981). Effect of continuous application of PK-fertilizers and farmyard manure on potato yield and some soil properties. *Journal of the Indian Society of Soil Science, 29*(1), 129-131.

Grove, S. K., & Cipher, D. J. (2019). *Statistics for Nursing Research - E-Book: A Workbook for Evidence-Based Practice*: Elsevier Health Sciences.

Gyem, T. (2012). Living Gross National Happiness. In *Organic without Boundaries. IFOAM Celebrating 40 years, 1972-2012* (pp. 43): IFOAM.

Hay, W. W. (1982). *Railroad Engineering*: Wiley.

Heinrichs, J., Kuhn, T., Pahmeyer, C., & Britz, W. (2021). Economic effects of plot sizes and farm-plot distances in organic and conventional farming systems: A farm-level analysis for Germany. *Agricultural Systems, 187*, 9. doi:10.1016/j.agsy.2020.102992

Herencia, J. F., & Maqueda, C. (2016). Effects of time and dose of organic fertilizers on soil fertility, nutrient content and yield of vegetables. *Journal of Agricultural Science, 154*(8), 1343-1361. doi:10.1017/s0021859615001136

Hirel, B., Le Gouis, J., Ney, B., & Gallais, A. (2007). The challenge of improving nitrogen use efficiency in crop plants: towards a more central role for genetic variability and quantitative genetics within integrated approaches. *Journal of Experimental Botany, 58*(9), 2369-2387. doi:10.1093/jxb/erm097

Hossain, M., & Salam, M. T. B. (2019). Changes in Soil Physico-Chemical Properties and Fertility Status of Long-Term Cultivated Soils in Southwestern Bangladesh. *Malaysian Journal of Soil Science, 23*, 31-41.

ICIMOD. (2018). *Organic Agriculture Development Strategies: Roadmap for 12th Five Year Plan and Beyond*. Integrated Centre for Mountain Development (ICIMOD)

Ierna, A., & Parisi, B. (2014). Crop growth and tuber yield of "early" potato crop under organic and conventional farming. *Scientia Horticulturae, 165*, 260-265. doi:10.1016/j.scienta.2013.11.032

IFOAM. (2015a). Fulfilling The Organic Vision. In: IFOAM Organics International.

IFOAM. (2015b). *Into the future. Consolidated annual report of IFOAM - organics international*. Retrieved from https://www.ifoam.bio/sites/default/files/annual_report_2015_0.pdf

IFOAM. (2015c). Organic Agriculture & Food Security. In (pp. 2): IFOAM Organics International.

IFOAM. (2017). Organic 3.0 - for truly sustainable farming and consumption. In: IFOAM - Organics International.

IFOAM. (2018). *Consolidated Annual Report of IFOAM - Organics International & its Action Group* Retrieved from https://www.ifoam.bio/sites/default/files/annualreport_2018.pdf

IPNI. (2021). Nutrient Source Specifics. In International Plant Nutrition Institute (IPNI) (Ed.), (Vol. 21, pp. 1). USA.

Jarvis, S. C., Stockdale, E. A., Shepherd, M. A., & Powlson, D. S. (1996). Nitrogen mineralization in temperate agricultural soils: processes and measurement. *Advances in agronomy, 57*, 187-235.

Jeyaseeli, P., Jeyamangalam, F., Selvaraj, S., & Vella Durai, S. (2021). Investigation of physico–chemical, physical properties and moisture content studies of soil using organic amendment. *International Journal of Agricultural Technology, 17*(3), 855-870.

Julio, G., Ruiz, I., & Cuesta, X. (2018). Expanding the agricultural frontier of the potato (*solanum tuberosum l.*) to reduce the effects of climate change. *Revista Universidad Y Sociedad, 10*(1), 46-51. Retrieved from <Go to ISI>://WOS:000437894000007

Juyjaeng, C.-o., & Suwanmaneepong, S. (2017). Comparison of Costs and Returns on Oil Palm Production of Member and Non-member Farmers under Large Agricultural Plot Scheme in Bang Saphan Noi District, Prachuap Khiri Khan Province. *International Journal of Agricultural Technology, 13*(7.2), 1923-1936.

Kahan, D. (2010). *Farm business analysis using benchmarking*. Rome: Food and Agriculture Organization of the United Nations (FAO).

Kahan, D. (2013). *Economics for farm management extension*: Food and Agriculture Organization of the United Nations (FAO)

Kalra, R., & Thanavisuth, C. (2018). Do you Like My English? Thai Students' Attitudes towards Five Different Asian Accents. *Arab World English Journal, 9*(4), 281-294. doi:10.24093/awej/vol9no4.21

Kimathi, S. M., Ayuya, O. I., & Mutai, B. (2020). Adoption of climate-resilient potato varieties under partial population exposure and its determinants: Case of smallholder farmers in Meru County, Kenya. *Cogent Food & Agriculture, 7*(1), 18. doi:10.1080/23311932.2020.1860185

Kothari, C. R. (2004). *Research methodology: Methods and techniques*. New Delhi, India: New Age International Publishers.

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and psychological measurement, 30*(3), 607-610.

Laibuni, N. M., & Omiti, J. M. (2014). Market Structure and Price: An empirical analysis of Irish potato markets in Kenya. *Future Agricultures Consortium: Nairobi, Kenya*.

Lhamo, P. (2019, 16th Jan 2020). In Phobji and Gangtey, farmers compete to use more fertilisers. Retrieved from https://kuenselonline.com/in-phobji-and-gangtey-farmers-compete-to-use-more-fertilisers/

Lichtenberg, P. A. (2010). *Handbook of Assessment in Clinical Gerontology*: Elsevier Science.

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of psychology*.

Lipsey, R. G. (1975). An introduction to positive economics, 4th Edition Weidenfeld and Nicolson. 214-217.

Lipsey, R. G., Chrystal, K. A., & Chrystal, K. A. (1995). *An introduction to positive economics*: Oxford university press oxford.

Lyngbaek, A. E., & Muschler, R. G. (2001). Productivity and profitability of multistrata organic versus conventional coffee farms in Costa Rica. *Agroforestry systems, 53*(2), 205-213.

Lyngbaek, A. E., Muschler, R. G., & Sinclair, F. L. (2001). Productivity and profitability of multistrata organic versus conventional coffee farms in Costa Rica. *Agroforestry systems, 53*(2), 205-213. doi:10.1023/a:1013332722014

Maggio, A., Carillo, P., Bulmetti, G. S., Fuggi, A., Barbieri, G., & De Pascale, S. (2008). Potato yield and metabolic profiling under conventional and organic farming. *European Journal of Agronomy, 28*(3), 343-350. doi:10.1016/j.eja.2007.10.003

Mahler, R. L. (2004). Nutrients Plants Require for Growth. In (pp. 4): University of Idaho, College of Agricultural and Life Sciences.

Mallory, E., & Griffin, T. (2007). Impacts of soil amendment history on nitrogen availability from manure and fertilizer. *Soil Science Society of America Journal, 71*(3), 964-973.

Mankeb, P., Limunggura, T., In-Go, A., & Chulilung, P. (2014). Adoption of Good Agricultural Practices by Durian Farmers in Koh Samui District, Surat Thani Province, Thailand.

Martuza, V. R. (1977). *Applying norm-referenced and criterion-referenced measurement in education*: Allyn & Bacon, Incorporated.

McCrae-Hokenson, M. (2014). Organic Agriculture in Bhutan: Barriers Going to 100%. *Independent Study Project (ISP) Collection, 1827.* Retrieved from https://digitalcollections.sit.edu/isp_collection/1827

Mendoza, T. C. (2004). Evaluating the benefits of organic farming in rice agroecosystems in the Philippines. *Journal of Sustainable Agriculture, 24*(2), 93-115. doi:10.1300/J064v24n02_09

Mikkelsen, R. (2006). Best management practices for profitable fertilization of potatoes. *Magnesium (Mg), 25*(15), 40.

Ministry of Agriculture and Forests (MoAF). (2020). *Agriculture Statistics 2019*. Thimphu, Bhutan: Renewable Natural Resources Ststistics Division (RSD)

Ministry of Agriculture and Forests [MoAF]. (2019). *Bhutan RNR Statistics 2018* Thimphu: Renewable Natural Resources Statistics Division, Directorate Services, Royal Government of Bhutan

MoAF. (2020). *Agriculture Statistics 2019*. Thimphu: Renewable Natural Resources Statistics Division (RSD), Royal Government of Bhutan

Montanarella, L., Badraoui, M., Chude, V., Baptista Costa, I. D. S., Mamo, T., Yemefack, M., . . . Vijarnsorn, P. (2015). Status of the World's Soil Resources Main report.

Morshedi, L., Lashgarara, F., Hosseini, S. J. F., & Najafabadi, M. (2017). The Role of Organic Farming for Improving Food Security from the Perspective of Fars Farmers. *Sustainability, 9*(11), 13. doi:10.3390/su9112086

Muchow, R. (1998). Nitrogen utilization efficiency in maize and grain sorghum. *Field Crops Research, 56*(1-2), 209-216.

Musyoka, M. W., Adamtey, N., Muriuki, A. W., & Cadisch, G. (2017). Effect of organic and conventional farming systems on nitrogen use efficiency of potato, maize and vegetables in the Central highlands of Kenya. *European Journal of Agronomy, 86*, 24-36. doi:10.1016/j.eja.2017.02.005

Naseer, M., Mehdi, M., Ashfaq, M., Hassan, S., & Abid, M. (2019). Effect of marketing channel choice on the profitability of citrus farmers: Evidence form Punjab-Pakistan. *Pakistan Journal of Agricultural Sciences, 56*(4), 1003-1011. doi:10.21162/pakjas/19.8671

National Center for Hydrology and Meteorology. (2020). *Annual report 2019-2020*. Retrieved from Thimphu:Bhutan:

National Organic Programme [NOP]. (2017). *National Organic Program (NOP): Major achievements 2016-2017 (Annual report)*. Thimphu: Department of Agriculture, Royal Government of Bhutan

National Potato Programme. (2019). Progress on ITPGRFA/CIP. Thimphu, Bhutan: National Potato Programme (NPP).

National Statistical Bureau [NSB]. (2017). *Bhutan living standards survey report 2017*. Bhutan: National Statistics Bureau (NSB), Royal Government of Bhutan

Netayarak P. (2007). *Agricultural economics*. Bangkok: Thammasat University Press.

Neuhoff, D., Tashi, S., Rahmann, G., & Denich, M. (2014). Organic agriculture in Bhutan: potential and challenges. *Organic Agriculture, 4*(3), 209-221. doi:10.1007/s13165-014-0075-1

Nmadu, J. N., & Simpa, J. O. (2014). *Rethinking the technical efficiency of small scale yam farmers in Nigeria using conventional and non-conventional inefficiency parameters*. Retrieved from

Norbu, C., & Floyd, C. (2004). Changing soil fertility management in Bhutan: Effects on practices, nutrient status and sustainability.

Norris, C. E., & Congreves, K. A. (2018). Alternative Management Practices Improve Soil Health Indices in Intensive Vegetable Cropping Systems: A Review. *Frontiers in Environmental Science, 6*, 18. doi:10.3389/fenvs.2018.00050

NSB. (2011). Annual Dzongkhag Statistics 2011 (Dzongkhag Administration Gasa). In N. S. Bureau (Ed.), (pp. i-iii, 1-48). Bhutan: National Statistics Bureau.

NSSC. (2008). Field Crops soil sampling (Leaflet No.2). Retrieved 17th Feb 2020, from National Soil Service Centre (NSSC), Dept. of Agriculture http://www.nssc.gov.bt/wp-content/uploads/2013/08/Field-Crops-Soil-Sampling.pdf

Nunan, D., & David, N. (1992). *Research methods in language learning*: Cambridge University Press.

Nwosisi, S. I. (2017). *Performance Evaluation of Organically Grown Sweetpotato Varieties, Nutritional and Cost-Benefit Analysis.* (Ph.D.). Tennessee State University, Ann Arbor. Retrieved from https://search.proquest.com/docview/1964388252?accountid=50158 ProQuest Dissertations & Theses Global database. (10615383)

Organisation for Economic Co-operation and Development [OECD]. (2001). *Measuring productivity-OECD Manual: Measurement of Aggregate and Industry-Level Productivity Growth*: Organisation for Economic Co-operation and Development.

Palmer, M. W., Cooper, J., Tetard-Jones, C., Srednicka-Tober, D., Baranski, M., Eyre, M., . . . Bilsborrow, P. E. (2013). The influence of organic and conventional fertilisation and crop protection practices, preceding crop, harvest year and weather conditions on yield and quality of potato (Solanum tuberosum) in a long-term management trial. *European Journal of Agronomy, 49*, 83-92. doi:10.1016/j.eja.2013.03.004

Parnell, G. S., Driscoll, P. J., & Henderson, D. L. (2011). *Decision Making in Systems Engineering and Management*: Wiley.

Paul, E. (2014). *Soil Microbiology, Ecology and Biochemistry*: Elsevier Science.

Population & Housing Census of Bhutan [PHCB]. (2017). *Population & Housing Census of Bhutan (PHCB) 2017* Bhutan: National Statistics Bureau, Royal Government of Bhutan

Poungsuk, P., Junlek, P., & Poeaim, S. (2018). Facilitation of organic agricultural learning in school and community. *International Journal of Agricultural Technology, 14*(7 Special Issue), 1669-1678.

Qaim Matin, & Arjunan, S. (2010). Benefits of Transgenic Plants: a Socioeconomic Perspective. In F. Kempken & C. Jung (Eds.), *Genetic Modification of Plants: Agriculture, Horticulture and Forestry* (pp. 615-627): Heidelberg : Springer.

Rajasekaran, V. (2010). *Cost Accounting*: Pearson Education India.

Rana, R. K., & Anwer, M. E. (2018). Potato production scenario and analysis of its total factor productivity in India. *Indian Journal of Agricultural Sciences, 88*(9), 1354-1361. Retrieved from <Go to ISI>://WOS:000445542200005

Randolph, J. (2004). *Environmental Land Use Planning and Management*: Island Press.

Reddy, K. R., & DeLaune, R. D. (2008). *Biogeochemistry of Wetlands: Science and Applications*: CRC Press.

Robinson, T. R., Henry, E., Pirie, W. L., Broihahn, M. A., & Cope, A. T. (2012). *International Financial Statement Analysis* (2 ed.). New Jersey: Wiley.

Roder, W., Nidup, K., & Chettri, G. B. (2008). *The Potato in Bhutan*. Thimphu: Bhutan Potato Development Progam.

Rosenbaum, J., Pearl, J., Perella, J. R., & Harris, J. (2013). *Investment Banking: Valuation, Leveraged Buyouts, and Mergers and Acquisitions* (2 ed.): Wiley.

Rovinelli, R., & Hambleton, R. (1977). On the use of content specialists in the assessment of criterion-referenced test item validity. *Tijdschrift voor Onderwijsresearch, 2*, 49-60.

Seldon, P. (2019, 23rd Nov 2019). Nu 1 billion flagship program for organic farming with Sikkim in mind. Retrieved from https://thebhutanese.bt/nu-1-billion-flagship-program-for-organic-farming-with-sikkim-in-mind/

Seufert, V., Ramankutty, N., & Foley, J. A. (2012). Comparing the yields of organic and conventional agriculture. *Nature, 485*(7397), 229-U113. doi:10.1038/nature11069

Sgroi, F., Candela, M., Di Trapani, A. M., Fodera, M., Squatrito, R., Testa, R., & Tudisca, S. (2015). Economic and Financial Comparison between Organic and Conventional Farming in Sicilian Lemon Orchards. *Sustainability, 7*(1), 947-961. doi:10.3390/su7010947

Sgroi, F., Fodera, M., Di Trapani, A. M., Tudisca, S., & Testa, R. (2015). Cost-benefit analysis: A comparison between conventional and organic olive growing in the Mediterranean Area. *Ecological Engineering, 82*, 542-546. doi:10.1016/j.ecoleng.2015.05.043

Sharifi, O., Sadati, S. A., Ghobadi, F. R., Sadati, S. A., Mohamadi, Y., & Del, P. T. T. (2010). Barriers to conversion to organic farming: A case study in Babol County in Iran. *African Journal of Agricultural Research, 5*(16), 2260-2267.

Sidhu, A. S., Thind, S. S., Sekhon, N. K., & Hira, G. S. (2007). Effect of farmyard manure and p application to potato on available p and crop yield of potato (Solanum tuberosum)-sunflower (Helianthus annuus) sequence. *Journal of Sustainable Agriculture, 31*(2), 5-15. doi:10.1300/J064v31n02_03

Sinha, N., Hui, Y. H., Evranuz, E. Ö., Siddiq, M., & Ahmed, J. (2010). *Handbook of Vegetables and Vegetable Processing*: Wiley.

Suanthaisong, D., Mankeb, P., & Limunggura, T. (2016). Factors affecting rice seed production of farmers in Sakon-Nakhon province, Thailand. *International Journal of Agricultural Technology, 12*(7.1), 1501-1510.

Subedi, K., & Ma, B. (2009). Corn crop production: growth, fertilization and yield. *Agriculture issues and policies*.

Suwanmaneepong, S., Kerdsriserm, C., Lepcha, N., Cavite, H. J., & Llones, C. A. (2020). Cost and return analysis of organic and conventional rice production in Chachoengsao Province, Thailand. *Organic Agriculture, 10*(3), 1-10. doi:10.1007/s13165-020-00280-9

Tashi, S., & Wangchuk, K. (2016). Organic vs. conventional rice production: comparative assessment under farmers' condition in Bhutan. *Organic Agriculture, 6*(4), 255-265. doi:10.1007/s13165-015-0132-4

Te Pas, C. M., & Rees, R. (2014). Analysis of differences in productivity, profitability and soil fertility between organic and conventional cropping systems in the tropics and sub-tropics. *Journal of Integrative Agriculture, 13*(10), 2299-2310.

Thorpe, E., & Thorpe, S. (2011). The Pearson CSAT Manual 2011, Dorling Kindersley (India) Pvt. *Ltd., New Delhi*.

Tiffany, P., & Peterson, S. D. (2011). *Business Plans For Dummies*: Wiley.

Tisdale, S., Nelson, W., Beaton, J., & Havlin, J. (1993). Soil fertility and fertilizers., 5th edn (Macmillan: New York). In: NY.

Turhan, S., Ozbag, B. C., & Rehber, E. (2008). A comparison of energy use in organic and conventional tomato production. *Journal of Food Agriculture & Environment, 6*(3-4), 318-321. Retrieved from <Go to ISI>://WOS:000260597200065

Uematsu, H., & Mishra, A. K. (2012). Organic farmers or conventional farmers: Where's the money? *Ecological economics, 78*, 55-62. doi:10.1016/j.ecolecon.2012.03.013

United Nations Development Program [UNDP]. (2015). Sustainable development goals. Retrieved 2nd Feb 2020, from United Nations Development Program (UNDP) https://www.undp.org/content/undp/en/home/sustainable-development-goals.html

Vaishnav, A., & Choudhary, D. K. (2021). *Microbial Polymers: Applications and Ecological Perspectives*: Springer Singapore.

Verma, H. V. (2011). *Services Marketing: Text and Cases, 2/e*: Pearson Education India, 2011.

Wangmo, S., & Iwai, C. B. (2018). Performance of Organic Agriculture (OA) based on Emergent Properties of Agriculture System in Gasa, Bhutan. *Khon Kaen Agriculture Journal, 1985*(1986), 1202-1210.

Wheeler, S. A. (2008). The barriers to further adoption of organic farming and genetic engineering in Australia: views of agricultural professionals and their information sources. *Renewable Agriculture and Food Systems, 23*(2), 161-170. doi:10.1017/s1742170507002128

Willer, H., & Lernoud, J. (2019). *The world of organic agriculture. Statistics and emerging trends 2019*: Research Institute of Organic Agriculture FiBL and IFOAM Organics International.

# 7. Appendix

## 7.1 Questionnaire

**Questionnaire**

to obtain data for a Ph.D. (Agriculture) research on

"An Assessment of Organic and Conventional Potato Production in West-Central Bhutan".

**Declaration and Confidentiality:**

The information obtained through this interview will be solely used for an academic research purpose of Mr.Norden Lepcha, pursuing Ph.D. in Agriculture at the King Mongkut's Institute of Technology Ladkrabang (KMITL), Bangkok, Thailand, holding student I.D no: 62604001. The research is fully supported by the KMITL.

The interviewer takes the full responsibility in keeping the confidentiality of all the information obtained through this interview.

**Enumerator Identification:**

Name:______________________________Date of interview (DD/MM/YR):____________

Start time: ________ End time: __________ Place of interview: _______________

Signature of Enumerator: ________________________

**Section I: Farm and farmer's Characteristics.**

**Note: Please tick ✓ an appropriate option**

**A. General Information**

1. Name: _________________________________
2. Gender: ☐1 Male ☐2 Female
3. Age: ________
4. District: ☐1 Gasa ☐2 Wangdue Phodrang
5. *Gewog* (Block): ☐1 Khatoed ☐2 Phobji

6. *Chiwog:*______________________
7. Village:_______________________

**B. Socio-economic profile**

**i) Social profile**

8. Marital status: ☐1 Single ☐2 Married ☐3 Widow/er ☐4 Divorce
9. Education level: ☐1 Illiterate ☐2 Non-formal education ☐3 Primary School (1-6 grade) ☐4 Middle School (7-8 grade) ☐5 Lower secondary ( 9-10 grade) ☐6 Upper Secondary (11-12 grade) ☐7 Bachelor degree (+ 3 years).
10. Secondary occupation: ☐1 None ☐2 Side retail business ☐3 Farm labourer ☐4 Masonry/carpentry ☐5 Others (specify)_______________________
11. Household size (nos.) ________
12. Family labour (nos.) _________

**ii) Farm size**

13. Total agricultural land (ac)______
14. Leased in land (ac)_______
15. Net cultivated area (ac)_________
16. Total potato cultivated area (ac) in 2019_____
17. Total potato production (kgs) in 2019_____
18. *Potato productivity (ton/ha)* ________.

**iii) Farming experience/networking**

19. Years in ☐Organic/☐Conventional potato farming: ______
20. Attend farmers' training on crop production/year _________numbers.
21. How often do you contact the Agricultural officials to seek crop/market related information? ☐0 Never ☐1 Frequent ☐2 Seldom
22. Are you a member of any farmers' group/cooperative ☐1 Yes ☐2 No (If Yes, specify i)_______________________ii)____________________iii)__________________________
23. Which potato variety do you grow? ☐1 *Desiree* ☐2 *Kufri Jyoti* ☐3 *Yusikap* ☐ 4 *Khangma kewa kap* ☐5 *Nasaphey kewa kaap* ☐6 *Yusi Maap* ☐7 *Others (specify):*_______________

**Section II: Production cost.**

**A) Variable Cost (VCs)**

**i) Farm inputs cost**

| 24.Item | PURCHASED/RENTED (Cash) | | | | OWNED (Non-cash) | | | | Other related information |
|---|---|---|---|---|---|---|---|---|---|
| | 25.Qty | 26.Unit | 27.Unit cost (Nu) | 28.Total (Nu) | 29.Qty | 30.Unit | 31.Unit cost (Nu) | 32.Total (Nu) | |
| 1. Potato seeds | | | | | | | | | |
| 2. Green manure seeds<br>☐1 Pea ☐2 Cowpea ☐3 Beans<br>☐4 Others<br>(Specify___________________________) | | | | | | | | | |
| 3. Urea | | | | | | | | | |
| 4. Suphala | | | | | | | | | |
| 5. Single Super Phosphate (SSP) | | | | | | | | | |
| 6. Muriate of Potash (MOP) | | | | | | | | | |
| 7. Other chemical fertilizer (Specify: ________________) | | | | | | | | | |

| 24.Item | PURCHASED/RENTED (Cash) | | | | OWNED (Non-cash) | | | | Other related information |
|---|---|---|---|---|---|---|---|---|---|
| | 25.Qty | 26.Unit | 27.Unit cost (Nu) | 28.Total (Nu) | 29.Qty | 30.Unit | 31.Unit cost (Nu) | 32.Total (Nu) | |
| 8. Farmyard manure (FYM) | | | | | | | | | |
| 9. Other organic fertilizer (Specify: ________________) | | | | | | | | | |
| 10. Other organic fertilizer (Specify: ________________) | | | | | | | | | |
| 11. Insecticide cost | | | | | | | | | 33.Specify the insecticide(s): |
| 12. Fungicide cost | | | | | | | | | 34. Specify the fungicide(s): |
| 13. Herbicide cost | | | | | | | | | 35. Specify the |

| 24.Item | PURCHASED/RENTED (Cash) | | | | OWNED (Non-cash) | | | | Other related information |
|---|---|---|---|---|---|---|---|---|---|
| | 25.Qty | 26.Unit | 27.Unit cost (Nu) | 28.Total (Nu) | 29.Qty | 30.Unit | 31.Unit cost (Nu) | 32.Total (Nu) | |
| | | | | | | | | | herbicide(s) : |
| 14. Power tiller/tractor rental cost | | | | | | | | | |
| 15. Fuel and other lubricants cost in case of owned Power tiller/tractor | | | | | | | | | |

**ii) Labour costs**

| 36.Activity | Hired labour (Cash) | | | | | | | | Family labour (Non-cash) | | | | Exchange labour (Non-cash) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | | | Female | | | | | | | | | | | |
| | 37.Persons | 38.Man-days | 39.Unit-cost (Nu) | 40.Total (Nu) | 41.Persons | 42.Man-days | 43.Unit-cost (Nu) | 44.Total (Nu) | 45.Persons | 46.Man-days | 47.Unit-cost for meals (Nu) | 48.Total (Nu) | 49.Persons | 50.Man-days | 51. Unit-cost for meals (Nu) | 52.Total (Nu) |
| 1.Land preparation | | | | | | | | | | | | | | | | |

| 36.Activity | Hired labour (Cash) | | | | | | | | Family labour (Non-cash) | | | | Exchange labour (Non-cash) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Male | | | | Female | | | | | | | | | | | |
| | 37.Persons | 38.Man-days | 39.Unit-cost (Nu) | 40.Total (Nu) | 41.Persons | 42.Man-days | 43.Unit-cost (Nu) | 44.Total (Nu) | 45.Persons | 46.Man-days | 47.Unit-cost for meals (Nu) | 48.Total (Nu) | 49.Persons | 50.Man-days | 51. Unit-cost for meals (Nu) | 52.Total (Nu) |
| 2.Compost/FYM application | | | | | | | | | | | | | | | | |
| 3. ☐Planting/ ☐Fertilizing/manuring | | | | | | | | | | | | | | | | |
| 4. Weeding and earthing up | | | | | | | | | | | | | | | | |
| 5. Irrigation | | | | | | | | | | | | | | | | |
| 6. Application of ☐herbicides/☐pesticides/☐bio-pesticides | | | | | | | | | | | | | | | | |
| 7. Potato harvesting/curing | | | | | | | | | | | | | | | | |

**A) Fixed Costs**

53.Land tax (Nu.) _______________

54. Land rent (Nu.) ______________

**Depreciation cost (Annual depreciation expense for a machine/farm equipment)**

| 55.Type of machine/farm equipment | 56. Asset cost (Nu) | 57. Useful life of the asset (years) | 58.Salvage/residual value (Nu) |
|---|---|---|---|
| 1. Tractor | | | |
| 2. Power tiller | | | |
| 3. Pesticide spray machine | | | |
| 4. Other (specify): | | | |

**Section III: Marketing information**

59. Qty of potato sold in 2019? ________(kgs)

60. Unit selling price in the market? (_________big size/50 kg bag _________medium size /50 kg bag ___________small size/50 kg bag)

61. Any extra income (premium) earned per kg of potato? Nu.________

62. Farm-gate price? (_________big size/50 kg bag _________medium size/50 kg bag ___________Small size/50 kg bag).

63. Marketing place? ☐1 Domestic market (Capital city) ☐2 Domestic market (High end tourist resorts) ☐3 Domestic market (local market) ☐4 Export market ☐5 Both domestic and export market.

64. How you market? ☐1 Individually ☐2 Group

65. How long your farm is certified organic? ☐1 more than 3 years ☐2 For 3 years ☐3 for 2 years ☐4 for 1 year

66. Certified organic under which brand? ☐1 Local Organic Assurance System (LOAS) ☐2 Bhutan Agriculture and Food Regulatory Authority (BAFRA) certification ☐3 Others (specify)___________________

**Section IV. Factors constraining potato production and marketing in the region:**

| | | | | | |
|---|---|---|---|---|---|
| **I) Labour constraints** | | | | | |
| 67. Unavailability of farm labour | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| 68. Labour hiring is expensive | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| **ii) Supply of inputs** | | | | | |
| 69. The supply of farm inputs is inadequate | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| 70. Seeds supply is inadequate | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| 70A. Fertilizers supply is inadequate | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| 70B. ☐Pesticides/☐bio-pesticides supply is inadequate | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| 71. Farm inputs are not accessible on time | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| 71A. Seeds are not accessible on time | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |

| | | | | | |
|---|---|---|---|---|---|
| 71B. Fertilizers are not accessible on time | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| 71C. ☐Pesticides/☐bio-pesticides are not accessible on time | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| **iii) Farm machineries constraints** | | | | | |
| 72. Does not own farm machineries (like power tiller). | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| 73. Unavailability of farm machineries for hiring | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| 74. Farm machineries are expensive to hire | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| **IV) Management constraints** | | | | | |
| **V) Pest and diseases, post-harvest, and marketing constraints** | | | | | |
| **i) Pest and diseases constraints** | | | | | |
| 75. Pest and disease problems in potato field | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| If agree then specify 1)________________________2)_________________________ 3)______________________________ | | | | | |
| 76. Damage of potato by wild animals | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| If agree then specify 1)________________________2)_________________________ 3)______________________________ | | | | | |
| **ii) Post harvest and marketing constraints** | | | | | |
| 77. Inadequate post-harvest facilities like | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |

| | | | | | |
|---|---|---|---|---|---|
| grading and storage facilities | | | | | |
| 78. Difficulties in accessing the markets | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| 79. Imported potato competes with local | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| 80. Price received is inadequate | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| 81. No premium price for your produce | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| 82. Roads are not easily accessible | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| **VI) Productivity and other constraints** | | | | | |
| 83. Land productivity is low | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| 84. Irrigation problems | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |
| 85. Climate change affects production | ☐1 Strongly agree | ☐2 Agree | ☐3 Undecided | ☐4 Disagree | ☐5 Strongly disagree |

❖ THANK YOU FOR YOUR TIME AND PATIENCE

## 7.2 Item-objective congruence (IOC) ratings for a survey questionnaire

| Sl.no | Item | Index of Item-Objective Congruence (IOC) | Ratings on each objective by three experts | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Objective 1: Socio-demographic, production, marketing, constraints | | | Objective 2: Compare productivity and profitability. | | |
| | | | Expert 1 | Expert 2 | Expert 3 | Expert 1 | Expert 2 | Expert 3 |
| 1 | Name? | 6 | 1 | 1 | 1 | 0 | -1 | -1 |
| 2 | Age? | 6 | 1 | 1 | 1 | 0 | -1 | -1 |
| 3 | Marital status? | 6 | 1 | 1 | 1 | -1 | -1 | 0 |
| 4 | Schooling years? | 6 | 1 | 1 | 1 | 0 | -1 | -1 |
| 5 | Secondary occupation? | 6 | 1 | 1 | 1 | 0 | -1 | -1 |
| 6 | Household size (numbers)? | 6 | 1 | 1 | 1 | 0 | -1 | -1 |
| 7 | Family labour (numbers)? | 6 | 1 | 1 | 1 | 0 | -1 | -1 |
| 8 | Total agricultural land? | 6 | 1 | 1 | 1 | -1 | 0 | -1 |
| 9 | Leased in land? | 6 | 1 | 1 | 1 | -1 | 0 | -1 |
| 10 | Net cultivated area? | 6 | 1 | 1 | 1 | 0 | -1 | -1 |
| 11 | Total potato cultivated area (acre) in 2019? | 5 | -1 | -1 | 0 | 1 | 1 | 0 |
| 12 | Total potato production (tons) in 2019 | 5 | 0 | -1 | -1 | 1 | 1 | 0 |
| 13 | Years in Organic/Conventional potato farming? | 5 | 1 | 1 | 0 | -1 | -1 | 0 |
| 14 | How many times do you attend farmers' training on crop production per year? | 6 | 1 | 1 | 1 | -1 | -1 | 0 |
| 15 | How often do you contact Agricultural officials to seek crop/market related information? | 6 | 1 | 1 | 1 | -1 | -1 | 0 |

| Sl.no | Item | Index of Item-Objective Congruence (IOC) | Ratings on each objective by three experts | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Objective 1: Socio-demographic, production, marketing, constraints | | | Objective 2: Compare productivity and profitability. | | |
| | | | Expert 1 | Expert 2 | Expert 3 | Expert 1 | Expert 2 | Expert 3 |
| 16 | Are you a member of any farmers' group/cooperative? | 6.5 | 1 | 1 | 0 | -1 | -1 | -1 |
| 17 | Which potato variety do you grow? | 6 | 1 | 1 | 1 | 0 | -1 | -1 |
| 18 | Potato seeds cost? | 5 | -1 | -1 | 0 | 1 | 1 | 0 |
| 19 | Urea cost? | 6 | 0 | -1 | -1 | 1 | 1 | 1 |
| 20 | Suphala cost | 6 | 0 | -1 | -1 | 1 | 1 | 1 |
| 21 | Single Super Phosphate (SSP) cost | 6 | 0 | -1 | -1 | 1 | 1 | 1 |
| 22 | Muriate of Potash (MOP) cost | 6 | 0 | -1 | -1 | 1 | 1 | 1 |
| 23 | Other chemical fertilizer cost (Specify: ________________) | 6 | 0 | -1 | -1 | 1 | 1 | 1 |
| 24 | Farmyard manure (FYM) cost? (purchased/owned) | 6 | 0 | -1 | -1 | 1 | 1 | 1 |
| 25 | Other organic fertilizer cost (purchased/owned) | 5 | -1 | -1 | 0 | 1 | 1 | 0 |
| 26 | Insecticide cost? | 5 | -1 | -1 | 0 | 1 | 1 | 0 |
| 27 | Fungicide cost? | 5 | -1 | -1 | 0 | 1 | 1 | 0 |
| 28 | Herbicide cost? | 5 | -1 | -1 | | 1 | 1 | 0 |
| 29 | Power tiller/tractor rental cost? | 5 | -1 | -1 | 0 | 1 | 1 | 0 |
| 30 | Fuel and other lubricants costs in case of owned Power tiller/tractor? | 5 | -1 | -1 | 0 | 1 | 1 | 0 |
| 31 | Land preparation cost? | 6 | -1 | -1 | 0 | 1 | 1 | 1 |

| Sl.no | Item | Index of Item-Objective Congruence (IOC) | Ratings on each objective by three experts | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Objective 1: Socio-demographic, production, marketing, constraints | | | Objective 2: Compare productivity and profitability. | | |
| | | | Expert 1 | Expert 2 | Expert 3 | Expert 1 | Expert 2 | Expert 3 |
| 32 | Planting cost? | 6 | 0 | -1 | -1 | 1 | 1 | 1 |
| 33 | Fertilizing/manuring cost? | 6 | -1 | -1 | 0 | 1 | 1 | 1 |
| 34 | Weeding and earthing up? | 7.5 | -1 | -1 | -1 | 1 | 1 | 1 |
| 35 | Irrigation cost? | 6 | 0 | -1 | -1 | 1 | 1 | 1 |
| 36 | Application of herbicides/pesticides | 5 | 0 | -1 | -1 | 1 | 1 | 0 |
| 37 | Potato harvesting cost? | 5 | 0 | -1 | -1 | 1 | 1 | 0 |
| 38 | Potato curing cost? | 5 | -1 | -1 | 0 | 1 | 1 | 0 |
| 39 | Land tax cost? | 5 | -1 | -1 | 0 | 1 | 1 | 0 |
| 40 | Land rent? | 6 | -1 | -1 | 0 | 1 | 1 | 1 |
| 41 | Tractor depreciation cost? | 6 | -1 | -1 | 0 | 1 | 1 | 1 |
| 42 | Power tiller depreciation cost? | 6 | -1 | -1 | 0 | 1 | 1 | 1 |
| 43 | Pesticide spray machine depreciation cost? | 5 | -1 | -1 | 0 | 1 | 1 | 0 |
| 44 | Other (specify) depreciation cost? | 5 | -1 | -1 | 0 | 1 | 1 | 0 |
| 45 | Qty of potato sold in 2019? | 6 | 0 | -1 | -1 | 1 | 1 | 1 |
| 46 | Unit selling price in the market? | 6 | 0 | -1 | -1 | 1 | 1 | 1 |
| 47 | Any premium earned per kg of potato? | 6 | 0 | -1 | -1 | 1 | 1 | 1 |
| 48 | Farm-gate price? | 6 | 0 | -1 | -1 | 1 | 1 | 1 |
| 49 | Marketing place? | 5 | 1 | 1 | 0 | -1 | -1 | 0 |
| 50 | How you market it, individually or in group? | 6 | 1 | 1 | 1 | 0 | -1 | -1 |

| Sl.no | Item | Index of Item-Objective Congruence (IOC) | Ratings on each objective by three experts | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Objective 1: Socio-demographic, production, marketing, constraints | | | Objective 2: Compare productivity and profitability. | | |
| | | | Expert 1 | Expert 2 | Expert 3 | Expert 1 | Expert 2 | Expert 3 |
| 51 | How long your farm is certified organic? | 5 | 1 | 1 | 0 | -1 | -1 | 0 |
| 52 | Certified organic under which brand? | 5 | 1 | 1 | 0 | 0 | -1 | -1 |
| 53 | Unavailability of farm labour? | 5 | 1 | 1 | 0 | 0 | -1 | -1 |
| 54 | Labour hiring is expensive? | 5 | 1 | 1 | 0 | 0 | -1 | -1 |
| 55 | The supply of farm inputs is inadequate? | 5 | 1 | 1 | 0 | -1 | -1 | 0 |
| 56 | Seeds supply is inadequate? | 5 | 1 | 1 | 0 | -1 | -1 | 0 |
| 57 | Fertilizers supply is inadequate? | 5 | 1 | 1 | 0 | 0 | -1 | -1 |
| 58 | Pesticides/bio-pesticides supply is inadequate? | 5 | 1 | 1 | 0 | -1 | -1 | 0 |
| 59 | Farm inputs are not accessible on time? | 6 | 1 | 1 | 1 | 0 | -1 | -1 |
| 60 | Seeds are not accessible on time? | 6 | 1 | 1 | 1 | 0 | -1 | -1 |
| 61 | Fertilizers are not accessible on time? | 6 | 1 | 1 | 1 | -1 | -1 | 0 |
| 62 | Pesticides/bio-pesticides are not accessible on time? | 5 | 1 | 1 | 0 | -1 | -1 | 0 |
| 63 | Unavailability of farm machineries for hiring? | 5 | 1 | 1 | 0 | -1 | -1 | 0 |
| 64 | Farm machineries are expensive to hire? | 5 | 1 | 1 | 0 | -1 | -1 | 0 |
| 65 | Pests and diseases problems? | 5 | 1 | 1 | 0 | -1 | 0 | -1 |
| 66 | Attack of wild animals in potato? | 5 | 1 | 1 | 0 | -1 | -1 | 0 |
| 67 | Inadequate post-harvest facilities like grading and storage facilities? | 5 | 1 | 1 | 0 | -1 | -1 | 0 |
| 68 | Difficulties in accessing the markets? | 5 | 1 | 1 | 0 | 0 | -1 | -1 |

| Sl.no | Item | Index of Item-Objective Congruence (IOC) | Ratings on each objective by three experts | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Objective 1: Socio-demographic, production, marketing, constraints | | | Objective 2: Compare productivity and profitability. | | |
| | | | Expert 1 | Expert 2 | Expert 3 | Expert 1 | Expert 2 | Expert 3 |
| 69 | Imported potato competes with local? | 5 | 1 | 1 | 0 | 0 | -1 | -1 |
| 70 | Price you receive is inadequate? | 6 | 1 | 1 | 1 | -1 | 0 | -1 |
| 71 | No premium price for your produce? | 6 | 1 | 1 | 1 | 0 | -1 | -1 |
| 72 | Productivity is low? | 5 | 1 | 1 | 0 | 0 | -1 | -1 |
| 73 | Irrigation problems? | 5 | 1 | 1 | 0 | -1 | -1 | 0 |
| 74 | Climate change affects production? | 6 | 1 | 1 | 1 | -1 | 0 | -1 |

### 7.3 Published papers in International Journals and conferences

Followings are the list of published papers in International Journals and conferences during the study:

1) Lepcha, N., Mankeb, P., & Suwanmaneepong, S. (2021). Productivity and profitability of organic and conventional potato (Solanum tuberosum L.) production in West-Central Bhutan. Open Agriculture, 6(1), 640-654. doi:https://doi.org/10.1515/opag-2021-0044. (Web of Science, SJR Q2, Scopus).
2) Lepcha, N., & Suwanmaneepong, S. (2021). Cost and return analysis of organic potato in Gasa district, Bhutan. Paper presented at the 9th International conference on integration of science and technology for sustainable development (ICIST) Bangkok, Thailand. (Conference paper).
3) Lepcha, N. and Suwanmaneepong, S. (2022). Macronutrients (NPK) and other soil properties influenced by long term organic and conventional potato farming in West-Central Bhutan. International Journal of Agricultural Technology 18(3): 2630-0192 (online) (Accepted paper vide letter Ref.03/001, dated 18th March, 2022, Editor-in-chief, IJAT, ISSN 2630-0192 (on-line). (SJR Q4, Scopus).

## 7.3.1 Published paper in Open Agriculture journal (SJR Q2, WOS listed

DE GRUYTER Open Agriculture 2021; 6: 640–654

Research Article

Norden Lepcha*, Panya Mankeb, Suneeporn Suwanmaneepong

# Productivity and profitability of organic and conventional potato (*Solanum tuberosum* L.) production in West-Central Bhutan

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**Abstract:** Bhutan aspires to be an entirely organic nation. Food self-sufficiency and increasing farm household income are critical priorities in the country. Realising these priorities necessitates assessing the country's current organic agriculture performance. The objectives of this study were to investigate the productivity and profitability of organic and conventional potato and farmers' constraints in producing organic potato in West-Central Bhutan. Multistage and purposive sampling techniques were used to select the study sample. A semi-structured questionnaire and face-to-face interviews were employed to gather primary data for the 2019 cropping cycle from 93 potato farmers: 43 organic farmers in the Gasa District and 50 conventional farmers in Wangdue Phodrang District. Descriptive statistics, cost and return analysis, and independent sample *t*-test were applied for data analysis. The results revealed that the conventional potato's productivity (tuber yield) and profitability were significantly higher ($p < 0.001$) than organic potatoes. The average productivities for organic and conventional potatoes were 7.48 and 19.22 t/ha, respectively. Organic potato farmers incurred a loss of −202,708.47 Ngultrum (Nu)/ha, while conventional potato farmers incurred a profit of 83,832.85 Nu/ha. The benefit-cost ratios of organic and conventional potato stood at 0.40 and 1.27, respectively. Lack of premium price, pest and disease problems, low crop productivity, and climate change were the constraints faced by organic potato farmers. The study found that the productivity and profitability of the conventional potatoes were higher than the organic potatoes in West-Central Bhutan in the current scenario. Further, the critical information will contribute to guiding Bhutan's vision for its organic agriculture development.

**Keywords:** cost and return analysis, constraints, farm household income, farm-gate price, organic agriculture's performance, potato production

## 1 Introduction

Organic farming is considered a viable choice for small farmers seeking to improve food security and farm income performance in the long term [1]. It is also viewed as a sustainable farming method that has been shown to help accomplish the Sustainable Development Goals [2]. In 2017, 181 countries were involved in organic operations, with the organic market valued at 90 billion euros. The global organic portion of total agricultural land was 1.4%, with 2.9 million organic growers around the globe. Asia has 40% of the world's organic producers [3].

The Kingdom of Bhutan shares similarities with these global trends; therefore, the Royal Government of Bhutan (RGoB) launched the National Framework for Organic Farming in 2006 [4]. The National Organic Programme (NOP) [5] reported that Bhutan has around 10,391.86 ha of land, with a production of 2,599.7 metric tonnes (t) under organic management in 2017, which included areas under agriculture, livestock, and wild collections. Bhutan is characterised predominantly by smallholder farmers engaged mainly in subsistence farming, holding an average of 1.16 ha [6]. The RGoB faces a difficult challenge in attaining food and nutritional security and poverty alleviation; around 2.8% of the Bhutanese population suffer from food poverty [7]. To promote sustainability and meet its Gross National Happiness goals, Bhutan pledged to be

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100% organic by 2020 [8]; however, Bhutan's current government has clarified that the plan to become one by 2023 is quite vague [9]. Nevertheless, the country has been pursuing its organic vision, as evidenced by the initiation of the National Organic Flagship Programme in its 12th Five Year Plan (2018–2023) [9]. The RGoB has prioritised household food security, alleviating poverty, substituting or reducing imports through increased domestic production, generating a marketable surplus, and enhancing farm household income and employment opportunities [10]. However, Bhutan's pledge to be 100% organic by 2020 seems not to favour the country's self-sufficiency and food security goals [8]. Food security is attained when all people have physical and economic access to adequate, safe, and nutritious food that fits their dietary needs and food choices for an active and healthy life at all times [11]. Therefore, to meet the government's priorities on food self-sufficiency and farm income generation, there is an absolute necessity to assess Bhutan's organic agriculture performance.

The potato is the fourth most significant crop in calories, following rice, maize, and wheat. Bajgai [12] reported that the potato is a widely cultivated, consumed, and traded crop in Bhutan, mainly due to the country's suitable agro-ecological conditions. It is grown as a non-cereal food and cash crop and a vegetable by around 22% of Bhutan's rural households. In 2019, there was a total potato production of 43,560 t, in a total area of 4,187 ha, with national average productivity of 10.40 t/ha in the country [13]. Potato productivity is one of the lowest in the South Asian region; however, generally, potato production is a profitable venture in Bhutan, with an average profit of 36.02% [14]. Bhutan exported 24,983.4 t and earned 511.06 Nu[1] million in 2018 [15]. In Bhutan, potato is one of the cash crops mainly cultivated through conventional farming practices [16]. According to the International Centre for Integrated Mountain Development [7], conventional agrochemicals like fertilisers and insecticides are used relatively in small amounts in Bhutan and are restricted to essential cereals and cash crops. However, conventional potato farmers also use some farmyard manure (FYM) and other organic amendments along with chemical fertilisers. Conventional farmers also use herbicides to control weeds in potatoes besides some manual weeding. Conventional farming in Bhutan is basically an integrated approach, and it is as good as the Good Agricultural Practices. In 2019, around 1.08% of the total potato area in the country was under organic potato production with a total of 45.15 ha [17]. Since 2016, around 20.34 ha or 0.50% of the total potato area in the country was certified organic in Gasa District by a competent government institution in Bhutan. All the organic certification cost in Gasa was borne by the government [17]. Certified organic farmers comply with Bhutan Organic Standards, strictly refrain from using any chemical fertilisers and agrochemicals in their fields and resort to using locally available organic inputs, such as the FYM and biopesticides.

One critical issue in accepting organic agriculture remains in its productivity [18]. Productivity increases are a critical precondition for attaining long-term food security in the face of rising demand for agricultural products [19]. Productivity is a performance metric for determining the quantity of output produced from a current resource base; it can be a strong indicator of long-term sustainability [20]. Conway [21] specified that productivity is also a measure of annual *crop yield* per hectare of land. The FAO [22] defined that land productivity measures the quantity of output produced by a given amount of land. There is a close relationship between agricultural productivity and farm income, influencing food security and rural livelihoods [20]. On the other hand, profitability is concerned as an economic concept in analysing the agriculture sector's performance [23]. Profit is gross revenue less total production costs, whereas profitability is a term that is obtained from it [24]. The farmer makes a profit if the difference is positive, but the farmer is at a loss if it is negative [25]. A measure of profitability performance demonstrates how efficiently the farmer's resources are utilised to generate income and profit [26]. The profitability study will be helpful to measure the household income for organic and conventional potato farmers. Similar studies were undertaken and reported in refs [27–31]. Therefore, it is crucial to apply the economic indicators to measure the performance of organic potato production.

A comparative assessment on organic and conventional rice farming in Bhutan was studied previously [29]; however, no such research has been carried out on potatoes, one of the critical horticultural crops in the country. Therefore, this study has focused on comparing the productivity and profitability of potatoes in these two farming systems in two representative districts in West-Central Bhutan. The data were collected for the 2019 production cycle and marketing year. The study's objectives were to assess the organic and conventional potatoes' productivity and profitability and examine different constraints faced by organic potato farmers in West-Central Bhutan. Furthermore, because different potato varieties can influence productivity and profitability, the study focused on the country's popular red potato variety, the *Desiree*. The study is expected to be helpful as a guide for policymakers, receive further support from agriculture officials and researchers, and help

1 Ngultrum (Nu) is a Bhutanese currency, 1 Nu = 0.014 USD.


**Figure 1:** The map of Bhutan showing study areas (Source: National Soil Service Centre-2020).

farmers in their decision-making to adopt a better farming system in potato production.

## 2 Materials and methods

### 2.1 Study area

West-Central Bhutan, among the four regions in Bhutan, was purposively selected for the study because it is one of the largest potato producers in the country. The region produced 16,478 t in 2019, comprising 38% of the total potato production in the country [32]. It was also due to the availability of both the commercial organic and conventional potato farmers. Therefore, two potato-producing and neighbouring representative districts in West-Central Bhutan, namely Gasa and Wangdue Phodrang districts, were selected for the study. Bhutan's West-Central region comprises five districts: Gasa, Wangdue Phodrang, Punakha, Dagana, and Tsirang [33].

Gasa District has a potato farming area of 30.08 ha with an annual production of 185.24 t [32]. Goenkhatoe *Gewog*[2] within the district located at 27°50′N 89°38′E, altitude ranging from 2,100 to 2,800 metres above mean sea level (masl) was selected as a research site for the organic potato assessment. The soil in the region is ferralsols type which is identified by low fertility, macro and micro-nutrient deficits, and soil acidity [29]. Soil textures in the *Gewog* are loam and silty clay loam as reported by the National Soil Service Centre (NSSC), Thimphu, in 2020. In 2019, the country as a whole received near-normal temperature and rainfall [34]. The annual national average maximum and minimum temperature were 22.4 and 11.8°C, respectively, and the annual national average precipitation was 1,825.2 mm.

Wangdue Phodrang District has a potato area of 882.62 ha with an annual production of 15,569.87 t [32]. Phobjikha *Gewog* within the district located at 27°30′N 90°10′E, altitude ranging from 2,300 to 4,000 masl was selected as a research site for the conventional potato assessment. Soil textures in the Phobjikha *Gewog* are comparable to Goenkhatoe *Gewog*, consisting of loam and silty clay loam, as reported by the NSSC. Both places fall under the same agroecological zone, that is, the temperate zone (Agroecological Zone 3) of Bhutan, located above 1,800 masl [35]. Figure 1 shows the study areas in West-Central Bhutan.

### 2.2 Cropping sequences in study areas

The annual sequences of different crops planted on the same plot of land in the study areas are depicted in Table 1. The cropping sequences of organic and conventional potato farmers were comparable, except some conventional farmers grow mustard after potato harvest. It was adopted from the study of Bajracharya and Sapkota [31].

2 A group of villages in Bhutan.

**Table 1:** Cropping sequences in study areas

| Gasa (Goenkhatoe *Gewog*) | Wangdue Phodrang (Phobjikha *Gewog*) |
|---|---|
| Potato–Sweet or bitter buckwheat | Potato–Sweet or bitter buckwheat |
| Potato–Turnip | Potato–Turnip |
| Potato–Garlic | Potato–Mustard |

## 2.3 Sampling procedure

Multistage and purposive sampling techniques were used to select the research sample. In the first stage, two neighbouring representative districts out of five districts in West-Central Bhutan were selected. Multistage and purposive sampling techniques were also applied [36,37]. Gasa District was chosen for the organic potato assessment because it was declared the first fully organic district in 2004 by its local government [38]. Wangdue Phodrang District was selected as the conventional potato research site because the district is the largest producer of potatoes in West-Central Bhutan [39]. Potatoes in Wangdue Phodrang are produced mainly through conventional farming practices.

In the second stage, Goenkhatoe *Gewog*, among four *Gewogs* in Gasa, was purposively selected for the organic potato assessment. Goenkhatoe *Gewog* was primarily selected because the *Gewog* has an organic farmers' group known as *Gasa Rangshin Sonam Detshen*, which has produced certified organic potatoes and other crops since 2016. The group is certified by the Bhutan Agriculture and Food Regulatory Authority [40]. Potatoes are the main cash crop grown in the *Gewog*.

Similarly, Phobjikha *Gewog*, among 15 *Gewogs* in Wangdue Phodrang, was purposively selected for conventional potato research due to the availability of commercial conventional potato farmers. Moreover, potato cultivation is the primary income source for almost all the households in Phobjikha *Gewog* [41], and they have been cultivating potatoes for decades.

## 2.4 Data collection

Data were collected from 43 organic potato farmers randomly spread across 17 villages in Goenkhatoe *Gewog* under the Gasa District. The conventional potato's data were collected from 50 farmers randomly spread across 13 villages in Phobjikha *Gewog* under Wangdue Phodrang District. The data were collected from mid-September to October end of 2020 for the previous year's potato cropping cycle (2019). These farmers cultivated potatoes in 58.49 ha with a total production of 1,068.54 t.

Primary data were collected through face-to-face interviews with individual farmers. During each farmer's interview, the head of the family, or any family member actively engaged in potato farming, was interviewed. The semi-structured questionnaire was applied to collect data from farmers. It consisted of three parts: the first part contained the socio-demographic characteristics, the second part gathered productivity and profitability data, and the last part comprised constraints. The constraints opined by farmers were recorded using the five-point Likert scale, ranging from strongly disagree = 1 to strongly agree = 5 [42].

**Informed consent:** Informed consent has been obtained from all individuals included in this study.

**Ethical approval:** The research related to human use has been complied with all the relevant national regulations, institutional policies and in accordance with the tenets of the Helsinki Declaration, and has been approved by the Ministry of Agriculture and Forests. Then, selected districts, *Gewogs* administrations and agriculture extension officials were approached, who readily provided consent to collect data.

### 2.4.1 Assessment of content validity

To assess the content validity of the items in the questionnaires, the item objective congruence (IOC) rating, interpretation, and decision as provided by Rovinelli and Hambleton [43] were applied, wherein each question item with an IOC rating of 0.5 and above was retained in the questionnaire. A draft of the semi-structured questionnaire was sent for review and feedback to three experts relevant to the study field to ensure that each of the questionnaire's items captured the intended objectives. The pre-testing of the questionnaire designed for an individual farmer's interview was carried out with at least 30 potato farmers who did not belong to the sample research farmers. The pre-testing was carried out in Geney *Gewog* under the Thimphu District in Bhutan on the 1st week of September 2020.

## 2.5 Data analysis

### 2.5.1 Socio-demographic characteristics

Descriptive statistics, namely, frequencies, arithmetic means, standard deviations, percentages, and maximum and minimum, were used to analyse the socio-demographic characteristics using the SPSS.

#### 2.5.2 Productivity analysis

Productivity was calculated using the following formula [22]:

$$\text{Land productivity} = \text{Volume of output/planted area}, \quad (1)$$

where the volume of output was measured in metric tonnes (t) and the planted area was measured in hectares (ha).

#### 2.5.3 Profitability measure using cost and return analysis (CRA)

The CRA is a form of economic assessment that takes into account both the implicit and explicit expenses borne by farmers [44,45]. Actual expenditures incurred fall under the explicit cost, while imputed or implied costs, which are not related to the actual expenditure payments, fall under implicit cost [44]. Thus, the costs can be categorised into explicit and implicit costs, which are cash and non-cash costs, respectively [28,46]. The CRA was computed using Microsoft Excel.

#### 2.5.4 Total cost (TC)

TC was computed using the following equation [28,36]:

$$\text{TC} = \text{TVC} + \text{TFC}, \quad (2)$$

where, TC is the total cost, TVC is the total variable cost, and TFC is the total fixed cost.

The TVCs are the costs incurred by the variable inputs, such as raw materials, labour, and other variable overhead expenses [47]. While TFCs are those production costs that do not change with production volume, such as land rent [48]. Non-cash costs were estimated based on the farm inputs' prevailing market prices. The labour costs were computed for the hired, exchange, and family labourers [25]. Hired labourers' cash costs were based on the prevailing farm labour wage, whereas exchange and family labourers' costs were based on the farmers' actual food and refreshments expenditures [29].

The TFCs also include the depreciation of farm tools and equipment [49]. The straight-line method shows the same value of depreciation cost in each period [50].

$$\text{Depreciation expense} = (\text{Asset cost} - \text{Salvage value})/\text{Useful life of the asset}. \quad (3)$$

#### 2.5.5 Gross return (GR)

GR was calculated with the following equation [28,29]:

$$\text{GR} = Q \times P, \quad (4)$$

where, $Q$ is the productivity (yield) and $P$ is the selling price (farm-gate price considered in this study).

#### 2.5.6 Profitability

The following equation determined the profit or gross margin (GM) [30,51]:

$$\text{Profit or GM} = \text{GR} - \text{TC}, \quad (5)$$

where, GR is the gross return and TC is the total cost.

#### 2.5.7 The benefit cost (B:C) ratio (BCR)

The BCR was calculated using the following equation [29,52]:

$$\text{B:C ratio} = \text{GR/TC}. \quad (6)$$

#### 2.5.8 Return on investment (ROI) [36]

$$\text{ROI} = \text{GM/TC expressed in \%}. \quad (7)$$

#### 2.5.9 Break-even price and break-even productivity (*yield*) analysis using break-even analysis

Alongside other parameters, the break-even price ($P$) and productivity ($Y$) were computed, which were adopted from the study of Dillon [53] as indicated in the equations below:

$$\text{Price } (P_i) = (\text{VC}_i + \text{FC}_i + \pi_i)/Y_i, \quad (8)$$

$$\text{Productivity } (Y_i) = (\text{VC}_i + \text{FC}_i + \pi_i)/P_i, \quad (9)$$

where $P_i$ is the output price of commodity $i$, $Y_i$ is the productivity of commodity $i$, $\text{VC}_i$ is the variable cost incurred to produce commodity $i$, and $\text{FC}_i$ represents the fixed costs to produce commodity $i$; break-even price or productivity can be inspected by setting profits ($\pi_i$) equal to zero.

### 2.6 Comparison of productivity and profitability statistically (mean differences)

The productivity and profitability mean differences were compared using the independent sample *t*-test, using the SPSS. Before the statistical analysis, the requirements of normal distribution and variance homogeneity were verified. All tests were performed at a significance level of 5% [54].

### 2.7 Constraints faced by organic potato farmers

Constraints encountered by organic potato farmers in the region were analysed using the descriptive analysis of the five-point Likert scale [42]. The various constraints were ranked following their mean values. The mean values were interpreted as follows: the ranges of 1.00–1.80, Strongly disagree; 1.81–2.60, Disagree; 2.61–3.40, Undecided; 3.41–4.20, Agree; and 4.21–5.00, Strongly agree [54]. It was adopted from a similar study on the barriers encountered in converting to organic farming [55].

## 3 Results

### 3.1 Socio-demographic profile of farmers

Details of the socio-demographic profile of farmers are presented in Table 2. Organic potato farmers had a higher female population (69.77%) than the male population (30.23%), but the conventional potato farmers had about equal distribution of male (48%) and female population (52%). In addition, organic farmers' average family labour was lower than the conventional farmers with two and three numbers, respectively.

Overall, the average year of farming experience was higher for organic farmers (31 years) than the conventional farmers (26 years). Organic farmers attended more technical training than conventional farmers, with two training sessions per year. Most organic farmers (83.7%) depended purely on farming for their income, while 40% of the conventional farmers had off-farm income. The conventional farmers cultivated potato in a larger area than the organic farmers, with a mean cultivated area of 1.08 and 0.11 ha, respectively. Interestingly, organic potato farmers owned larger landholding than conventional farmers; the conventional farmers leased in more land for potato cultivation. The average farm size of the organic farmers was comparable with the national average of 1.16 ha, but the conventional farmers had lesser than the national average.

### 3.2 Productivity and profitability analysis of organic potatoes

The details of the productivity and profitability analysis with the CRA are provided in Table 3. The TC of organic potato production was 340,771.17 Nu/ha. The TVC was 338,211.89 Nu/ha, which accounted for 99.63% of the total production cost. The TFC was 2,559.28 Nu/ha, and its share of total production cost was only 0.75%. The total cash cost was 135,671.90 Nu/ha, and the total non-cash cost was 203,790.90 Nu/ha. The government provided input support with seeds and bio-pesticides, amounting to an average of 1,308.37 Nu/ha. Therefore, the actual cost of organic potato production to a farmer with this input support was 339,462.80 Nu/ha. Under the variable costs (VCs), the labour cost was higher than the input cost. The total input cost accounted for 41.96% of the total production cost. The highest input cost was incurred on purchasing potato seeds comprising 18.43%, while the lowest input cost incurred was for the use of bio-pesticides comprising only 0.04% of the total production cost.

The total labour cost was the highest contributor (57.67%) to the total production cost. The highest labour cost incurred was in weeding and earthing up activities, comprising 25.53%, while the lowest labour cost incurred was on applying bio-pesticides, which consisted of only 0.02% of the total production cost. The depreciation cost contributed the highest under the fixed costs, comprising only 0.74% of the total production cost.

Farmers received an average farm-gate price of 18.29 Nu/kg, and the GM or the profit was negative at −202,708.47 Nu/ha. The GM over cash cost and variable cost were 1,082.43 Nu/ha and −201,457.56 Nu/ha, respectively. The average productivity of organic potatoes was 7.48 t/ha. The break-even productivity and break-even prices were 18.63 t/ha and 45.58 Nu/kg, respectively, while the BCR stood at 0.40, and the ROI was −59.71%.

### 3.3 Productivity and profitability analysis of conventional potatoes

The details of productivity and profitability analysis with the CRA are presented in Table 4. The TC of conventional

Table 2: Socio-demographic profile of farmers

| Items | Organic farmers (n = 43) | | Conventional farmers (n = 50) | |
|---|---|---|---|---|
| | Frequency | Percentage | Frequency | Percentage |
| Gender | | | | |
| Male | 13 | 30.23 | 24 | 48.00 |
| Female | 30 | 69.77 | 26 | 52.00 |
| Age | | | | |
| Average age (years) | 52 | | 43 | |
| <40 years | 10 | 23.26 | 23 | 46.00 |
| 40–50 years | 10 | 23.26 | 16 | 32.00 |
| 51–60 years | 13 | 30.23 | 7 | 14.00 |
| >60 years | 10 | 23.26 | 4 | 8.00 |
| Education level | | | | |
| Illiterate | 27 | 62.79 | 26 | 52.00 |
| Non-formal education | 4 | 9.30 | 4 | 8.00 |
| Primary School | 9 | 20.93 | 17 | 34.00 |
| Middle School | 1 | 2.33 | 2 | 4.00 |
| Lower secondary | 2 | 4.65 | 0 | 0.00 |
| Upper secondary | 0 | 0.00 | 1 | 2.00 |
| Marital status | | | | |
| Single | 0 | 0.00 | 1 | 2.00 |
| Married | 38 | 88.37 | 46 | 92.00 |
| Household members | | | | |
| Average member(s) | 4 | | 6 | |
| ≤3 | 18 | 41.86 | 10 | 20.00 |
| 4–5 | 13 | 30.23 | 16 | 32.00 |
| ≥6 | 12 | 27.91 | 24 | 48.00 |
| Family labour | | | | |
| Average persons | 2 | | 3 | |
| 1–2 | 35 | 81.40 | 22 | 44.00 |
| 3–4 | 7 | 16.28 | 21 | 42.00 |
| ≥5 | 1 | 2.33 | 7 | 14.00 |
| Experience in farming | | | | |
| Average years | 31 | | 26 | |
| 1–10 years | 9 | 20.93 | 5 | 10.00 |
| 11–20 years | 9 | 20.93 | 12 | 24.00 |
| >20 years | 25 | 58.14 | 33 | 66.00 |
| Attend farmers' training | | | | |
| Average per year | 2 | | 1 | |
| No training | 6 | 13.95 | 22 | 44.00 |
| 1 to 2 times per year | 30 | 69.77 | 28 | 56.00 |
| 3 times per year | 7 | 16.28 | 0 | 0.00 |
| Off-farm income | | | | |
| None | 36 | 83.7 | 30 | 60 |
| Yes | 7 | 16.3 | 20 | 40 |
| Average farm size (ha) | 1.17 | | 0.84 | |
| Potato cultivated area (ha) | | | | |
| Mean | 0.11 | | 1.08 | |
| Std. Dev | 0.14 | | 0.49 | |
| Minimum | 0.02 | | 0.20 | |
| Maximum | 0.92 | | 2.12 | |

potato production was 309,012.30 Nu/ha, with a TVC of 290,591.79 Nu/ha and a TFC of 18,420.51 Nu/ha. The total variable and fixed costs accounted for 94.04 and 5.96% of the total production cost, respectively. The total cash cost was 108,133.20 Nu/ha, and the total non-cash was 200,879.10 Nu/ha. Under the VCs, the input cost was higher than the labour cost. The total input cost comprised 60.10% of the total production cost. The cost

**Table 3:** Cost and return analysis of organic potatoes

| Item | Quantity | Cash (Nu) | Non-cash (Nu) | Total (Nu) | % |
|---|---|---|---|---|---|
| (A) Variable costs (VCs) (Nu/ha) | | | | | |
| (1) Input cost | | | | | |
| (i) Seed | 2.39 t | 9,321.90 | 53,243.60 | 62,565.50 | 18.43 |
| (ii) FYM and other organic fertilisers | 41.34 t | 1,550.39 | 56,792.70 | 58,343.09 | 17.19 |
| (iii) Bio-pesticides | 0.002 L | 0 | 145.38 | 145.38 | 0.04 |
| (iv) Fuel & rental | | 21,374.03 | 0 | 21,374.03 | 6.30 |
| Total input cost (Nu/ha) | | 32,246.32 | 110,181.68 | 142,427.99 | 41.96 |
| (2) Labour cost (man-days/ha) | | | | | |
| (i) Land preparation | 133.42 | 8,681.41 | 14,998.68 | 23,680.09 | 6.98 |
| (ii) Compost/FYM application | 46.89 | 6,570.37 | 6,801.57 | 13,371.94 | 3.94 |
| (iii) Planting | 84.41 | 13,814.76 | 8,338.41 | 22,153.17 | 6.53 |
| (iv) Weeding & earthing up | 297.17 | 43,861.92 | 42,793.78 | 86,655.70 | 25.53 |
| (v) Bio-pesticides application | 1.01 | 0 | 83.73 | 83.73 | 0.02 |
| (vi) Harvesting/curing | 196.93 | 30,466.60 | 19,372.67 | 49,839.27 | 14.68 |
| Total labour cost (Nu/ha) | | 103,395.05 | 92,388.84 | 195,783.89 | 57.67 |
| TVC (Nu/ha) | | 135,641.37 | 202,570.52 | 338,211.89 | 99.63 |
| (B) Fixed costs (FCs) (Nu/ha) | | | | | |
| (1) Land tax | | 30.53 | 0 | 30.53 | 0.01 |
| (2) Land rent | | 0 | 0 | 0 | 0.00 |
| (3) Depreciation cost | | 0 | 2,528.75 | 2,528.75 | 0.74 |
| TFC (Nu/ha) | | 30.53 | 2,528.75 | 2,559.28 | 0.75 |
| TC = (TVC + TFC) (Nu/ha) | | 135,671.90 | 205,099.27 | 340,771.17 | |
| TC with deductions of an average govt. support on seeds & bio-pesticides worth of Nu. 1,308.37/ha (Nu/ha) | | 135,671.90 | 203,790.90 | 339,462.80 | |
| GR (Nu/ha) ($Q \times P$) | | | | 136,754.33 | |
| Productivity (kg/ha) ($Q$) | | | | 7,477 | |
| Farm-gate price (Nu/kg) ($P$) | | | | 18.29 | |
| GM (profit) (Nu/ha) (GR-TC) | | | | −202,708.47 | |
| Break-even productivity (kg/ha) | | | | 18,631.56 | |
| Break-even price (Nu/ha) | | | | 45.58 | |
| BCR (GR/TC) | | | | 0.40 | |
| ROI (GM/TC × 100) (%) | | | | −59.71 | |
| Gross margin over cash cost (Nu/ha) (GR-Total cash cost) | | | | 1,082.43 | |
| Gross margin over variable cost (Nu/ha) (GR-TVC) | | | | −201,457.56 | |

Nu = Ngultrum (Bhutanese currency); 1 Nu = 0.014 USD.

incurred on the seed purchase was the highest input cost comprising 29.03%, and the lowest input cost was on purchasing insecticides, which constituted 0.01% of the total production cost. The total labour cost made up 33.94% of the total production cost. The highest labour cost was on the harvesting/curing, comprising 22.07%, and the lowest labour cost was on applying pesticides, which made up only 0.37% of the total production cost. The depreciation cost was the highest cost within the fixed costs, which comprised 3.79% of the total production cost. Many conventional farmers also leased the land, which made up 2.17% of the total production cost.

The conventional potato farmers received an average farm-gate price of 20.44 Nu/kg, and the GM or profit was 83,832.85 Nu/ha. The GM over cash and variable costs stood at 284,711.95 and 102,253.36 Nu/ha, respectively. The average conventional potato productivity was 19.22 t/ha. The break-even productivity and break-even prices were 15.12 t/ha and 16.08 Nu/ha, respectively, while the BCR was 1.27 and the ROI was 27.13%.

## 3.4 Comparison of productivity and profitability statistically (mean difference)

Detailed results with the $p$-value and significance level of mean differences are provided in Table 5. The independent sample $t$-tests results showed that the conventional potato had significantly higher values in both the productivity and profitability parameters at $p < 0.001$ than the

**Table 4:** Cost and return analysis of conventional potatoes

| Item | Quantity | Cash (Nu) | Non-cash (Nu) | Total (Nu) | % |
|---|---|---|---|---|---|
| (A) Variable costs (VCs) (Nu/ha) | | | | | |
| (1) Input cost | | | | | |
| (i) Seed | 3.06 t | 2,198.25 | 87,522.03 | 89,720.28 | 29.03 |
| (ii) Chemical fertilisers | 0.97 t | 32,458.18 | 0 | 32,458.18 | 10.50 |
| (iii) Agrochemicals | | | | | |
| (a) Insecticide | 0.07 L | 20.4 | 0 | 20.4 | 0.01 |
| (b) Fungicide | 0.004 t | 1,050.75 | 0 | 1,050.75 | 0.34 |
| (c) Herbicide | 0.0073 t | 5,785.26 | 0 | 5,785.26 | 1.87 |
| (d) Sticker | 0.10 L | 24.39 | 0 | 24.39 | 0.01 |
| (iv) FYM and other organic fertilisers | 16.08 t | 1,759.98 | 43,873.20 | 45,633.18 | 14.77 |
| (v) Fuel & rental | | 11,024.77 | 0 | 11,024.77 | 3.57 |
| Total input cost (Nu/ha) | | 54,321.98 | 131,395.23 | 185,717.22 | 60.10 |
| (2) Labour cost (man-days/ha) | | | | | |
| (i) Land preparation | 10.21 | 956.68 | 1,655.03 | 2,611.71 | 0.85 |
| (ii) Compost/FYM application | 20.27 | 3,879.78 | 3,760.38 | 7,640.16 | 2.47 |
| (iii) Planting/fertilising | 42.35 | 8,106.79 | 7,893.78 | 16,000.57 | 5.18 |
| (iv) Weeding & earthing up | 28.62 | 3,492.76 | 5,790.46 | 9,283.22 | 3.00 |
| (v) Pesticide application | 5.15 | 575.78 | 569.74 | 1,145.52 | 0.37 |
| (vi) Harvesting/curing | 195.70 | 30,075.72 | 38,117.67 | 68,193.40 | 22.07 |
| Total labour cost (Nu/ha) | | 47,087.52 | 57,787.05 | 104,874.58 | 33.94 |
| TVC (Nu/ha) | | 101,409.51 | 189,182.28 | 290,591.79 | 94.04 |
| (B) Fixed costs (FCs) (Nu/ha) | | | | | |
| (1) Land tax | | 21.11 | 0 | 21.11 | 0.01 |
| (2) Land rent | | 6,702.58 | 0 | 6,702.58 | 2.17 |
| (3) Depreciation cost | | 0 | 11,696.82 | 11,696.82 | 3.79 |
| TFC (Nu/ha) | | 6,723.69 | 11,696.82 | 18,420.51 | 5.96 |
| TC = (TVC + TFC) (Nu/ha) | | 108,133.20 | 200,879.10 | 309,012.30 | |
| GR (Nu/ha) ($Q \times P$) | | | | 392,845.15 | |
| Productivity (kg/ha) ($Q$) | | | | 19,220.00 | |
| Farm-gate price (Nu/kg) ($P$) | | | | 20.44 | |
| GM (profit) (Nu/ha) (GR-TC) | | | | 83,832.85 | |
| Break-even productivity (yield) (kg/ha) | | | | 15,118.47 | |
| Break-even price (Nu/ha) | | | | 16.08 | |
| BCR (GR/TC) | | | | 1.27 | |
| ROI (GM/TC × 100) (%) | | | | 27.13 | |
| Gross margin over cash cost (Nu/ha) (GR-Total cash cost) | | | | 284,711.95 | |
| Gross margin over variable cost (Nu/ha) (GR-TVC) | | | | 102,253.36 | |

Nu = Ngultrum (Bhutanese currency); 1 Nu = 0.014 USD.

organic potato. Furthermore, the BCR was also significantly higher in conventional farming.

Regarding input cost, the costs of seed, fertiliser and manure, pesticide/bio-pesticide, and total input cost were significantly higher in conventional potato production than organic production. But the fuel and farm machinery rental cost was significantly higher in organic potato production.

In labour cost, land preparation, compost/FYM application, weeding and earthing up, and total labour cost were significantly higher in organic potato production than in conventional potato production. However, the labour cost for pesticide/bio-pesticide application was significantly higher in conventional potato production. There were no significant differences observed in both the farming systems on the labour cost on planting and harvesting/curing activities. No significant differences were observed in the TC of production.

The productivity of the organic potatoes was also significantly lower than the national average (10.40t/ha), while it was significantly higher for the conventional potato, both at $p < 0.001$. It was statistically compared using one-sample $t$-tests with the SPSS; between organic potato and national average, the $t$-test value was −6.818 with d.f. of 42; between conventional potato and the national average, the $t$-test value was 11.961, d.f. of 49.

**Table 5:** Independent sample *t*-test results on productivity and profitability ($N = 93$)

| Item | Mean | | *t*-test | *p*-value |
|---|---|---|---|---|
| | Organic | Conventional | | |
| Productivity (t/ha) | 7.48 | 19.22 | −13.767 | 0.000*** |
| Profit (Nu/ha) | −202,708.47 | 860,31.02 | −7.669 | 0.000*** |
| BCR | 0.52 | 1.39 | 12.640 | 0.000*** |
| Input cost (Nu/ha) | | | | |
| Seed | 62,565.49 | 89,720.28 | −6.119 | 0.000*** |
| Fertiliser/manure | 58,169.07 | 78,091.37 | −2.281 | 0.025* |
| Pesticide/bio-pesticide | 145.39 | 6,880.79 | −13.440 | 0.000*** |
| Fuel & rental | 21,374.03 | 11,024.78 | 2.923 | 0.006** |
| Total input cost | 120,879.95 | 174,692.45 | −5.039 | 0.000*** |
| Labour cost (Nu/ha) | | | | |
| Land preparation | 23,680.09 | 2,611.71 | 5.231 | 0.000*** |
| Compost/FYM application | 13,371.94 | 7,640.17 | 2.387 | 0.019* |
| Planting & fertilizing | 22,153.17 | 16,000.57 | 1.496 | 0.138 |
| Weeding & earthing up | 86,655.70 | 9,283.22 | 3.274 | 0.002** |
| Pesticide/bio-pesticide application | 83.73 | 1,145.52 | −3.525 | 0.001** |
| Harvesting/curing | 49,839.27 | 68,193.39 | −1.526 | 0.131 |
| Total labour cost | 146,141.55 | 89,428.34 | 2.076 | 0.043* |
| Total production cost (Nu/ha) | 339,462.79 | 306,814.13 | 0.867 | 0.390 |

$N$ = sample size; organic farmers ($n_1$) = 43; conventional farmers ($n_2$) = 50; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

## 3.5 Constraints encountered by organic potato farmers

Constraints of the organic potato farmers are shown in Table 6. As determined by the mean analysis, the first four constraints are main constraints, namely: no price premium for organic produce, pest and disease problems, low crop productivity, and climate change affects production. Other undecided constraints are the unavailability of farm labour and the inadequate supply of bio-pesticides in their place.

# 4 Discussion

Bhutan envisages becoming a fully organic nation. However, there is a prior need to assess organic

**Table 6:** Constraints faced by organic potato farmers ($N = 43$)

| Constraint | Mean | Interpretation |
|---|---|---|
| 1. No premium price for organic potato | 4.84 | Strongly agree |
| 2. Pest and disease problems | 4.02 | Agree |
| 3. Low potato productivity | 4.00 | Agree |
| 4. Climate change affects the production | 3.69 | Agree |
| 5. Labour unavailability | 3.14 | Undecided |
| 6. Bio-pesticide supply is inadequate | 2.65 | Undecided |
| 7. Bio-pesticides are not accessible on time | 2.50 | Disagree |
| 8. Imported potato competes with local | 2.09 | Disagree |
| 9. Fertiliser supply is inadequate | 2.02 | Disagree |
| 10. Inadequate knowledge of potato production | 2.02 | Disagree |
| 11. Damage of potato by wild animals | 1.77 | Strongly disagree |
| 12. Fertilisers are not accessible on time | 1.51 | Strongly disagree |
| 13. Seed supply is inadequate | 1.49 | Strongly disagree |
| 14. Seeds are not accessible on time | 1.39 | Strongly disagree |
| 15. Unavailability of farm machinery for hire | 1.07 | Strongly disagree |
| 16. Irrigation problem | 1.00 | Strongly disagree |

$N$ = sample size (number of respondents).

agriculture's performance in the country [38,56]. It was found that conventional potato farming was more productive and profitable than organic farming in West-Central Bhutan.

Organic farmers, having attended more technical training, received farm input support and organic certification free of charges from the RGoB indicated the government's effort to promote organic farming in the Gasa District and the country. Both organic and conventional potato farmers were well experienced in potato farming. Most organic farmers depended purely on farming for their income, while some conventional farmers had off-farm income. Despite conventional farmers having lesser farm size than organic farmers, they cultivated potatoes in larger areas by leasing in more land.

The study found that the conventional potato's productivity was significantly higher than the organic potato at $p < 0.001$; on average, it was 2.57 times higher. Similar findings on organic potatoes were reported by Ierna and Parisi [57] and Maggio et al. [58]. This finding contradicts the report of Tashi and Wangchuk [29], where rice grain yields between organic and conventional rice were not significantly different in Bhutan. Interestingly, the productivity of the organic potatoes was also significantly lower than the national average, while it was significantly higher for the conventional potato. The cost of organic potato production per hectare was higher than the conventional potato, on average by 30,450.50 Nu/ha, but it was not significantly different. On the other hand, Tashi and Wangchuk [29] found that the total production cost for organic rice was significantly higher than the conventional rice in Bhutan.

The total labour cost was significantly higher in organic potato production than the conventional production at $p < 0.05$. The weeding/earthing up activity was the largest contributor to the labour cost for organic farmers. The higher cost incurred on the weeding and earthing-up operation by the organic farmers was due to the need for more farm labourers (297.17 man-days/ha) to control the weeds in the absence of synthetic herbicides, unlike conventional farmers (28.62 man-days/ha). Similar findings were reported in organic rice [29,46] and in organic maize [27]. The total input cost was significantly higher in conventional potato production than in organic production at $p < 0.001$. The costs to purchase external inputs is reduced in organic farming [1]. The input costs for seed, fertiliser/manure, and pesticide/bio-pesticide were also significantly higher in conventional potato production. Such observation agrees with report of Tashi and Wangchuk [29], where conventional rice farmers incurred significantly higher agrochemical costs in Bhutan. The seed cost was the highest under the conventional farmers' input cost, contributing to 29.03% of the total production cost. The TFC accounted for 5.96% of the total production cost to conventional farmers, while only 0.75% to organic farmers. The higher fixed cost in the conventional farms was mainly due to paying the rent for leased lands, and the farm machinery's higher depreciation cost. The profitability of the conventional potato was significantly higher than the organic potato at $p < 0.001$. On average, it was higher by 286,541.32 Nu/ha than the organic potato. This result is supported by significantly higher BCR in conventional potatoes. Coppola et al. [59] and Tashi and Wangchuk [29] also reported similar findings in hazelnut and rice, respectively. However, it contradicts the findings reported by Turhan et al. [60] in organic tomatoes. The BCR of organic production was <1 at 0.40 and the ROI was negative at −59.71%, which indicated that organic potato production was not profitable. The BCR of the conventional potato was >1 at 1.27 and ROI was positive at 27.13%, showing that conventional potato production was profitable. This implies that the conventional farmers earned an average of 1.27 Nu for every 1 Nu of their investment. Conventional potato farmers also received higher farm-gate prices than organic farmers by 2.15 Nu/kg. The important reason for receiving lower farm-gate prices or the market price for organic potatoes, as opined by some organic farmers, was the overall poor appearance of organic potato tubers compared to the conventional counterpart. They pointed out that organic potato tubers are generally small-sized, and tubers are also not as smooth and attractive as the conventional potatoes, partly due to pest and disease infestations. Bhutanese traders and local customers are willing to give higher price according to the size and better appearance of potato tubers, and generally did not bother if it is organically or conventionally produced. However, they said there are a few educated customers in the market who really seek organic potatoes.

The unprofitability of the organic potato was mainly due to low productivity and lower farm-gate price. The organic potato had a 45.40 Nu/kg break-even price in the current productivity level but received only 18.29 Nu/kg. Higher price and premium price above the break-even price would ensure profitability to the organic farmers. Sgroi et al. [61] realised higher profitability in organic lemon farming due to premium price. The unprofitability of organic potato cultivation also explains why organic farmers cultivated the potato in a smaller area in 2019, despite having larger farmable land than conventional farmers. According to Kahan [25], farmers may choose to cultivate more of a particular crop because of its potential for higher profits.

The study also observed that organic potato farmers engaged in group marketing. Most of their harvests were sold to a prior identified common middleman who purchased directly from the farmers, but the farmers receive the payment separately. The farm-gate price offered by the middleman was not profitable to the organic farmers. Likewise, in Bhutan, studies also reported that there was no premium price for organic rice [29]. The scale of organic farming adoption would be determined by customers' limited market size and willingness to pay a price premium [62]. Because price disparities occur across different business channels, exploring better marketing channels would be helpful [28]. Due to the global economy, farm products can be sold anywhere in the globe, giving farmers greater opportunities to earn more money and profit [25]. The profitability of farm production should be maintained by boosting marketability [23].

A prevalence of pest and disease problems, another major constraint, and subsequent constraints on climate change, could have contributed to lower crop productivity of organic potatoes. Wheeler [62] reported that the second most vital obstacle to organic farming adoption is production difficulties and pest and disease problems. Crop yields are influenced by diseases and weather [25]. The primary cause of yield loss in organic potato cultivation is insufficient disease and pest management [63]. Late blight infection was one of the causes for lower potato productivity in organic farming than the conventional production method [57]. An adverse impact of climate change on potato production has also been reported by many researchers [64–66]. As a result, more research needs to be conducted to address pest and disease issues, lower crop productivity, and climate change issues. Increasing the productivity of organic potatoes in the Gasa District will entail improving farming practices in line with the International Federation of Organic Agriculture Movement's (IFOAM) principles. Farm labour unavailability could have been due to lesser family labour with the organic farmers. The farm labour shortage is a growing problem in Bhutan, mainly resulting from an increasing rural to urban migration [67]. Regarding inadequate supply of bio-pesticides, many imported bio-pesticides in the country have a shorter shelf life, are relatively expensive, and their efficacy trials are still underway [68]. Considering the adverse impact of pesticides on the environment and human health, the supply of pesticides and bio-pesticides is centralised by the government and accessible only through limited government agencies.

## 5 Conclusion

The study revealed that the productivity and profitability of conventional potatoes were significantly higher than organic potatoes. It was also found that the productivity of the organic potatoes was also significantly lower than the national average. The total input cost was significantly higher in conventional potato farming, while the total labour cost was significantly higher in organic potato farming. The lower BCR of the organic potato and unfavourable ROI indicated that it was not profitable. A higher BCR of the conventional potato and a favourable ROI revealed a profitable venture. The unprofitability of organic potatoes was mainly due to lower crop productivity and lower farm-gate price.

The researchers hope that the empirical data generated will contribute to guiding policymakers on the development of Bhutan's vision for its organic agriculture. In addition, it will further instigate support from agriculture officials in the country to address the constraints of organic potato farmers. It will also help farmers in the decision-making process, while adopting a suitable farming system of potato production. Furthermore, long-term scientific field research on the performance of organic, conventional, and Good Agriculture Practices potatoes needs to be carried out in Bhutan, also considering their contributions to environmental pollutions. Research and technology generation to increase the productivity of organic potato considering pest and disease, climate change constraints, and market research will be crucial for organic potato development in the country.

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**Data availability statement:** The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

## References


[1] Morshedi L, Lashgarara F, Hosseini SJF, Najafabadi M. The role of organic farming for improving food security from the perspective of farmers. Sustainability. 2017;9(11):2086. doi: 10.3390/su9112086.

[2] Willer H, Lernoud J. The world of organic agriculture. Statistics and emerging trends 2019: Research institute of organic agriculture FiBL and IFOAM organics international; 2019.

[3] IFOAM. Consolidated annual report of IFOAM – Organics international & its action group; 2018. Retrieved from https://www.ifoam.bio/sites/default/files/annualreport_2018.pdf

[4] Department of Agriculture [DoA]. National framework for organic farming in Bhutan. In agriculture Do, editor. Thimphu, Bhutan: Department of agriculture, Royal Government of Bhutan (RGoB); 2006. p. 44.

[5] National Organic Programme [NOP]. National organic program (NOP): Major achievements 2016-2017 (Annual report). In Agriculture Do, editor. Thimphu: Department of Agriculture, Royal Government of Bhutan; 2017. p. 7.

[6] National Statistical Bureau [NSB]. Bhutan living standards survey report 2017. Bhutan: National Statistics Bureau (NSB), Royal Government of Bhutan; 2017. p. 1–210, i–xvi.

[7] ICIMOD. Organic agriculture development strategies: roadmap for 12th five year plan and beyond. International Centre for Integrated Mountain Development (ICIMOD); 2018. p. 34.

[8] McCrae-Hokenson M. Organic agriculture in Bhutan: barriers going to 100%. Independent Study Project (ISP) collection, 1827; 2014.

[9] Seldon P. Nu 1 billion flagship program for organic farming with Sikkim in mind. The Bhutanese; 2019. Retrieved from https://thebhutanese.bt/nu-1-billion-flagship-program-for-organic-farming-with-sikkim-in-mind/.

[10] Ghimiray M, Katwal TB, Tshering K, Dorjee, Dukpa W, Lakey, et al. Agriculture research strategy 2018–2028. In Agriculture Do, editor. Thimphu, Bhutan: Agriculture Research and Extension Division (ARED), Department of Agriculture; 2019. p. 56.

[11] Pieters H, Guariso A, Vandeplas A. Conceptual framework for the analysis of the determinants of food and nutrition security. Foodsec Proj. 2013;45.

[12] Bajgai Y. In Lakey, editor. Standard evaluation guidelines for field & horticultural crops. Thimphu, agriculture research & extension division (ARED). Thimphu: Department of Agriculture, Ministry of Agriculture & Forests; 2018. p. 27–39.

[13] Ministry of Agriculture and Forests (MoAF). Agriculture Statistics 2019. In Agriculture Do, editor. Thimphu, Bhutan: Renewable Natural Resources Statistics Division (RSD); 2020. p. 1–123, I–VII.

[14] BPV Consultancy & research services. Lot 2: potato value chain analysis. Thimphu, Bhutan: Bhutan Philanthropy Ventures Pvt. Ltd; 2018. p. 98.

[15] Ministry of Agriculture and Forests [MoAF]. Bhutan RNR Statistics 2018. Thimphu: Renewable Natural Resources Statistics Division, Directorate Services, Royal Government of Bhutan; 2019. p. 121.

[16] Lhamo P. In Phobji and Gangtey, farmers compete to use more fertilisers. Kuensel; 2019. Retrieved from https://kuenselonline.com/in-phobji-and-gangtey-farmers-compete-to-use-more-fertilisers/.

[17] Agriculture Research & Development Centre (ARDC)-Yusipang. Annual report (2018–2019), ARDC-Yusipang, Royal Government of Bhutan. In Agriculture Do, editor. Thimphu: Department of Agriculture; 2019. p. 106, i–x.

[18] Connor DJ. Organic agriculture cannot feed the world. Field Crop Res. 2008;106(2):187–90. doi: 10.1016/j.fcr.2007.11.010.

[19] Qaim M, Arjunan S. In Kempken F, Jung C, editors. Genetic modification of plants: agriculture, horticulture and forestry. Heidelberg: Springer; 2010. p. 615–27.

[20] FAO. Guidelines for the measurement of productivity and efficiency in agriculture: Food and Agriculture Organization of the United Nations (FAO); 2018.

[21] Conway GR. Agroecosystem analysis for research and development. Bangkok: Winrock International Institute for Agrcultural Development; 1986.

[22] FAO. Productivity and efficiency measurement in agriculture – literature review and gaps analysis Food and Agriculture Organization of the United Nations (FAO); 2017.

[23] Baležentis T, Galnaitytė A, Kriščiukaitienė I, Namiotko V, Novickytė L, Streimikiene D, et al. Decomposing dynamics in the farm profitability: an application of index decomposition analysis to Lithuanian FADN sample. Sustainability. 2019;11(10):2861. doi: 10.3390/su11102861.

[24] Lipsey RG. An introduction to positive economics. 4th edn. London: Weidenfeld and Nicolson; 1975. p. 214–7.

[25] Kahan D. Economics for farm management extension: food and agriculture organization of the united nations (FAO); 2013.

[26] Kahan D. Farm business analysis using benchmarking. Rome: Food and Agriculture Organization of the United Nations (FAO); 2010.

[27] Adamtey N, Musyoka MW, Zundel C, Cobo JG, Karanja E, Fiaboe KKM, et al. Productivity, profitability and partial nutrient balance in maize-based conventional and organic farming systems in Kenya. Agric Ecosyst Env. 2016;235:61–79. doi: 10.1016/j.agee.2016.10.001.

[28] Suwanmaneepong S, Kerdsriserm C, Lepcha N, Cavite HJ, Llones CA. Cost and return analysis of organic and conventional rice production in Chachoengsao Province, Thailand. Org Agriculture. 2020;10(3):369–78. doi: 10.1007/s13165-020-00280-9.

[29] Tashi S, Wangchuk K. Organic vs. conventional rice production: comparative assessment under farmers' condition in

Bhutan. Org Agriculture. 2016;6(4):255–65. doi: 10.1007/s13165-015-0132-4.
[30] Lyngbaek AE, Muschler RG. Productivity and profitability of multistrata organic versus conventional coffee farms in Costa Rica. Agrofor Syst. 2001;53(2):205–13. doi: 10.1023/a:1013332722014.
[31] Bajracharya M, Sapkota M. Profitability and productivity of potato (*Solanum tuberosum*) in Baglung district, Nepal. Agriculture & Food Security. 2017;6(1):47. doi: 10.1186/s40066-017-0125-5.
[32] MoAF. Agriculture statistics 2019. In Services D, editor. Thimphu: Renewable Natural Resources Statistics Division (RSD), Royal Government of Bhutan; 2020. p. 1–123, I–VII.
[33] ARDC-Bajo. About ARDC Bajo. Wangduephodrang: Agriculture Research & Development Centre (ARDC)-Bajo; 2020. Retrieved from http://rcbajo.gov.bt/bsws/by-laws/.
[34] National Center for Hydrology and Meteorology. Annual report 2019–2020. Thimphu: Bhutan, National Center for Hydrology and Meteorology, Royal Government of Bhutan; 2020. p. 1–73, i–iii.
[35] Feuerbacher A, Luckmann J, Boysen O, Zikeli S, Grethe H. Is Bhutan destined for 100% organic? Assessing the economy-wide effects of a large-scale conversion policy. PLoS One. 2018;13(6):e0199025.
[36] Chidiebere-Mark N, Ohajianya D, Obasi P, Onyeagocha S. Profitability of rice production in different production systems in Ebonyi State, Nigeria. Open Agriculture. 2019;4(1):237–46. doi: 10.1515/opag-2019-0022.
[37] Anwar M, Zulfiqar F, Ferdous Z, Tsusaka TW, Datta A. Productivity, profitability, efficiency, and land utilization scenarios of rice cultivation: an assessment of hybrid rice in Bangladesh. Sustain Prod Consum. 2020;26:752–8. doi: 10.1016/j.spc.2020.12.035.
[38] Wangmo S, Iwai CB. Performance of organic agriculture (OA) based on emergent properties of agriculture system in Gasa, Bhutan. Khon Kaen Agric J. 2018;1985(1986):1202–10.
[39] Department of Agriculture (DoA). Agriculture statistics 2016. In Agriculture Do, editor. Thimphu, Bhutan: Department of Agriculture, Ministry of Agriculture & Forests (MoAF); 2017. p. 81.
[40] Department of Agricultural Marketing and Cooperatives [DAMC] & DAS Gasa. Gasa Dzongkhag leading the way in organic crop production. Thimphu: MoAF; 2016. Retrieved from http://www.moaf.gov.bt/gasa-dzongkhag-leading-the-way-in-organic-crop-production.
[41] Dorji C. Potato farmers of Gangteng and Phobji use more fertilisers for better yield. Bhutan Broadcasting Service (BBS); 2019. Retrieved from http://www.bbs.bt/news/?p=112250
[42] Likert R. A technique for the measurement of attitudes. Archives of psychology. New York: The Science Press; 1932. p. 140.
[43] Rovinelli R, Hambleton R. The use of content specialists in the assessment of criterion-referenced test item validity: 1977. Dutch J Edu Res. 1977;2:49–60.
[44] Ciaian P, PALOMA S, Delincé J. Literature review on cost of production methodologies. The first scientific advisory committee meeting. Vol. 1; 2013. p. 1–19.
[45] Netayarak P. Agricultural economics. Bangkok: Thammasat University Press; 2007.
[46] Mendoza TC. Evaluating the benefits of organic farming in rice agroecosystems in the Philippines. J Sustain Agric. 2004;24(2):93–115. doi: 10.1300/J064v24n02_09.
[47] Delaney PR, Whittington OR. Wiley CPA examination review, outlines and study guides. Hoboken, New Jersey: John Wiley & Sons; 2011.
[48] Thorpe E, Thorpe S. The Pearson CSAT Manual 2011. New Delhi: Dorling Kindersley (India) Pvt. Ltd; 2011.
[49] Charantimath PM. Entrepreneurship development and small business enterprise. India: Pearson Education; 2005.
[50] Robinson TR, Henry E, Pirie WL, Broihahn MA, Cope AT. International financial statement analysis. 2 edn. Hoboken, New Jersey: Wiley; 2012.
[51] Husin L. Productivity and income peformance comparison of smallholder oil palm plantation at dry land and wet land of South Sumatra Indonesia. APCBEE Procedia. 2012;3:270–5.
[52] Adhikari RK. Economics of organic rice production. J Agric Environ. 2011;12:97–103.
[53] Dillon CR. Microeconomic effects of reduced yield variability cultivars of soybeans and wheat. J Agric Appl Econ. 1992;24(1):121–33.
[54] Best JW, Kahn JV. Research in education. 8 edn. Boston: Allyn and Bacon; 1998.
[55] Sharifi O, Sadati SA, Ghobadi FR, Sadati SA, Mohamadi Y, Del PTT. Barriers to conversion to organic farming: a case study in Babol county in Iran. Afr J Agric Res. 2010;5(16):2260–7.
[56] Neuhoff D, Tashi S, Rahmann G, Denich M. Organic agriculture in Bhutan: potential and challenges. Org Agric. 2014;4(3):209–21. doi: 10.1007/s13165-014-0075-1.
[57] Ierna A, Parisi B. Crop growth and tuber yield of "early" potato crop under organic and conventional farming. Sci Hortic. 2014;165:260–5. doi: 10.1016/j.scienta.2013.11.032.
[58] Maggio A, Carillo P, Bulmetti GS, Fuggi A, Barbieri G, De Pascale S. Potato yield and metabolic profiling under conventional and organic farming. Eur J Agron. 2008;28(3):343–50. doi: 10.1016/j.eja.2007.10.003.
[59] Coppola G, Costantini M, Orsi L, Facchinetti D, Santoro F, Pessina D, et al. A comparative cost-benefit analysis of conventional and organic Hazelnuts production systems in center Italy. Agriculture (Basel). 2020;10(9):409. doi: 10.3390/agriculture10090409.
[60] Turhan S, Ozbag BC, Rehber E. A comparison of energy use in organic and conventional tomato production. J Food Agric Env. 2008;6(3–4):318–21.
[61] Sgroi F, Candela M, Di Trapani AM, Fodera M, Squatrito R, Testa R, et al. Economic and financial comparison between organic and conventional farming in sicilian lemon orchards. Sustainability. 2015;7(1):947–61. doi: 10.3390/su7010947.
[62] Wheeler SA. The barriers to further adoption of organic farming and genetic engineering in Australia: views of agricultural professionals and their information sources. Renew Agr Food Syst. 2008;23(2):161–70. doi: 10.1017/s1742170507002128.
[63] Finckh M, Schulte-Geldermann E, Bruns C. Challenges to organic potato farming: disease and nutrient management. Potato Res. 2006;49(1):27–42.
[64] Bhatnagar A, Dua VK, Chakrawarti SK. Scenario, implications and prospects of climate change on potato (*Solanum



*tuberosum*) insect pests: a review. Indian J Agric Sci. 2018;88(9):1331–9.
[65] Julio G, Ruiz I, Cuesta X. Expanding the agricultural frontier of the potato (*Solanum tuberosum* L.) to reduce the effects of climate change. Rev Univ Soc. 2018;10(1):46–51.
[66] Kimathi SM, Ayuya OI, Mutai B. Adoption of climate-resilient potato varieties under partial population exposure and its determinants: case of smallholder farmers in Meru County, Kenya. Cogent Food Agr. 2021;7(1):1860185. doi: 10.1080/23311932.2020.1860185.
[67] Population & Housing Census of Bhutan [PHCB]. Population & Housing Census of Bhutan (PHCB) 2017. Bhutan: National Statistics Bureau, Royal Government of Bhutan; 2017. p. 1–268, i–xvii.
[68] DoA. Implementation framework and guidelines for supply of bio-inputs in the country. In Agriculture Do, editor. Thimphu, Bhutan: Department of Agriculture, Royal Government of Bhutan; 2015. p. 10.

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## Cost and return analysis of organic potato in Gasa District, Bhutan

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**Abstract:** Gasa District became the first district in Bhutan to fully embrace organic farming in 2004. The Government has been assertive to increase farmers' household earnings and alleviate poverty. Therefore, the study's objectives were to examine the cost and return analysis of organic potatoes (*Solanum tuberosom* L.) in the Gasa District. Purposive sampling was employed to select 43 organic potato farmers from Goenkhatoe *Gewog* (a group of villages in Bhutan) in the Gasa District. Primary data for the 2019 production and marketing cycle were gathered from September to October 2020, using a semi-structured questionnaire through face-to-face interviews. Descriptive statistics and cost-and-return analysis were used to analyze the data. According to the findings, the total production cost was 339,462.80 Ngultrum per hectare (Nu/ha) (1Nu=0.014 USD). The total variable cost was 338,211.89 Nu/ha, and the total fixed cost was 2,559.28 Nu/ha, comprising 99.63% and 0.75% of the total production cost, respectively. Within the variable costs, the total input cost was 142,427.99 Nu/ha, and the total labour cost was 195,783.89 Nu/ha, which made up 41.96% and 57.67% of the total production cost, respectively. The depreciation cost was the highest contributor within the fixed costs with 2,528.75 Nu/ha, comprising meagre 0.74% of the total production cost. The average yield of potato tuber was 7.48 metric tons per hectare (MT/ha). The average Gross margin (profit) was -202,708.47 Nu/ha. The break-even yield and price were 18.63 MT/ha and 45.58 Nu/ha, respectively. The benefit-cost ratio (B:C ratio) was 0.40, and Return on Investment (ROI) stood at -59.71. The Gross margin over cash and variable cost were 1,082.43 and -201,457.56 Nu/ha, respectively. Considering the lesser B:C ratio (<1), it indicated that organic potato farming is not a profitable venture in the current situation. For a profitable venture, the farmers either need to increase their yield or obtain a farm-gate price greater than the respective break-evens.

**Keywords:** farm household income; farm-gate price; potato production; production cost; profit.

### Introduction

Organic farming is viewed as a means of increasing the sustainability of agriculture (Feuerbacher *et al.*, 2018). Additionally, many studies have shown that organic farming is profitable (Adhikari, 2011, Mendoza, 2004, Suwanmaneepong *et al.*, 2020). In 2019, organic farming accounted for 1.5% of total farmland worldwide, equivalent to 72.3 million hectares (ha). There were 3.1 million organic producers worldwide. Organic activities were conducted in 187 countries, with the organic market estimated at 106.4 billion euros. The per capita consumption of organic commodities was 14.0 euros (IFOAM, 2020).

In the wake of the global movement towards organic farming, Gasa District, one of Bhutan's 20 districts located in the West-Central part of the country, became a fully organic district in 2004 (Wangmo and Iwai, 2018). Bhutan is a tiny mountainous nation on the Himalayan southeast slope (D'Avanzo, 2008), and it has an ambitious goal to be a completely organic country in the globe (Department of Agriculture [DoA], 2006). Agriculture is a vital primary sector in Bhutan, providing livelihood and jobs to 43.9% of the population (Population & Housing Census of Bhutan [PHCB], 2017). Rice, maize, mandarin, apple, potato, and other vegetables, cardamom, and other spices are among the important crops grown in the country. Bhutan has largely smallholder farmers primarily involved in subsistence farming (National Statistical Bureau [NSB], 2017). After rice, maize, and wheat, the potato is the fourth most important crop in terms of calories. According to Bajgai (2018), the potato is one of Bhutan's most commonly grown, consumed, and traded horticultural crops, owing to favourable agro-ecological conditions. About 22% of the country's rural households cultivate it as a non-cereal crop, cash crop, and vegetable. Potato is a cash crop in Bhutan; it is primarily grown using conventional farming practices such as agrochemicals and mineral fertilizers (Lhamo, 2019). In the country, the total potato production in 2019 was 43,560 metric tonnes (MT), with a total area of 4,187 ha and average national yield of 10.40 MT/ha (Ministry of Agriculture and Forests (MoAF), 2020). Around 0.5%, equivalent to 20.34 ha of the country's total potato area, is certified organic. The certified potatoes are grown in the Gasa District, certified by a reliable Bhutanese government institution (Agriculture Research & Development Centre (ARDC)-Yusipang, 2019). The Bhutan Organic Standards is complied with by certified organic potato farmers.

Among others, poverty alleviation, increasing farm household income and job opportunities are vital priorities for the Royal Government of Bhutan (RGoB) (Ghimiray *et al.*, 2019). The Goenkhatoe *Gewog*, a research area for the study within Gasa District, has been producing certified organic potatoes since 2016 (Department of Agricultural Marketing and Cooperatives [DAMC] & DAS Gasa, 2016). However, there are no studies on the cost and return analysis of organic potatoes in Bhutan, especially in the Gasa District. Therefore, the study's objectives were to investigate the cost and return analysis (CRA) of organic potato farming and socio-demographic characteristics of the farmers in Bhutan's first and only organic district, Gasa. The CRA is a type of economic evaluation that considers both implicit and explicit farm expenditures (Ciaian *et al.*, 2013, Netayarak P, 2007). Actual expenses are classified as Explicit costs, but Imputed or Implied costs are classified as Implicit costs since they are unrelated to actual expenditure payments (Ciaian, *et al.*, 2013). In addition, a profitability performance metric indicates how effectively the farmer's resources are used to create revenue and profit (Kahan, 2010). Therefore, the application of economic indicators will be vital to measure the farm household income generated through organic potato farming.

Considering the country's vision to be an organic state and the priorities of the RGoB, this study will help to understand the extent of farm household income generation from organic potato farming in the Gasa District and the country. Such empirical data are expected to help policymakers, obtain additional backing from agriculture officials and researchers, and assist farmers in making decisions about choosing a better potato farming system in Bhutan and around the globe. In addition, academicians and students will find it helpful in understanding field situations.

## Materials and methods

### *Study area*

The Gasa District, the first and only organic district in Bhutan, was chosen for the study. It is one of Bhutan's 20 districts located in the West-Central part of the country (ARDC-Bajo, 2020). With just 3,952 residents, Gasa is the country's least populated district, accounting for only 0.5% of the total population (Population & Housing Census of Bhutan [PHCB], 2017). The district's average annual temperature is 10°C, with a maximum of 15°C and a minimum of 6°C. It has a variety of climates, from temperate to alpine (NSB, 2011). It has around 30 ha under the total potato area with production of about 185 MT/year (MoAF, 2020).

Goenkhatoe *Gewog* (a group of villages in Bhutan) was purposively opted as a research site within Gasa District. The altitude in Goenkhatoe *Gewog* varies between 2,100 and 2,800 meters above mean sea level. The annual rainfall in the *Gewog* is approximately 2,241 millimetres (mm) (NSB, 2011). The National Soil Service Centre (NSSC), Thimphu, identified loamy and silty clay loam soil textures in the *Gewog* in 2020. Fig. 1. depicts the study area in Bhutan.


**Figure 1.** The study region is depicted on a map of Bhutan (encircled). Source: wikipedia.org/wiki/Districts of Bhutan, accessed 22/03/21.

### *Sampling procedure*

The study sample was determined using a technique of purposive sampling. The Gasa District was selected for the organic potato evaluation because its local Government proclaimed it to be the first completely organic district since 2004 (Wangmo and Iwai, 2018). Goenkhatoe *Gewog*, one of four *Gewogs* in the district, was purposefully chosen for the study due to the availability of certified organic potato farmers. Purposive sampling is ideally suited to a small population with well-understood characteristics (Kothari, 2004). Forty-three organic farmers were chosen for the study. *Gasa Rangshin Sonam Detshen* is the organic farmers' group in the *Gewog* that cultivates organic potatoes and other crops. The group has been producing organic potatoes since 2016. Bhutan Agriculture and Food Regulatory Authority (BAFRA) has certified the group (Department of Agricultural Marketing and Cooperatives [DAMC] & DAS Gasa, 2016). Potatoes are the *Gewog*'s main cash-generating crop, but they also cultivate garlic, carrots, wheat, buckwheat, and barley.

***Data collection***

The information was randomly gathered from 43 organic potato farmers spread out across 17 villages in Goenkhatoe *Gewog*, Gasa District. Data was taken during September and October 2020. Face-to-face, individual farmer interviews were used to collect primary data. In addition, the head of the family or any family member actively involved in organic farming was interviewed during the individual farmer's interview. To collect data from farmers, a semi-structured questionnaire was used. It was divided into two parts: the first part covered the socio-demographic characteristics, and the second part on cost and return analysis data.

***Assessment of content validity***

The Item Objective Congruence (IOC) rating, interpretation, and decision as provided by (Rovinelli and Hambleton, 1977) were used to determine the content validity of the items of the questionnaire. To ensure that each questionnaire item captures the intended objectives, a draft semi-structured questionnaire was sent to three experts specific to the study field for review and feedback. Each question item with an IOC rating of 0.5 or higher was kept in the questionnaire. In addition, at least 30 potato farmers who did not belong to the sample study farmers were pre-tested with the questionnaire. In September 2020, pre-testing was carried out in Geney *Gewog*, Thimphu District, Bhutan.

***Data analysis***

***Socio-demographic characteristics***

Descriptive statistics such as frequencies, percentages, standard deviations, arithmetic means, maximum and minimum were used to analyze the socio-demographic variables.

***Cost and return analysis (CRA)***

The farm production costs may be divided into two categories: explicit and implicit costs, which are cash and non-monetary expenses, respectively (Mendoza, 2004, Suwanmaneepong, *et al.*, 2020). Microsoft Excel was used to compute the CRA. Cash costs encompassed those cash payments on farm inputs such as seeds, fuel, farm machinery rental, and hired labour payments. Non-cash expenses encompassed the farm machinery depreciation cost, own potato seeds, input support from the Government, and actual food and refreshments expenses for the exchange and family labour.

***Total cost***

The total cost (TC) was calculated using the equation as follows: (Chidiebere-Mark *et al.*, 2019, Suwanmaneepong, *et al.*, 2020):

TC=TVC + TFC -------------(i)

Where TC is a Total Cost, TVC is a Total Variable Cost, and TFC is a Total Fixed Cost.

The variable input costs, like raw materials, labour, and other variable overhead charges, are referred to as TVCs (Delaney and Whittington, 2011). TFCs, on the other hand, are production expenses that do not vary with output or production volume, like land rent (Thorpe and Thorpe, 2011). The non-cash expenses were computed using current market pricing for agriculture supplies. Labour expenses for hired, exchange and family labourers were determined (Kahan, 2013). The monetary expenses of hired labourers were based on the current agricultural labour rate, but the expenses of exchange and family labourers were determined on the farmers' real food and refreshment expenses (Tashi and Wangchuk, 2016).

The depreciation of farm implements and equipment is included in the TFCs (Charantimath, 2005). The straight-line approach gives the same depreciation expense each year (Robinson *et al.*, 2012).

Depreciation expense = (Asset cost - Salvage value)/Useful life of the asset--(ii)

***Gross return***

Gross return was calculated using the equation below (Adhikari, 2011, Tashi and Wangchuk, 2016).

Gross return (GR) = Q x P---------(iii)

Where GR is Gross Return, Q is yield, P is Selling Price (farm-gate price on this study).

***Profitability***

Profit, Gross Margin, or Net Income (NI) were calculated using the following calculation (Husin, 2012, Lyngbaek and Muschler, 2001):

Profit or GM or NI = GR – TC---------(iv)

where GM is Gross Margin, NI is Net Income; GR is Gross Return, TC is Total Cost

***The Benefit: Cost (B:C) ratio***

The following equation calculated the Benefit: Cost (B:C) ratio (Adhikari, 2011, Tashi and Wangchuk, 2016):

B:C ratio = GR/TC---------(v)

Where, B:C ratio is Benefit: Cost Ratio, GR is Gross Return, TC is Total Cost.

***Return on Investment (ROI)*** (Chidiebere-Mark, *et al.*, 2019)

ROI = GM/TC expressed in %----------(vi)

Where GM is Gross Margin (profit), TC is Total Cost

***Break-even analysis***

In addition to other factors, analyses for break-even price (P) and yield (Y) were performed, as shown in the equations below, based on (Dillon, 1992):

Price $(P_i) = (VC_i + FC_i + \pi_i) / Y_i$-------------(vii)

Yield $(Y_i) = (VC_i + FC_i + \pi_i) / P_i$ ------------(viii)

Where Pi is the output price of commodity i; $Y_i$ is the yield of commodity i; $VC_i$ are the variable costs incurred to produce commodity i; $FC_i$ represents the fixed costs to produce commodity i; Break-even price or yield can be inspected by setting profits $(\pi_i)$ equal to zero.

***Yield calculation***

The yield was calculated using the formula below (FAO, 2017):

Land productivity (yield) = Volume of output/Planted Area----------(ix)

The production volume was determined in metric tons (MT), while the planted area was determined in hectares (ha).

**Results**

***Socio-demographic characteristics of farmers***

The socio-demographic characteristics of the farmers are provided in Table 1. Gender, age, education, household members, family labour, farm size, experience in farming, farmers' training, farmers' group, and others were the parameters to study organic farmers' socio-demographic characteristics. The findings indicated that organic farmers had a higher female (69.77%) than male population (30.23%). The average age of organic farmers was 52 years, the minimum was 26, and the maximum was 84 years.

Most of the organic farmers (21%) who went to school did their primary schooling (1-6 grade). The highest educational achievement was the lower secondary (9-10 grade), with only 5% making it. Around 9% of organic farmers also went to non-formal education. More than half of organic farmers were illiterate (63%). Most organic farmers (88%) were married. The average household member was four, the minimum was one, and the maximum was 12.

The average family labour of organic farmers was two, the minimum was one, and the maximum was five. The average year of farming experience for organic farmers was 31 years, with a minimum of five and a maximum of 70 years. Organic farmers attended an average of two training per year, the minimum was zero, and the maximum was three. The average farm size of organic potato farmers was 1.17 ha, with a minimum of 0.13 and a maximum of 6.88 ha. Most of the farmers (95.3%) were a member of the organic farmers' group–*Gasa Rangsin Sonam Detchen*. The majority of farmers (83.7%) depended purely on farming for their income. More than half (72.1%) of the farmers frequently contacted the Agriculture Extension Agent for farming-related enquiries.

***Cost and return analysis (CRA) of organic potatoes***

The CRA is provided in Table 2. Organic potato cultivation cost a total of 340,771.17 Nu*/ha. The total variable cost per hectare was 338,211.89 Nu, accounting for 99.25% of the total production cost. The total fixed cost was 2,559.28 Nu/ha, and its proportion of total production cost was just 0.75%. The total cash cost per hectare was 135,671.90 Nu, whereas the total non-cash cost per hectare was 205,099.27 Nu. The Government offered input support in the form of seeds and bio-pesticides worth an average of 1,308.37 Nu/ha. As a result, with this input assistance, the real cost of organic potato production to a farmer was 339,462.80 Nu/ha. The labour cost was more than the input cost under variable costs. The total input cost per hectare was 142,427.99 Nu, accounting for 41.96% of the total production cost. The highest input cost was spent while acquiring potato seeds, which was 62,565.50 Nu/ha and accounted for 18.43% of the total production cost. While the cost of bio-pesticides resulted in the lowest input cost of 145.38 Nu/ha, accounting for just 0.04% of the total production cost. The total labour cost was 195,783.89 Nu/ha, accounting for 57.67% of the total production cost. It was the highest contributor to the total cost of production.

Weeding and earthing up activities incurred the highest labour cost of 86,655.70 Nu/ha, accounting for 25.53% of the total production cost. While applying biopesticides had the lowest labour cost of 83.73 Nu/ha, it accounted for just 0.02% of the total production costs. Under fixed costs, the depreciation cost contributed the most, amounting to 2,528.75 Nu/ha, accounting for just 0.74% of the total production cost. Farmers got an average farm-gate price of 18.29 Nu/kg, with a negative gross margin (GM) or a profit of -202,708.47 Nu/ha. The gross margin over cash and

* Nu=Ngultrum (Bhutanese currency); 1 Nu= 0.014 USD

variable costs was 1082.43 Nu/ha and -201,457.56 Nu/ha, respectively. The average organic potato yield was 7.48 MT/ha. The break-even yield and prices were 18.63 MT/ha and 45.58 Nu/kg, respectively, with a benefit-cost ratio (B:C ratio) of 0.40 and a return on investment (ROI) of -59.71%.

**Table 1.** Socio-demographic characteristics of organic potato farmers (n=43).

| Item | Frequency | % | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|---|---|
| Gender | | | | | | |
| Male | 13 | 30.23 | | | | |
| Female | 30 | 69.77 | | | | |
| Age (years) | | | 52.35 | 13.90 | 26 | 84 |
| Education attainment | | | | | | |
| Illiterate | 27 | 62.79 | | | | |
| Non-formal education | 4 | 9.30 | | | | |
| Primary School | 9 | 20.93 | | | | |
| Middle School | 1 | 2.33 | | | | |
| Lower secondary | 2 | 4.65 | | | | |
| Marital status | | | | | | |
| Single/widow/er/divorce | 5 | 11.70 | | | | |
| Married | 38 | 88.37 | | | | |
| Household members | | | 4.49 | 2.43 | 1 | 12 |
| Family labour (persons) | | | 1.98 | 0.91 | 1 | 5 |
| Farming experience (years) | | | 31.05 | 19.81 | 5 | 70 |
| Attend farmers' training (numbers per year) | | | 1.65 | 0.92 | 0 | 3 |
| Farm size (ha) | | | 1.17 | 1.07 | 0.13 | 6.88 |
| Membership in a farmers' group | | | | | | |
| Member | 41 | 95.30 | | | | |
| Non-member | 2 | 4.70 | | | | |
| Off-farm income | | | | | | |
| None | 36 | 83.70 | | | | |
| Yes | 7 | 16.30 | | | | |
| Consult Agriculture Extension Agent | | | | | | |
| Never | 6 | 14.00 | | | | |
| Frequently | 31 | 72.10 | | | | |
| Seldomly | 6 | 14.00 | | | | |

**Table 2.** Cost and return analysis of organic potatoes.

| Item | Cash (Nu) | Non-cash (Nu) | Total (Nu) | % |
|---|---|---|---|---|
| A) Variable costs (VCs) (Nu/ha) | | | | |
| 1) Input cost | | | | |
| i) Seed | 9,321.90 | 53,243.60 | 62,565.50 | 18.43 |
| ii) Farmyard Manure (FYM) and other organic fertilizers | 1,550.39 | 56,792.70 | 58,343.09 | 17.19 |
| iii) Bio-pesticides | 0 | 145.38 | 145.38 | 0.04 |
| iv) Fuel & rental | 21,374.03 | 0 | 21,374.03 | 6.30 |
| **Total input cost** (Nu/ha) | **32,246.32** | **110,181.68** | **142,427.99** | **41.96** |
| 2) Labour cost | | | | |
| i) Land preparation | 8,681.41 | 14,998.68 | 23,680.09 | 6.98 |
| ii) Compost/FYM application | 6,570.37 | 6,801.57 | 13,371.94 | 3.94 |
| iii) Planting | 13,814.76 | 8,338.41 | 22,153.17 | 6.53 |
| iv) Weeding & earthing up | 43,861.92 | 42,793.78 | 86,655.70 | 25.53 |
| v) Bio-pesticides application | 0 | 83.73 | 83.73 | 0.02 |
| vi) Harvesting/curing | 30,466.60 | 19,372.67 | 49,839.27 | 14.68 |
| **Total labour cost** (Nu/ha) | **103,395.05** | **92,388.84** | **195,783.89** | **57.67** |
| **Total Variable Cost (TVC)** (Nu/ha) | **135,641.37** | **202,570.52** | **338,211.89** | **99.63** |
| B) Fixed Costs (FCs) (Nu/ha) | | | | |
| 1) Land tax | 30.53 | 0 | 30.53 | 0.01 |
| 2) Land rent | 0 | 0 | 0 | 0.00 |
| 3) Depreciation cost | 0 | 2,528.75 | 2,528.75 | 0.74 |
| **Total Fixed cost (TFC)** (Nu/ha) | **30.53** | **2,528.75** | **2,559.28** | **0.75** |
| **Total Cost (TC) = (TVC + TFC)** (Nu/ha) | **135,671.90** | **205,099.27** | **340,771.17** | |
| **Total cost with deductions of an average Govt. support on seeds & bio-pesticides worth of Nu.1,308.37/ha.** (Nu/ha) | **135,671.90** | **203,790.90** | **339,462.80** | |
| Gross Return (GR) (Nu/ha) (Q x P) | | | 136,754.33 | |
| Yield (kg/ha) (Q) | | | 7,477 | |
| Farmgate price (Nu/kg) (P) | | | 18.29 | |
| Gross margin (GM) (profit) (Nu/ha) (GR-TC) | | | -202,708.47 | |
| Break-even productivity (kilograms/ha) | | | 18,631.56 | |
| Break-even price (Nu/ha) | | | 45.58 | |
| Benefit-cost ratio (B:C ratio) (GR/TC) | | | 0.40 | |
| Return on Investment (GM/TC x 100) (%) | | | -59.71 | |
| Gross margin over cash cost (Nu/ha) (GR-Total cash cost) | | | 1,082.43 | |
| Gross margin over variable cost (Nu/ha) (GR-TVC) | | | -201,457.56 | |

Nu=Ngultrum (Bhutanese currency); 1 Nu= 0.014 USD

## Discussion

### *Socio-demographic characteristics*

In the study, more female than male population composed the organic potato farmers. Suwanmaneepong, *et al.* (2020) also found more women than men practising organic rice farming. It was found that organic potato farmers were ageing. Takagi *et al.* (2020) also found that more than half of organic farmers were above 50 years old. More than half of organic farmers were illiterate. According to the (Population & Housing Census of Bhutan [PHCB], 2017), the Gasa District has the lowest literacy rate in the country.

Organic farmers had only two-family farm labourers on average signifying farm labour shortage. The shortages are becoming more of a concern in Bhutan, owing mostly to rising rural-to-urban migration (Population & Housing Census of Bhutan [PHCB], 2017). The study indicated that the organic potato farmers were well experienced in their field, and additionally, they were regularly receiving technical training from the Agriculture Department. Suwanmaneepong, *et al.* (2020) also found that organic rice growers attended more training. The average farm size of organic potato farmers was comparable with the national mean landholding in rural areas of 1.18 ha (Population & Housing Census of Bhutan [PHCB], 2017). Most of the farmers belonged to the organic farmers' group in the district, and a majority of them depended purely on farming for their income. Many organic potato farmers were in constant touch with the Agriculture Extension officer for farming-related enquiries.

An ageing population, higher illiteracy rate, and more female gender observed with the organic farmers could affect the farmers' performance, subsequently affecting the crop yield and other farm outputs. In addition, farmers' education level (Andaregie and Astatkie, 2020, Nyagaka *et al.*, 2010) and age (Chemak *et al.*, 2014) influenced the potato production efficiency.

***Cost and Return Analysis***

It was found that most of the production cost was due to the variable cost, whereas the fixed cost was a negligible one. Kahan (2013) stated that small scale farmers often have a low level of fixed costs. Much of the time, they do not have to bother about distributing fixed expenses across farm businesses. The variable costs are almost all their expenses. The total non-cash cost was greater than the total cash cost; it was mainly due to higher expenses on the labour cost incurred on serving the food and refreshments to the exchange and family labour. The actual cost of production to an organic potato farmer was reduced due to farm inputs support of the Government on the potato seeds, bio-pesticides, and other inputs. It was observed that the labour cost exceeded the input cost under variable costs.

Additionally, the total labour cost was the highest contributor to the total production cost. Within the labour cost weeding and earthing up activities incurred the highest cost. Other organic and conventional rice research supports this finding (Mendoza, 2004, Tashi and Wangchuk, 2016) and organic and conventional maize (Adamtey *et al.*, 2016). The lowest labour cost on the application of bio-pesticides and also being the lowest input cost suggest that organic farmers do not use it much for plant protection activities. Tashi and Wangchuk (2016) also reported that conventional rice producers in Bhutan paid considerably high for agrochemicals. Regarding lesser input costs, Morshedi *et al.* (2017) also stated that organic farming lowers the expense of purchasing farm raw materials.

Many organic potato farmers perceived that the average farm-gate prices obtained by them were below the normal prevailing rates. They reasoned that the general poor appearance of organic potato tubers than the conventional potatoes characterized by smaller tuber size and rough appearance led to lower price. The average yield of organic potato was lower than the average national potato yield. This finding agrees with (Ierna and Parisi, 2014, Maggio *et al.*, 2008) on lower yields in organic potatoes. It contradicted with the findings of (Tashi and Wangchuk, 2016), where no significant differences in rice grain yields were observed between organic and conventional rice in Bhutan. Organic potato production had a B:C ratio of <1 and a negative ROI, indicating that it was not lucrative. If the B:C ratio is larger than one, the benefits outweigh the costs; if it is less than one, the costs outweigh the benefits, and the business is unprofitable (Hay, 1982). A prominent indicator for assessing a company's profitability is the return on investment (ROI) (Rosenbaum *et al.*, 2013, Tiffany and Peterson, 2011).

The organic potato was unprofitable mainly owing to low yield and a lower farm-gate price. Therefore, organic potato farmers either need to increase their yield or obtain farm gate prices higher than their respective break-evens to ensure profitability. Additionally, there is a need to research to find the actual causes of the low yield of organic potatoes and generate appropriate technologies. There is also a need to implement market research to increase the income of the organic potato farmers in the Gasa District, Bhutan.

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## References

Adamtey, N., Musyoka, M. W., Zundel, C., Cobo, J. G., Karanja, E., Fiaboe, K. K. M., Muriuki, A., Mucheru-Muna, M., Vanlauwe, B., Berset, E., Messmer, M. M., Gattinger, A., Bhullar, G. S., Cadisch, G., Fliessbach, A., Mader, P., Niggli, U. and Foster, D. (2016). Productivity, profitability and partial nutrient balance in maize-based conventional and organic farming systems in Kenya. Agriculture Ecosystems & Environment, 235:61-79

Adhikari, R. K. (2011). Economics of organic rice production. Journal of Agriculture and Environment, 12:97-103

Agriculture Research & Development Centre (ARDC)-Yusipang, 2019. Annual report (2018-2019), ARDC-Yusipang, Royal Government of Bhutan. In: D.o. Agriculture (ed), 2019, (Department of Agriculture, Thimphu), i-x, 106

Andaregie, A. and Astatkie, T. (2020). Determinants of technical efficiency of potato farmers and effects of constraints on potato production in Northern Ethiopia. Experimental Agriculture, 56:699-709

ARDC-Bajo, 2020. About ARDC Bajo. 2020, (Agriculture Research & Development Centre (ARDC)-Bajo, Wangduephodrang

Bajgai, Y. (2018). Standard evaluation guideline for potato germplasm. In: Lakey ed, Standard evaluation guidelines for field & horticultural crops, Agriculture Research & Extension Division (Ared), Department Of Agriculture, Ministry of Agriculture & Forests, Thimphu, Thimphu, pp. 27-39.

Charantimath, P. M. (2005). Entrepreneurship Development and Small Business Enterprise, Pearson Education, pp.

Chemak, F., Allagui, L. and Ali, Y. (2014). Analysis of the technical performance of potato growers in Tunisia, A non parametric approach. New Medit, 13:72-80

Chidiebere-Mark, N., Ohajianya, D., Obasi, P. and Onyeagocha, S. (2019). Profitability of rice production in different production systems in Ebonyi State, Nigeria. Open Agriculture, 4:237-246

Ciaian, P., PALOMA, S. and Delincé, J. (2013). Literature review on cost of production methodologies. The First Scientific Advisory Committee Meeting, 1-19 p.

D'Avanzo, C. (2008). Mosby's Pocket Guide to Cultural Health Assessment - E-Book, Elsevier Health Sciences, pp.

Delaney, P. R. and Whittington, O. R. (2011). Wiley CPA Examination Review, Outlines and Study Guides, New Jersey, Wiley, pp. 1008.

Department of Agricultural Marketing and Cooperatives [DAMC] & DAS Gasa, 2016. Gasa Dzongkhag leading the way in organic crop production. 2016, (MoAF, Thimphu),
Department of Agriculture [DoA], 2006. National Framework for Organic Farming in Bhutan In: D.o. Agriculture (ed), 2006, (Department of Agriculture, Royal Government of Bhutan (RGoB), Thimphu, Bhutan), 44
Dillon, C. R. (1992). Microeconomic effects of reduced yield variability cultivars of soybeans and wheat. Journal of Agricultural and Applied Economics, 24:121-133
FAO. (2017). Productivity and Efficiency Measurement in Agriculture - Literature Review and Gaps Analysis Food and Agriculture Organization of the United Nations (FAO), pp. 77.
Feuerbacher, A., Luckmann, J., Boysen, O., Zikeli, S. and Grethe, H. (2018). Is Bhutan destined for 100% organic? Assessing the economy-wide effects of a large-scale conversion policy. PloS one, 13:24
Ghimiray, M., Katwal, T. B., Tshering, K., Dorjee, Dukpa, W., Lakey, Phuntsho, L., Dendup, S., Gyalmo, T. and Ngawang, 2019. Agriculture Research Strategy 2018-2028. In: D.o. Agriculture (ed), 2019, (Agriculture Research and Extension Division (ARED), Department of Agriculture., Thimphu, Bhutan), 56
Hay, W. W. (1982). Railroad Engineering, Wiley, pp.
Husin, L. (2012). Productivity and income peformance comparison of smallholder oil palm plantation at dry land and wet land of South Sumatra Indonesia. APCBEE Procedia, 3:270-275
Ierna, A. and Parisi, B. (2014). Crop growth and tuber yield of "early" potato crop under organic and conventional farming. Scientia Horticulturae, 165:260-265
IFOAM, 2020. Annual Report 2020 Consilidated Annual Report of IFOAM - Organics International & its Action Group. 2020, 22
Kahan, D. (2010). Farm business analysis
using benchmarking, Rome, Food and Agriculture Organization of the United Nations (FAO), pp.
Kahan, D. (2013). Economics for farm management extension, Food and Agriculture Organization of the United Nations (FAO) pp. i-vi, 1-97.
Kothari, C. R. (2004). Research methodology: Methods and techniques, New Delhi, India, New Age International Publishers, pp. i-xvi, 1-401.
Lhamo, P., 2019. In Phobji and Gangtey, farmers compete to use more fertilisers. 2019, (kuensel,
Lyngbaek, A. E. and Muschler, R. G. (2001). Productivity and profitability of multistrata organic versus conventional coffee farms in Costa Rica. Agroforestry systems, 53:205-213
Maggio, A., Carillo, P., Bulmetti, G. S., Fuggi, A., Barbieri, G. and De Pascale, S. (2008). Potato yield and metabolic profiling under conventional and organic farming. European Journal of Agronomy, 28:343-350
Mendoza, T. C. (2004). Evaluating the benefits of organic farming in rice agroecosystems in the Philippines. Journal of Sustainable Agriculture, 24:93-115
Ministry of Agriculture and Forests (MoAF), 2020. Agriculture Statistics 2019. In: D.o. Agriculture (ed), 2020, (Renewable Natural Resources Ststistics Division (RSD), Thimphu, Bhutan), I-VII, 1-123
MoAF, 2020. Agriculture Statistics 2019. In: D. Services (ed), 2020, (Renewable Natural Resources Statistics Division (RSD), Royal Government of Bhutan, Thimphu), I-VII, 1-123
Morshedi, L., Lashgarara, F., Hosseini, S. J. F. and Najafabadi, M. (2017). The Role of Organic Farming for Improving Food Security from the Perspective of Fars Farmers. Sustainability, 9:13
National Statistical Bureau [NSB], 2017. Bhutan living standards survey report 2017. 2017, (National Statistics Bureau (NSB), Royal Government of Bhutan, Bhutan), i-xvi, 1-210
Netayarak P. (2007). Agricultural economics, Bangkok, Thammasat University Press, pp.
NSB, 2011. Annual Dzongkhag Statistics 2011 (Dzongkhag Administration Gasa). In: N.S. Bureau (ed), 2011, (National Statistics Bureau, Bhutan), i-iii, 1-48
Nyagaka, D. O., Obare, G. A., Omiti, J. M. and Nguyo, W. (2010). Technical efficiency in resource use: Evidence from smallholder Irish potato farmers in Nyandarua North District, Kenya. African Journal of Agricultural Research, 5:1179-1186
Population & Housing Census of Bhutan [PHCB], 2017. Population & Housing Census of Bhutan (PHCB) 2017 2017, (National Statistics Bureau, Royal Government of Bhutan Bhutan), i-xvii,1-268
Robinson, T. R., Henry, E., Pirie, W. L., Broihahn, M. A. and Cope, A. T. (2012). International Financial Statement Analysis, New Jersey, Wiley, pp.



Rosenbaum, J., Pearl, J., Perella, J. R. and Harris, J. (2013). Investment Banking: Valuation, Leveraged Buyouts, and Mergers and Acquisitions, Wiley, pp.
Rovinelli, R. and Hambleton, R. (1977). The use of content specialists in the assessment of criterion-referenced test item validity: 1977. Dutch J Edu Res, 2:49-60
Suwanmaneepong, S., Kerdsriserm, C., Lepcha, N., Cavite, H. J. and Llones, C. A. (2020). Cost and return analysis of organic and conventional rice production in Chachoengsao Province, Thailand. Organic Agriculture, 10:1-10
Takagi, C., Purnomo, S. H. and Kim, M. K. (2020). Adopting Smart Agriculture among organic farmers in Taiwan. Asian Journal of Technology Innovation:16
Tashi, S. and Wangchuk, K. (2016). Organic vs. conventional rice production: comparative assessment under farmers' condition in Bhutan. Organic Agriculture, 6:255-265
Thorpe, E. and Thorpe, S. (2011). The Pearson CSAT Manual 2011, Dorling Kindersley (India) Pvt. Ltd., New Delhi,
Tiffany, P. and Peterson, S. D. (2011). Business Plans For Dummies, Wiley, pp.
Wangmo, S. and Iwai, C. B. (2018). Performance of Organic Agriculture (OA) based on Emergent Properties of Agriculture System in Gasa, Bhutan. Khon Kaen Agriculture Journal, 1985:1202-1210

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1) Accepted letter

AATSEA

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Ref. 03/001
Date: 18 March 2022
Dear **Lepcha, N.**

Your manuscript entitled **"Macronutrients (NPK) and other soil properties influenced by long term organic and conventional potato farming in West-Central Bhutan"** is accepted to publish in International Journal of Agricultural Technology Volume 18 Number 3 in May 2022.

Further correspondence with regards to the proof and publication of your article should be reconfirmed **within 3 days** and addressed to Ijat.publication@gmail.com

Please contact us to e-mail: ijat.publication@gmail.com, if you have any questions.

Best regards,

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# Macronutrients (NPK) and other soil properties influenced by long term organic and conventional potato farming in West-Central Bhutan

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Lepcha, N. and Suwanmaneepong, S. (2022). Macronutrients (NPK) and other soil properties influenced by long term organic and conventional potato farming in West-Central Bhutan. International Journal of Agricultural Technology 18(3).

**Abstract** There are reported overuse of chemical fertilizers by some conventional potato farmers in Bhutan. On the other hand, over the years, some farmers have been growing potatoes (*Solanum tuberosum* L.) organically. The macronutrients (NPK) and other soil properties influenced by long-term organic and conventional potato farming were investigated in Gasa and Wangdue Phodrang Districts in West-Central Bhutan. The total nitrogen (N)% in organic potato soil (0.38%) was significantly higher than in conventional soil (0.26%) at $p<0.01$. Available phosphorus (P) was significantly higher in conventional potato soil (8.87 mg/kg) than in organic soil (4.87 mg/kg) at $p<0.05$. There was no significant difference in available and exchangeable potassium (K) between organic and conventional soils. The pH of conventionally cultivated soil (4.99) was significantly lower than organic soil (5.57) at $p<0.01$. There was a positive correlation (0.883) between total N% and soil organic matter in conventional soil at $p<0.01$. However, no significant difference was observed in the organic matter% content between these farming systems. Further, the Carbon: Nitrogen (C: N) ratio was significantly lower in organic (9.99) than conventional soil (11.52) at $p<0.01$. The cation exchange capacity (CEC) was significantly higher in organic soil (22.26) than in conventional soils (19.45) at $p<0.05$. The study revealed that organic farming led to higher soil residual N and higher CEC than conventional one. It also showed a lower C:N ratio, whereas conventional farming led to higher P but lower pH than organic farming.

**Keywords:** Farming system, Long-term farming, Soil analysis, Soil properties, Soil sampling

activity in the soil, and these elements also influence its complexity, soil fertility, and productivity, which are critical for sustained agricultural output (FAO, 2009). Organic soil management fertilizes with natural sources such as compost, whereas conventional soil management utilizes mineral fertilizers as the primary source of crop nutrition (Bajgai *et al.*, 2015). Crop nutrients are mostly obtained from two sources: a) Organic sources are those that result from the breakdown of organic biomass through decomposition b) Inorganic sources are those plant nutrients such as macro and micro-ones and soil amendments provided in an artificially made chemical medium known as fertilizers and supplements. Organic manures such as the farmyard manure (FYM) are naturally renewable resources of soil organic matter that include all the required plant nutrients. It offers numerous advantages that improve soils' physical, chemical, and biological characteristics (Subedi and Ma, 2009). The importance of chemical fertilizers in contemporary agriculture cannot be overstated. In the absence of fertilizers, agricultural output would not have been able to meet the rapidly rising food demand of the world's population (FAO, 1998).

Bhutan, a small and mountainous country on the southeast slope of the Himalayas, has been promoting organic farming as a mainstay farming system since 2006 (Department of Agriculture [DoA], 2006). In Bhutan, the potato is an important cash crop mainly cultivated through conventional farming practices using chemical fertilisers and agrochemicals (Lhamo, 2019). However, the conventional potato farmers also use some FYM and other organic amendments along with chemical fertilizers. There was a total area of 4,187 hectares (ha) with a total production of 43,560 metric tonnes (mt) in 2019 under potato farming in the country (Ministry of Agriculture and Forests (MoAF), 2020). About 0.5% of the total potato area is certified organic in Gasa District, corresponding to 20.34 ha (Agriculture Research & Development Centre (ARDC)-Yusipang, 2019). The certified organic potato farmers adhere to Bhutan's national organic standards and only apply organic fertilizers and amendments such as the FYM and bio-pesticides for crop production.

Bhutan's Himalayan soils are classified as *ferralsols* which are associated with low fertility, poor P availability, soil acidity, and macro and micronutrient deficits (Tashi and Wangchuk, 2016). Conventional agrochemicals such as fertilizers and insecticides are used in minimal quantities in the country and mostly used in key cereals and cash crops, according to (ICIMOD, 2018).

Potato demands a considerable quantity of nutrients while being a high producing, short-duration crop compared to cereals with its shallow root structure. It grows best in sandy-textured, well-drained soils. Since nitrate is prone to leaching losses, these soil types typically make water and N management problematic (Mikkelsen, 2006). Local authorities and agriculture officials in Gangtey and Phobjikha *Gewogs* (a group of villages in Bhutan) under Wangdue Phodrang District are worried about the rising use of chemical fertilizers in potato farming. It appears that farmers in these *Gewogs* are contending to use more chemical fertilizers each year for potato cultivation (Lhamo, 2019). The overuse and inappropriate application of manure and fertilizers in the field have generated public concern over surface and groundwater contamination and gaseous N emissions that harm the environment. Eutrophication is caused by excessive bacteria, an algae bloom in surface waters as a result of excess nutrients, most often of N and P (Subedi and Ma, 2009). Soil fertility is lost, and soils are degraded due to poor farming practices (Kshash and Oda, 2021). As a result, manures and fertilizers must be handled with caution in order to maximize earnings, improve crop quality, conserve energy, and safeguard the environment (Schröder *et al.*, 2000). The substantial rise in atmospheric $N_2O$ is attributable to human changes to the global N cycle, with agricultural soils and N fertilizer accounting for 24% of yearly emissions (Bouwman, 1996, Mosier, 2001). Soil properties such as pH, organic carbon, and CEC impact crop nutrient availability, growth, nutrient use efficiency, and, ultimately, crop productivity (Subedi and Ma, 2009, Westerman *et al.*, 1999).

Potato is one of the cash crops in Bhutan, where farmers use relatively high quantities of agrochemicals (Roder *et al.*, 2008). Consequently, there lies a necessity to examine the effects of long-term conventional and organic potato farming on the physicochemical properties of soil in West-Central Bhutan. However, except for the assessment on organic vis-à-vis conventional rice farming in Bhutan (Tashi and Wangchuk, 2016), no other similar studies have been carried out in the country, especially for important income-generating crops such as potato. Similar studies on the impact of organic and conventional farming on soil properties were implemented by (Adamtey *et al.*, 2016, Bajgai, *et al.*, 2015, Mendoza, 2004, Tashi and Wangchuk, 2016).

The important objective was to determine the long-term effects of organic and conventional potato farming on soil properties in West-Central Bhutan, which included comparing soil nutrient status (NPK) and other soil properties. Soil sampling and analysis can give critical information on the initial point and residual nutrients for crop growth circumstances (Mikkelsen, 2006, Schröder, *et al.*, 2000).

## Materials and methods

### *Study area*

Gasa and Wangdue Phodrang Districts, both potato-producing and neighbouring districts with similar agro-ecological characteristics in West-Central Bhutan, were selected for the study (Figure 1). Further, Gasa District is the first completely organic district since 2004 (Wangmo and Iwai, 2018). Wangdue Phodrang District is the largest producer of conventional potatoes in West-Central Bhutan (Department of Agriculture (DoA), 2017). Gasa's mean annual temperature is 10°C. It has a total potato area of 30.08 ha and produces 185.24 mt per year (MoAF, 2020). Goenkhatoed *Gewog* (a group of villages in Bhutan), situated at 27°50′N 89°38′E was chosen as a research site for organic potato's soil sampling within the district. The altitude of the *Gewog* extends from 2,100 to 2,800 metres above mean sea level (m.a.s.l). Annual rainfall in the *Gewog* is about 2,241 millimetres (mm) (NSB, 2011a). *Ferralsols* make up Bhutan's Himalayan soils (Tashi and Wangchuk, 2016); this also makes up the soil type in the study area. According to the National Soil Service Centre (NSSC), Thimphu, in 2020, the *Gewog* has loamy and silty clay loam soil texture.

The average annual temperature in Wangdue Phodrang District is 21°C. It has 882.62 ha under potato cultivation, with 15,569.87 mt per year (MoAF, 2020). Phobjikha *Gewog,* located at 27°30′N 90°10′E was chosen as a research site for conventional potato's soil evaluation. Phobjikha *Gewog* is situated between 2,300 and 4,000 m.a.s.l. It receives 1,099 mm of rain per year (NSB, 2011b). According to the NSSC in 2020, the soil textures in Phobjikha *Gewog* are similar to Goenkhatoed *Gewog*, consisting of loam and silty clay loam. Both research sites are situated in Bhutan's temperate zone above 1,800 m.a.s.l (Feuerbacher *et al.*, 2018).

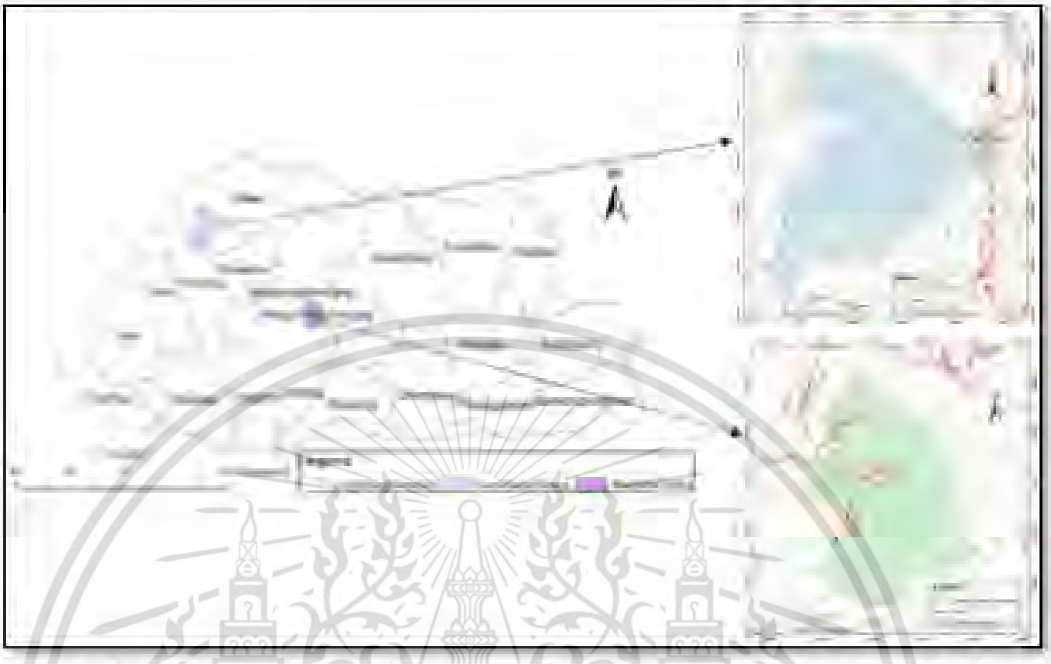

**Figure 1.** Soil sampling in study areas in Gasa and Wangdue Phodrang Districts, Black dots on the right are probable soil sampling sites (Source the NSSC, Bhutan, 2020)

***Sampling procedure***

The Goenkhatoed *Gewog*, one of four *Gewogs* in Gasa District, was purposively chosen for the study because it has an organic farmers' group producing certified organic potatoes since 2016 (Department of Agricultural Marketing and Cooperatives [DAMC] & DAS Gasa, 2016). On the other hand, Phobjikha *Gewog*, one of 15 *Gewogs* in Wangdue Phodrang District, was chosen for conventional potato's soil study. For years, the farmers in the *Gewog* have grown conventional potatoes. Potato farming is their main source of income (Dorji, 2019).

A total of 30 soil samplings were taken from the study sites through a systematic sampling technique. Systematic sampling requires some level of randomness by selecting a random point in the list, and then every $n^{th}$ member is selected until the required number is obtained (Kothari, 2004). In this study, every $3^{rd}$ farmer was selected until 15 samples were obtained in each farming system. In Goenkhatoed *Gewog* under the Gasa District, the soil samplings were collected from 15 farms, out of 43 organic potato farms, spread across ten villages. In Phobjikha *Gewog* under Wangdue Phodrang District, the soil samplings were collected from 15 farms out of 50 conventional potato farms, spread across 11 villages. The soil samples were collected in August-September 2020.

*Data collection*

Soil samplings were carried out in the study areas according to the standard protocol outlined in the National Soil Service Centre (NSSC) Thimphu, Bhutan field crops soil sampling leaflet (NSSC, 2008). The field was divided into 8 to 10 parts at random to represent the area. Grass and other plant debris on the soil surface were scraped away. A soil sample was taken to a depth of 20 cm with a soil augur and placed on the tray. A composite sample was formed by taking similar soil samples from 8-10 more points and putting them on the tray. All the samples were thoroughly mixed, and any stones or plant roots in the tray were removed. Air-dried composite soil samples were sieved with a 2-mm sieve. A kilogram of composite soil was placed in the plastic bag and appropriately labelled. The soil sample was accompanied by a completed soil analysis request form (soil information sheet). The soil sample was then packed and sent to the NSSC's Soil and Plant Analytical Laboratory (SPAL) for laboratory analysis. Soil samples were taken in the field after the potato crop was harvested (Figure 2). Data on the type and quantity of different fertilizers applied by the potato growers and their socio-demographic characteristics were obtained using a semi-structured questionnaire through face-to-face interviews. It was gathered to understand their farming approach and enrich the discussion holistically.

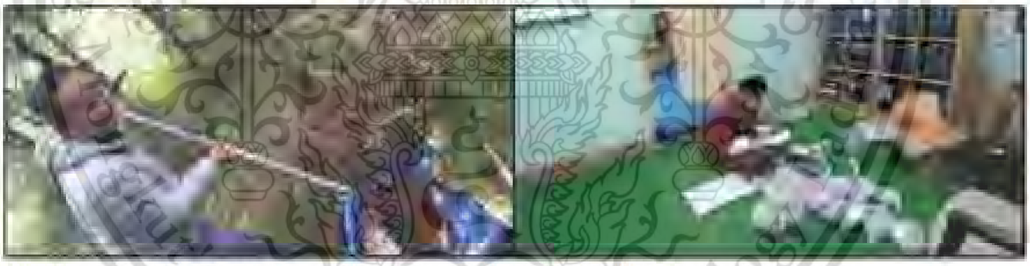

**Figure 2.** Soil samplings pictures in Bhutan in 2020.

*Data analysis*

**Laboratory analysis of soil**

The Soil and Plant Analytical Laboratory (SPAL) at the NSSC, Bhutan, analysed the physicochemical properties of soils. The SPAL is a member of the

Southeast Asian Laboratory (SEAL) and is affiliated with the Netherlands University. Other studies have also analysed their soils at the SPAL (Bajgai and Sangchyoswat, 2018, Tashi and Wangchuk, 2016). The total N% was analysed using the Micro-Kjeldahl method. Available P and K were analysed using the Bray method and calcium chloride extraction, respectively. Total carbon was determined using the Walkley-Black method. 1 M ammonium acetate extraction at pH 7 was used to determine exchangeable K and CEC. Using a PHM 83 automatic pH meter, soil pH was determined in distilled water-soil suspension (1:2.5). The hand method is determined the texture of the soil.

**Statistical analysis of soil properties**

The Independent Sample t-test was used to compare the mean differences of different soil characteristics. The criteria of normal distribution and variance homogeneity were confirmed prior to statistical analysis. All tests were run at a 5% level of significance (Best and Kahn, 1998, Kothari, 2004). The Pearson correlations were used to determine correlations between the soil properties (Tashi and Wangchuk, 2016). The SPSS was used for the data analysis.

## Results

Socio-demographic characteristics revealed that the mean age of organic potato farmers was 47 years, whereas it was 40 years for conventional farmers. More female farmers (80%) took up organic potato farming, whereas more male farmers (67%) did conventional potato farming. Educational level was slightly better with the conventional farmers, with more farmers attending primary and middle school. The conventional potato farmers had a larger mean family size (6 persons) than organic farmers (4 persons). Conventional farmers also had larger mean family labour (3 persons) than organic farmers (2 persons). Organic potato farmers had a larger mean farm size (0.99 ha) than the conventional farmers (0.89 ha). Organic farmers had a larger average experience in farming (28 years) than conventional farmers (22 years). Farmers' training was attended more by organic farmers (1.5 times/year) than the conventional farmers (1 time/year) (Table 1).

**Table 1.** Socio-demographic profile of the farmers

| Variables | Organic farmers | | | | Conventional farmers | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean | S.D | Min | Max | Mean | S.D | Min | Max |
| Age | 47.73 | 15.31 | 26 | 71 | 40.87 | 8.06 | 29 | 56 |
| Sex | - | - | 3 M | 12 F | - | - | 5 F | 10 M |
| Education level | 4 (PS), 1 (NF), 10 (I) | | | | 5 (PS), 1 (MS), 2 (NF), 7 (I) | | | |
| Household size (numbers) | 3.47 | 1.77 | 1 | 7 | 6 | 2.29 | 3 | 10 |
| Family labour (person) | 1.67 | 0.72 | 1 | 3 | 3.13 | 1.36 | 2 | 6 |
| Farm size (ha) | 0.99 | 0.72 | 0.13 | 2.82 | 0.89 | 0.44 | 0.40 | 1.82 |
| Farming experience (years) | 28.47 | 19.32 | 5 | 60 | 22 | 7.36 | 10 | 35 |
| Farmers' training (numbers/year) | 1.47 | 0.92 | 0 | 3 | 1.13 | 0.83 | 0 | 2 |

M=male, F=Female; PS (Primary school), NF (Non-formal), I (Illiterate), MS (middle school).

Organic potato farmers applied around 41 mt/ha of FYM & other organic amendments in 2019, supplying about 449 kgs/ha of N, 224 kgs/ha of P, and 815 kgs/ha of K. The conventional potato farmers added around 16 mt/ha of FYM & other organic amendments, 0.004 mt/ha of urea (0:46:0), 0.74 mt/ha of Suphala (15:15:15), and 0.23 mt/ha of single super phosphate (SSP) (0:16:0) in 2019. As a result, it supplied around 287 kgs/ha of N, 235 kg/ha of P, and 428 kgs/ha of K (Table 2 and Figure 3).

**Table 2.** Different types and average quantities of chemical and organic fertilizers applied in the cropping cycle 2019

| Farming type in potato | Organic amendments (mt/ha) | Chemical fertilizers (mt/ha) | | | NPK (Kg/ha) | | |
|---|---|---|---|---|---|---|---|
| | FYM & other organic amendments | Urea (0:46:0) | Suphala (15:15:15) | Single Super Phosphate (0:16:0) | N | P | K |
| Organic | 41.34 | - | - | - | 449.78 | 224.89 | 815.22 |
| Conventional | 16.08 | 0.004 | 0.74 | 0.23 | 287.79 | 235.28 | 428.10 |

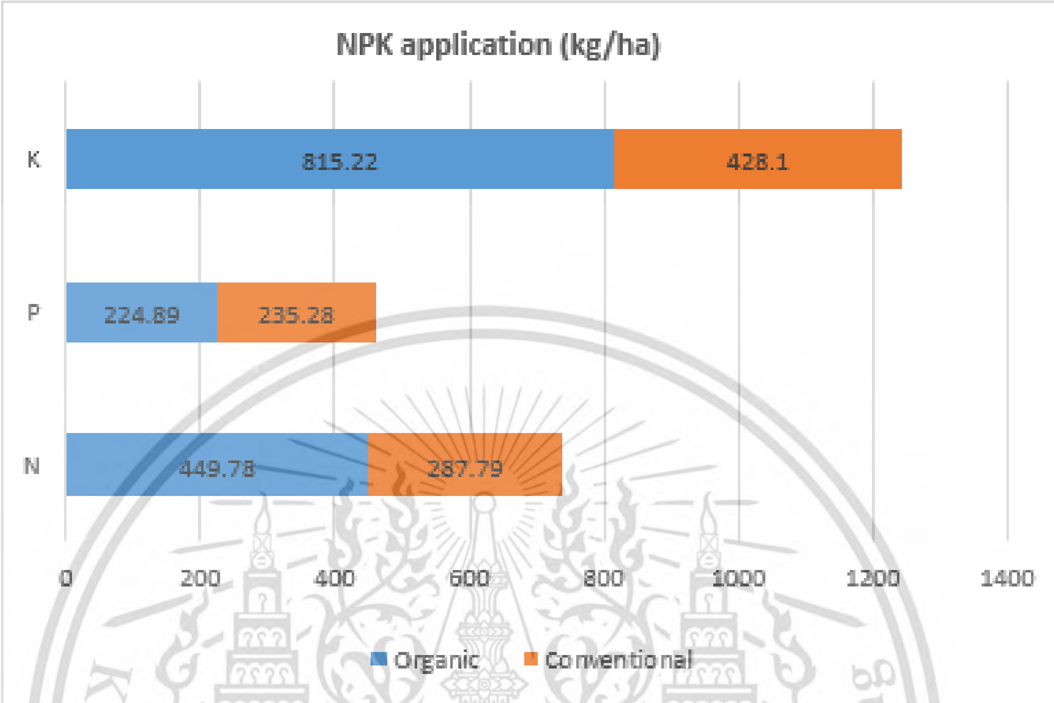


**Figure 3.** Graphical representation of NPK applied by the potato farmers

Both organic and conventional potato fields had similar soil textures consisting of loam and silty clay loam. The analysis indicated that the soils in the organic field comprised 73.3% loam and 26.7% silty clay loam. In conventional fields, 60% of the soil textures constituted silty clay loam, while the remaining 40% was loam.

The results showed that the pH ($H_2O$) of conventional soils (4.99) was significantly lower than the organic soils (5.57) at $p<0.01$. The available (Av.) P was significantly higher in the conventional soils (8.87 mg/kg) than the organic soils (4.87 mg/kg) at $p<0.05$. Organic matter (OM) (%) content was not significantly different between organic and conventional soils. Total N% was significantly higher in the organic soils (0.38%) compared to the conventional soils (0.26%) at $p<0.01$. The Carbon: Nitrogen (C: N) ratio was significantly lower in organic soils (9.99) than conventional soils (11.52) at $P<0.01$. There were no significant differences in Av. K between the two farming systems. The mean Av. K for organic and conventional soils were 183.02 and 143.47 mg/kg, respectively. There were also no significant differences in exchangeable (Ex.) K between the two farming systems. The cation exchange capacity (CEC) (me/100g) was significantly higher in the organic soils (22.26) than the conventional soils (19.45) at $P<0.05$ (Table 3).

**Table 3.** Comparisons of means of different soil properties (independent sample t-test, N=30)

| Item[†] | Mean | | d.f. | t-test | p-value |
|---|---|---|---|---|---|
| | Organic | Conventional | | | |
| pH ($H_2O$) | 5.57 | 4.99 | 28 | 4.41 | 0.000** |
| Av. P (mg/kg) | 4.87 | 8.87 | 28 | -2.392 | 0.024* |
| OM (%) | 5.87 | 5.10 | 28 | 1.700 | 0.100 |
| Total N (%) | 0.38 | 0.26 | 28 | 3.848 | 0.001** |
| C:N ratio | 9.99 | 11.52 | 28 | -3.304 | 0.003** |
| Av. K (mg/kg) | 183.02 | 143.47 | 28 | 1.214 | 0.235 |
| Ex.K (me/100g) | 0.84 | 0.51 | 28 | 1.001 | 0.326 |
| CEC (me/100g) | 22.26 | 19.45 | 28 | 2.483 | 0.019* |

N=Number of samples: organic soil (n1) = 15; conventional soil (n2) = 15. *$p<0.05$; **$p<0.01$.

The Pearson correlation between different soil properties under organic potato farming showed that the soil organic matter (SOM) was correlated with C:N ratio and CEC at $P<0.05$. Furthermore, total N% was correlated with CEC at $P<0.05$ (Table 4).

**Table 4.** Correlations between different soil properties under organic potato farming (Pearson correlation).

| Soil property | C:N ratio | CEC |
|---|---|---|
| SOM | 0.534* | 0.517* |
| Total N% | | 0.540* |

*$p<0.05$

Similarly, the Pearson correlation between different soil properties under conventional potato farming showed that its pH was correlated with the Av. K at $P<0.05$, Ex. K at $P<0.01$. The SOM was correlated with total N% at $P<0.01$ and the CEC at $P<0.05$. Total N% was correlated with the CEC at $P<0.05$ (Table 5).

**Table 5.** Correlations between different soil properties under conventional potato farming (Pearson correlation)

| Soil property | Total N% | Av. K | Ex. K | CEC |
|---|---|---|---|---|
| pH | | 0.612* | 0.719** | |
| SOM | 0.883** | | | 0.551* |
| Total N% | | | | 0.610* |

*$p<0.05$; **$p<0.01$

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[†] Items arranged as per the soil analysis report

## Discussion

To understand the farming approach holistically and facilitate meaningful discussions, the study also delved into soil fertility management in the 2019 cropping cycle and the socio-demography characteristics of target farmers. Both the organic and conventional potato farmers were well experienced in their farming practices. The organic farmers possessed a relatively larger farm area than the conventional farmers, whereas the conventional farmers had comparatively more family labour than organic farmers. Technical farmer's training was attended more by the organic farmers than conventional ones. Organic potato farmers applied only organic fertilizers in their fields, comprising of FYM and other organic fertilizers. On the other hand, conventional potato farmers used both chemical fertilizers and some quantities of organic fertilizers. The recommended rates of fertilizer application in Bhutan for potato cultivation depending on location are 59-100 kg N/ha and 26-34 kg P/ha (Roder, *et al.*, 2008). Considering an estimated proportion of N available to the potato crop through the application of the FYM was at 30% (BPDP, 2008), both organic and conventional potato farmers applied N more than the recommended rates. The N available to potatoes with organic fertilizer only in organic farming is estimated to be 134 kg/ha, whereas it was 165 kg/ha for conventional farming with the combined chemical and organic fertilizers. This agrees with the report (BPDP, 2008) that many potato farmers in Central and Western Bhutan applied fertilizers (in combinations of chemical and organic fertilizers) more than the N and P recommended rates. The NPK from the FYM and organic fertilizers were computed based on the (Chettri *et al.*, 2003); the authors reported that the FYM produced through a heap-storage method in Bhutan has a dry matter content of around 68% with 1.6% N, 0.8% P, and 2.9% K of dry matter nutrient contents.

The ideal soil pH is >5.5 (water), and below that, it is regarded as highly acidic, which has a higher risk of aluminium toxicity. The key plant nutrients may have limited availability to plants in acidic soils with pH less than 4.8 ($CaCl_2$) or 5.5 (water) (Botta, 2015). The significantly lower pH of conventional potato soil than the organic soils and below the ideal one suggest a highly acidic one. Long-term alterations in soil pH resulted primarily from cation displacement or the addition of acidity sources such as $H^+$ to the soil's exchange sites (Tisdale *et al.*, 1993). Norbu and Floyd (2004) mentioned that the widespread application of urea in Bhutan is likely to intensify the low soil pH issue. Liming to neutralize acidic soils is not a common practice in Bhutan. The prolonged use of chemical fertilizers such as urea could have lowered the pH of the conventional soil, accompanied by poor soil fertility management.

This finding contradicts (Tashi and Wangchuk, 2016), where soil pH was not significantly different in organic and conventional rice fields in Bhutan.

Significantly higher available P in the conventional soil than the organic soil could have been due to the P build-up with a long-term application of chemical P fertilizer in the form of Single Super Phosphate (SSP, 16% of $P_2O_5$) along with organic fertilizers. Similar results were reported by (Bajgai, *et al.*, 2015, Grewal *et al.*, 1981). On the contrary, (Herencia and Maqueda, 2016, Tashi and Wangchuk, 2016) found that available P in organically managed soils was significantly higher than conventional. Soil sample with <5 mg P/kg and <15 mg P/kg is considered to contain very low and low levels of P, respectively (Roder, *et al.*, 2008). This indicates that the organic potato soil had a very low level (4.87 mg P/kg) while the conventional soil had a low level of P (8.87 mg P/kg). After N, P is often considered the next most crucial nutrient limiting crop yield in Bhutan (Chettri, *et al.*, 2003). P is required for energy storage and transmission, early shoot and root development, and legume nodulation functions in plants (Botta, 2015).

The lack of significant differences in organic matter content between the organic and conventional soils could be due to the conventional farmers' practice of applying organic fertilizers besides chemical fertilizers. There was an increase in the soil's organic C pool in field experiments using integrated nutrient management methods (Choudhary *et al.*, 2013). In contrast, in two consecutive years, the soil organic matter (SOM) was consistently and significantly higher in the organic rice farm in Bhutan (Tashi and Wangchuk, 2016).

Interestingly, total N was significantly higher in the organic soils than conventional soils. The N is a critical plant nutrient since it is required to produce proteins and chlorophyll, the preservation of photosynthetic efficiency, the increase of leaf area, and, eventually, the synthesis of dry matter. It concerns one of the essential yield-limiting nutrients on the planet (Muchow, 1998). Similar results of higher N percent availability in organic plots than the conventional plots were reported by (Bajgai, *et al.*, 2015, Das *et al.*, 2017, Tashi and Wangchuk, 2016). The N mineralization rates of a conventional system are estimated to be 100% greater than an organic one; therefore, organic soil management systems are expected to retain more N (Bajgai, *et al.*, 2015, Mallory and Griffin, 2007). Plant nutrients stored in SOM are released into the soil as inorganic forms through decomposition and mineralization (Jarvis *et al.*, 1996). In these systems, N supply is frequently restricted by mineralization and immobilization processes and can be unexpected, resulting in excess or insufficient asynchrony (Mallory and Griffin, 2007, Palmer *et al.*, 2013). Organic potato farmers added the FYM and other organic fertilizers 2.57 times more than the conventional farmers per hectare of the land. The presence of correlation between the SOM with the total N in the conventional soils also supports this view. N applied through urea and other chemical fertilizers in conventional farming are readily absorbed by the plants, remaining are lost as leaching and volatilization losses. The use of readily accessible conventional fertilizers may lead to losses such as denitrification and leaching (Chien *et al.*, 2009, Hirel *et al.*, 2007). The N use efficiency for chemical fertilizers is higher than the organic fertilizers (Adamtey, *et al.*, 2016, Eghball and Power, 1999). Due to its excellent mobility and tendency for loss from the soil-plant system into the environment, N management is a critical problem in most agricultural systems (Musyoka *et al.*, 2017). Further, the N mineralization and thereby its availability to plants is also affected by the soil pH. It was found that the pH of conventional soil was significantly lower than that of organic soil. Mallory and Griffin (2007) reported that the organic N mineralization is known to decrease gradually when pH falls below pH 6.

The significantly higher N content of organic field soils than the conventional ones but with similar carbon content led to a significantly higher C:N ratio in the conventional ones than the organic ones. The C:N ratio indicates the pattern of N mineralization and immobilization (Reddy and DeLaune, 2008). The lower C:N ratio in the organic soils could be due to the addition of large amounts of cow dung manure in FYM. Due to its high N content, cow dung manure has a lower C:N ratio (Adegunloye *et al.*, 2007).

Interestingly, no significant differences in available and exchangeable K were observed between organic and conventional systems. Similar results were obtained by (Herencia and Maqueda, 2016, Tashi and Wangchuk, 2016). K is essential in plants for controlling water and nutrient absorption, blooming and seed development, and tolerance to environmental stressors and disease (Botta, 2015). In research on changing soil fertility management in Bhutan, Norbu and Floyd (2004) reported that the soil parent materials are generally rich in K in the country, as evidenced by mostly moderate to high amounts of exchangeable K.

Higher CEC in organic soils than conventional soils could be due to the application of higher quantities of SOM in the form of organic fertilizers. The CEC and the SOM were correlated in both the farming system soils, suggesting that the higher CEC in the organic soils was due to the application of higher quantities of organic fertilizers. Similar results were obtained by (Bajgai, *et al.*, 2015, Schjønning *et al.*, 1994, Sidhu *et al.*, 2007).

Conventional potato farming was found to lower soil pH than organic farming, possibly due to the prolonged use of mineral fertilizers such as urea. Such a situation can affect the availability of various nutrients to the potato crop. Therefore, conventional farmers are recommended to use lime ($CaCO_3$) in their soil to rectify the acidic soil. However, this study could only collect 30 soil samples (15 for each farming system); therefore, it is suggested that other studies with a higher sample size encompassing other physicochemical soil properties could be taken up. Nevertheless, the research could generate empirical data on selected soil properties induced by organic and conventional potato farming in West-Central Bhutan. Such findings will be informative and helpful to policymakers, agriculture officials, academicians, local and global researchers, farmers, and agriculture development.

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## References

Adamtey, N., Musyoka, M. W., Zundel, C., Cobo, J. G., Karanja, E., Fiaboe, K. K. M., Muriuki, A., Mucheru-Muna, M., Vanlauwe, B., Berset, E., Messmer, M. M., Gattinger, A., Bhullar, G. S., Cadisch, G., Fliessbach, A., Mader, P., Niggli, U. and Foster, D. (2016). Productivity, profitability and partial nutrient balance in maize-based conventional and organic farming systems in Kenya. Agriculture Ecosystems & Environment, 235:61-79

Adegunloye, D., Adetuyi, F., Akinyosoye, F. and Doyeni, M. (2007). Microbial analysis of compost using cowdung as booster. Pakistan Journal of Nutrition, 6:506-510

Agriculture Research & Development Centre (ARDC)-Yusipang, 2019. Annual report (2018-2019), ARDC-Yusipang, Royal Government of Bhutan. In: D.o. Agriculture (ed), 2019, (Department of Agriculture, Thimphu), i-x, 106

Bajgai, Y., Kristiansen, P., Hulugalle, N. and McHenry, M. (2015). Comparison of organic and conventional managements on yields, nutrients and weeds in a corn-cabbage rotation. Renewable Agriculture and Food Systems, 30:132-142

Bajgai, Y. and Sangchyoswat, C. (2018). Farmers knowledge of soil fertility in West-Central Bhutan. Geoderma Regional, 14:8

Best, J. W. and Kahn, J. V. (1998). Research in education, Boston, Allyn and Bacon, pp.

Botta, C. (2015). Understanding your soil test step by step, Shepparton, pp. i-vi, 1-49.

Bouwman, A. (1996). Direct emission of nitrous oxide from agricultural soils. Nutrient Cycling in Agroecosystems, 46:53-70

BPDP, 2008. Soil fertility management for sustained potato production in the mountain of Bhutan., 2008, (CIP/CFC/BPDP Thimphu),

Chettri, G. B., Ghimiray, M. and Floyd, C. N. (2003). Effects of farmyard manure, fertilizers and green manuring in rice-wheat systems in Bhutan: Results from a long-term experiment. Experimental Agriculture, 39:129-144

Chien, S., Prochnow, L. and Cantarella, a. H. (2009). Recent developments of fertilizer production and use to improve nutrient efficiency and minimize environmental impacts. Advances in agronomy, 102:267-322

Choudhary, A. K., Thakur, S. K. and Suri, V. K. (2013). Technology Transfer Model on Integrated Nutrient Management Technology for Sustainable Crop Production in High-Value Cash Crops and Vegetables in Northwestern Himalayas. Communications in Soil Science and Plant Analysis, 44:1684-1699

Das, A., Patel, D. P., Kumar, M., Ramkrushna, G. I., Mukherjee, A., Layek, J., Ngachan, S. V. and Buragohain, J. (2017). Impact of seven years of organic farming on soil and produce quality and crop yields in eastern Himalayas, India. Agriculture Ecosystems & Environment, 236:142-153

Department of Agricultural Marketing and Cooperatives [DAMC] & DAS Gasa, 2016. Gasa Dzongkhag leading the way in organic crop production. 2016, (MoAF, Thimphu),

Department of Agriculture (DoA), 2017. Agriculture Statistics 2016. In: D.o. Agriculture (ed), 2017, (Department of Agriculture, Ministry of Agriculture & Forests (MoAF)

Thimphu, Bhutan), 81

Department of Agriculture [DoA], 2006. National Framework for Organic Farming in Bhutan In: D.o. Agriculture (ed), 2006, (Department of Agriculture, Royal Government of Bhutan (RGoB), Thimphu, Bhutan), 44

Dorji, C., 2019. Potato farmers of Gangteng and Phobji use more fertilisers for better yield. 2019, (Bhutan Broadcasting Service (BBS), Eghball, B. and Power, J. F. (1999). Composted and noncomposted manure application to conventional and no – tillage systems: Corn yield and nitrogen uptake. Agronomy journal, 91:819-825

FAO (1998). Guide to efficient plant nutrition management. Land Water Development Division. FAO, Rome, Italy,

FAO. (2009). Sustainable Potato Production - Guidelines For Developing Countries, Food and Agriculture Organization of the United Nations pp. 91.

FAO (2016). Climate change and food security: risks and responses. Food and Agriculture Organization of the United Nations (FAO) Report, 110

Feuerbacher, A., Luckmann, J., Boysen, O., Zikeli, S. and Grethe, H. (2018). Is Bhutan destined for 100% organic? Assessing the economy-wide effects of a large-scale conversion policy. PloS one, 13:24

Grewal, J., Sharma, R. C. and Sud, K. (1981). Effect of continuous application of PK-fertilizers and farmyard manure on potato yield and some soil properties. Journal of the Indian Society of Soil Science, 29:129-131

Herencia, J. F. and Maqueda, C. (2016). Effects of time and dose of organic fertilizers on soil fertility, nutrient content and yield of vegetables. Journal of Agricultural Science, 154:1343-1361

Hirel, B., Le Gouis, J., Ney, B. and Gallais, A. (2007). The challenge of improving nitrogen use efficiency in crop plants: towards a more central role for genetic variability and quantitative genetics within integrated approaches. Journal of Experimental Botany, 58:2369-2387

ICIMOD, 2018. Organic Agriculture Development Strategies: Roadmap for 12th Five Year Plan and Beyond. 2018, (Integrated Centre for Mountain Development (ICIMOD), 34

Jarvis, S. C., Stockdale, E. A., Shepherd, M. A. and Powlson, D. S. (1996). Nitrogen mineralization in temperate agricultural soils: processes and measurement. Advances in agronomy, 57:187-235

Kothari, C. R. (2004). Research methodology: Methods and techniques, New Delhi, India, New Age International Publishers, pp. i-xvi, 1-401.

Kshash, B. and Oda, H. (2021). Awareness and use of soil conservation practices among Iraqi wheat farmers. International Journal of Agricultural Technology, 17:1373-1382

Lhamo, P., 2019. In Phobji and Gangtey, farmers compete to use more fertilisers. 2019, (kuensel,

Mallory, E. and Griffin, T. (2007). Impacts of soil amendment history on nitrogen availability from manure and fertilizer. Soil Science Society of America Journal, 71:964-973

Mendoza, T. C. (2004). Evaluating the benefits of organic farming in rice agroecosystems in the Philippines. Journal of Sustainable Agriculture, 24:93-115

Mikkelsen, R. (2006). Best management practices for profitable fertilization of potatoes. Magnesium (Mg), 25:40

Ministry of Agriculture and Forests (MoAF), 2020. Agriculture Statistics 2019. In: D.o. Agriculture (ed), 2020, (Renewable Natural Resources Ststistics Division (RSD), Thimphu, Bhutan), I-VII, 1-123

MoAF, 2020. Agriculture Statistics 2019. In: D. Services (ed), 2020, (Renewable Natural Resources Statistics Division (RSD), Royal Government of Bhutan, Thimphu), I-VII, 1-123

Mosier, A. R. (2001). Exchange of gaseous nitrogen compounds between agricultural systems and the atmosphere. Plant and Soil, 228:17-27

Muchow, R. (1998). Nitrogen utilization efficiency in maize and grain sorghum. Field Crops Research, 56:209-216

Musyoka, M. W., Adamtey, N., Muriuki, A. W. and Cadisch, G. (2017). Effect of organic and conventional farming systems on nitrogen use efficiency of potato, maize and vegetables in the Central highlands of Kenya. European Journal of Agronomy, 86:24-36

Norbu, C. and Floyd, C. (2004). Changing soil fertility management in Bhutan: Effects on practices, nutrient status and sustainability.

NSB, 2011a. Annual Dzongkhag Statistics 2011 (Dzongkhag Administration Gasa). In: N.S. Bureau (ed), 2011a, (National Statistics Bureau, Bhutan), i-iii, 1-48

NSB, 2011b. Annual Dzongkhag Statistics 2011 (Dzongkhag Administration Wangdue Phodrang). 2011b, (National Statistics Bureau
Bhutan), i-iv, 1-51

NSSC, 2008. Field Crops soil sampling (Leaflet No.2). 2008, (National Soil Service Centre (NSSC), Dept. of Agriculture,

Palmer, M. W., Cooper, J., Tetard-Jones, C., Srednicka-Tober, D., Baranski, M., Eyre, M., Shotton, P. N., Volakakis, N., Cakmak, I., Ozturk, L., Leifert, C., Wilcockson, S. J. and Bilsborrow, P. E. (2013). The influence of organic and conventional fertilisation and crop protection practices, preceding crop, harvest year and weather conditions on yield and quality of potato (Solanum tuberosum) in a long-term management trial. European Journal of Agronomy, 49:83-92

Reddy, K. R. and DeLaune, R. D. (2008). Biogeochemistry of Wetlands: Science and Applications, CRC Press, pp.

Roder, W., Nidup, K. and Chettri, G. B. (2008). The Potato in Bhutan, Thimphu, Bhutan Potato Development Progam, pp. i-viii, 185.

Schjønning, P., Christensen, B. and Carstensen, B. (1994). Physical and chemical properties of a sandy loam receiving animal manure, mineral fertilizer or no fertilizer for 90 years. European Journal of Soil Science, 45:257-268

Schröder, J., Neeteson, J., Oenema, O. and Struik, P. (2000). Does the crop or the soil indicate how to save nitrogen in maize production?: Reviewing the state of the art. Field Crops Research, 66:151-164

Sidhu, A. S., Thind, S. S., Sekhon, N. K. and Hira, G. S. (2007). Effect of farmyard manure and p application to potato on available p and crop yield of potato (Solanum tuberosum)-sunflower (Helianthus annuus) sequence. Journal of Sustainable Agriculture, 31:5-15

Subedi, K. and Ma, B. (2009). Corn crop production: growth, fertilization and yield. Agriculture issues and policies,

Tashi, S. and Wangchuk, K. (2016). Organic vs. conventional rice production: comparative assessment under farmers' condition in Bhutan. Organic Agriculture, 6:255-265

Tisdale, S., Nelson, W., Beaton, J. and Havlin, J., 1993. Soil fertility and fertilizers., 5th edn (Macmillan: New York). 1993, (NY,

Wangmo, S. and Iwai, C. B. (2018). Performance of Organic Agriculture (OA) based on Emergent Properties of Agriculture System in Gasa, Bhutan. Khon Kaen Agriculture Journal, 1985:1202-1210

Westerman, R., Raun, W. and Johnson, G. (1999). Nutrient and water use efficiency. Handbook of soil science. CRC Pres, Boca Raton, FL:175-189

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**7.3.4 Accepted and presented paper (Seminar 2) in the International Conference on Environment and Life Science.**

1) Accepted letter in the International Conference on Environment and Life Science.

International Institute for Research in Science and Technology (IIRST)

**Conference Name: International Conference on Environment and Life Science (ICENLISC-21)**

**Date of Conference: 8th April 2021**

**Place of Conference: Bangkok, Thailand**

**Paper Id: IIRST_17290**

**Dear Norden Lepcha,**

This is the official notification to inform you that your Oral/Poster presentation proposal entitled "**Socio-demographic characteristics and constraints of farmers in organic potato (Solanum tuberosum) production, Gasa, Bhutan**" submitted to **International Conference on Environment and Life Science** (ICENLISC-21) has been accepted as a result of blind reviews.

On behalf of *International Institute for Research in Science and Technology (IIRST)*. I would like to congratulate you.

Looking forward to meet you in **Bangkok, Thailand** at the conference on **8th April 2021**

Event link : https://www.iirst.com/event/index.php?id=1328916

For Registration : https://www.iirst.com/event/reg.php?id=1328916

Last Date of registration : 1st Apr,2021

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2) Presented paper in the International Conference on Environment and Life Science.

**Socio-demographic characteristics and constraints of farmers in organic potato production, Gasa, Bhutan**

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**Abstract**

Potato (*Solanum tuberosum*. L) is an important food security crop in Bhutan. The National Organic Farming Framework-2006 indicated the country's intention to be fully organic. This study investigates socio-demographic characteristics and constraints confronting organic potato farmers in Bhutan's first and only organic district, Gasa. Purposive sampling, semi-structured questionnaires, face-to-face individual farmer interviews were employed to gather data from 43 certified organic farms from September-October 2020. Descriptive statistics were applied for data analysis. The results showed more female farmers (70%) were involved than males (30%). The average age of the farmers was 52 years, and 63% of them were illiterate. The average household member and family labour were four and two, respectively. The average farming experience was 31 years. The farmers attended an average of two training per year. The average farm size was 1.17 hectares. Most of the farmers (95.3%) were a member of the organic farmers' group, and a majority (83.7%) depended purely on farming for their livelihood. Lack of premium price, pest and disease problems, low crop yields, and climate change were the farmers' constraints. Strategies to receive a premium price, investments in pest and disease control, and embracing improved climate-resilient organic farming practices would benefit the farmers.

**Keywords**

Bhutan, Constraints, Organic Potato, Socio-demographic characteristics.

**1. Introduction**

Over the years, global organic area and other pointers have gradually increased [1]. In 2017, 181 countries were involved in

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organic operations, with a market worth 90 billion euros, global per-capita organic food consumption of 10.8 euros, and organic agricultural land covering 69.8 million hectares (ha), with 6.1 million ha in Asia. Organic farming accounted for 1.4 percent of total farmland worldwide, with Asia accounting for 0.4 percent. There were 2.9 million organic producers worldwide, with 1.1 million in Asia [2].

Bhutan is a tiny mountainous nation on the Himalayan southeast slope [3]. In 2006, Bhutan's Royal Government unveiled the National Framework for Organic Farming to encourage organic farming [4]. Bhutan had about 10,391.86 ha of land under organic control in 2017, with an output of 2,599.7 MT, according to the [5], which included agricultural, livestock, and wild collection areas. Agriculture is a vital primary sector in Bhutan, providing livelihood and jobs to 43.9 percent of the population [6]. Rice, maize, mandarin, apple, potato, and other vegetables, cardamom, and other spices are among the important crops grown in the country [7]. Bhutan has mainly smallholder farmers who are primarily involved in subsistence farming and own an average of 1.16 hectares.

Organic farming is seen as a way of making agriculture further sustainable [8]. Bhutan has proposed to be 100 percent organic by 2020 in order to promote sustainability and achieve its Gross National Happiness targets [9]. Bhutan's new government, on the other hand, explained that the proposal to become 100 percent organic by 2023 is unclear. However, the country has been working to realize its organic vision, as supported by the launch of the National Organic Flagship Program in the 12th Five Year Plan (2018-2023) [10].

According to Bajgai [11], the potato is one of Bhutan's most commonly grown, consumed, and traded horticultural crops, owing to favorable agro-ecological conditions. About 22% of the country's rural households cultivate it as a non-cereal crop, cash crop, and vegetable. In 2018, the country produced 44,278 MT of potatoes, with a total area of 4,506 ha and national average productivity of 9.83 MT/ha [12]. Potato is a cash crop in Bhutan; it is primarily grown using conventional farming practices such as chemical fertilizers and other agrochemicals [13]. In addition to chemical fertilizers, conventional potato farmers use farmyard manure (FYM) and other organic inputs. Around 0.2 percent of the total potato production in the country is certified organic. The certified potatoes are grown in the Gasa District, certified by a reliable Bhutanese government institution [14]. The Bhutan Organic Standards is complied with by certified organic farmers. They avoid using agrochemicals in their fields, instead opting for locally available organic fertilizers such as FYM and bio-pesticides.

Organic agriculture's yield is still one of the significant issues in its acceptance [15]. To address global food demand, the FAO estimates that food crop yield must increase by at least 43% by 2030, assuming that all other factors remain unchanged [16]. Household food security, poverty alleviation, substituting or reducing imports by increased domestic production, creating a marketable surplus, and increasing household income and job opportunities are all priorities for the government [17]. Bhutan's commitment to go 100 percent organic by 2020 appears to be contradictory to its target of increasing self-sufficiency and food security [9]. As a result, evaluating organic agriculture's performance in the country is essential to meet the government's goals on food self-sufficiency and other issues.

The study's goals were to investigate the socio-demographic characteristics of organic potato farmers in Bhutan's first and only organic district, Gasa, and the various constraints they face. The study is expected to help policymakers, obtain additional backing from Agriculture officials and researchers, and assist farmers in making decisions about implementing a better potato farming system in Bhutan and around the world. Academicians and students will find it helpful in understanding field situations.

## 2. Methodology

### 2.1 Study area

The Gasa district was purposively selected for the study because of the presence of certified organic farmers. It is one of Bhutan's 20 districts [18]. With just 3952 residents, Gasa is the country's least populated district, accounting for only 0.5 percent of the total population [6].

The district's average annual temperature is 10°C, with a maximum of 15°C and a minimum of 6°C. It has a variety of climates, from temperate to alpine [19]. Goenkhatoed *Gewog* (a group of villages in Bhutan) was purposively chosen as a research site within Gasa. The altitude in Goenkhatoed *Gewog* varies between 2,100 and 2,800 meters above mean sea level (mamsl). The annual rainfall in the *gewog* is approximately 2,241 millimetres (mm) [19]. The National Soil Service Centre (NSSC), Thimphu, identified loamy, silty clay loam, and sandy loam types in the *gewog* in 2020. The study site is in Bhutan's temperate zone [Agroecological Zone (AEZ) 3], which is above 1,800 mamsl [8]. Fig 1. Study area in Bhutan.


**Fig.1.** The study region depicted on a map of Bhutan (encircled). Source: wikipedia.org/wiki/Districts of Bhutan, accessed 22/03/21.

2.2 Sampling procedure

The study sample was chosen using a purposeful sampling technique. The Gasa District was selected for the organic potato evaluation because its local government proclaimed it to be the first fully organic district since 2004 [20].

Goenkhatoe *Gewog*, one of four *gewogs* in Gasa, was purposefully chosen for the study due to the availability of certified organic farmers. Purposive sampling is ideally suited to a small population with well-understood characteristics [21]. The *gewog* was primarily chosen because it has an organic farmers' group, *Gasa Rangshin Sonam Detshen*, producing certified organic potatoes since 2016. Bhutan Agriculture and Food Regulatory Authority (BAFRA) has certified the group [22]. Potatoes are the *gewog*'s main cash crop, but they also cultivate garlic, carrots, wheat, buckwheat, and barley.

2.3 Data collection

The information was randomly gathered from 43 organic potato farmers spread out across 17 villages in Goenkhatoed *Gewog*, Gasa district. From August to October 2020, data was obtained. Face-to-face, individual farmer interviews were used to collect primary data. The head of the family or any family member actively involved in organic farming was interviewed during the individual farmer's interview. To collect data from farmers, a semi-structured questionnaire was used. It was divided into three parts: the first part contained the socio-demographic characteristics, production, and marketing aspects, the second part collected productivity and profitability data, and the third part contained the constraints confronted by farmers. The farmers' constraints were measured on a five-point Likert scale that ranged from strongly disagree = 1 to strongly agree = 5 [23].

2.3.1 Assessment of content validity

The Item Objective Congruence (IOC) rating, interpretation, and decision as provided by [24] were used to determine the content validity of the items of the questionnaire. To ensure that each questionnaire item captures the intended objectives, a draft semi-structured questionnaire was sent to three experts specific to the study field for review and feedback. Each question item with an IOC rating of 0.5 or higher was kept in the questionnaire. At least 30 potato farmers who did not belong to the sample study farmers were used to pre-test the questionnaire. In September 2020, pre-testing was carried out in Geney *Gewog*, Thimphu District, Bhutan.

2.4 Data analysis

2.4.1 Socio-demographic characteristics

The socio-demographic characteristics were analysed using descriptive statistics, such as frequencies, percentages, standard deviations, arithmetic means, maximum and minimum.

2.4.2 Constraints faced by organic potato farmers.

The descriptive statistics of the five-point Likert scale were used to investigate the constraints faced by organic potato farmers in the area. The several constraints were ranked according to their mean values, as in a previous study on the barriers to organic farming conversion [25]. The following is how the mean values were interpreted [26].

**Table I: Interpretation of mean values**

| Mean | Interpretation |
|---|---|
| 1.00 – 1.80 | Strongly disagree |
| 1.81 - 2.60 | Disagree |
| 2.61 - 3.40 | Undecided |
| 3.41 - 4.20 | Agree |
| 4.21 - 5.00 | Strongly agree |

3. Results and Discussions

Bhutan aspires to be a completely organic nation; nevertheless, a preliminary examination of organic agriculture's performance in the country is necessary [27] [20].

3.1 Socio-demographic characteristics of farmers

Gender, age, education, household members, family labor, farm size, experience in farming, farmers' training, farmers' group, and others were the parameters to study organic farmers' socio-demographic characteristics. Table II provides the socio-demographic characteristics of the farmers.

The findings indicated that organic farmers had a higher female (70%) than male population (30%). Suwanmaneepong, Kerdsriserm [28] also found more women than men practicing organic rice farming. This contradicts with [29] where more male (60%) was engaged than female (40%) in organic farming. The [6] states that the Gasa district overall has a more male population (53.2%) than female (46.8%) with a total of 3952 people.

The average age of organic farmers was 52 years, the minimum was 26, and the maximum was 84 years. Fifty-three percent of organic farmers were above 50 years, whereas 23% were in 40-50 years and less than 40 years of age group. Takagi, Purnomo [29] also found that more than half of organic farmers were above 50 years. The mean age of Bhutan stood at 29.2 years [6]. This indicated an aging organic farmers' population. It contradicts [28], where relatively younger farmers were engaged in organic rice farming. Gasa at a district level has its aging index below the national average at 21.2, while the country's national average stood at 22.7 [6].

Most of the organic farmers (21%) who went to school did their primary schooling (1-6 grade). The highest educational achievement was the lower secondary (9-10 grade), with only 5% making it. Around 9% of organic farmers also went to non-formal education. More than half of organic farmers were illiterate (63%). It contradicts with [29] where around half of organic farmers completed college. According to the [6], Gasa district has the lowest literacy rate in the country with 59.8%, while the National literacy rate stood at 71.4%.

An aging population, higher illiteracy rate, and more female gender observed with the organic farmers could affect the farmers' performance, subsequently affecting the crop yield and other farm outputs. Farmers' education level [30, 31] and age [32] influenced the potato production efficiency. In other studies, rice production's technical efficiency was affected by farmers' age, education, and gender [33, 34].

Technical efficiency and organic rice production were significantly related to household size, farm size, labor, and market accessibility [35]. Most organic farmers (88%) were married.

The average household member was four, the minimum was one, and the maximum was 12. Fifty-seven percent of the farmers had a minimum of 4 household members. The Gasa District's mean household size stood at 3.6 persons, whereas the national average household size is 3.9 persons [6].

The average family labour of organic farmers was two, the minimum was one, and the maximum was five. Most organic farmers (81%) had 1-2 family labor while only 2% had more than or equal to five.

The average year of farming experience for organic farmers was 31 years, with a minimum of five and a maximum of 70 years. Seventy-nine percent of organic farmers had more than ten years of farming experience, indicating that the organic farmers were experienced in their field.

Organic farmers attended an average of two training per year, the minimum was zero, and the maximum was three. Fourteen percent did not participate in any training, while most (70%) attended 1-2 training per year. Suwanmaneepong, Kerdsriserm [28] also found that organic rice growers attended more training. Considering adequate annual technical training attended by organic potato farmers and having received some farm inputs support free of cost from the Royal Government of Bhutan, this indicated the government's effort to promote organic farming in the Gasa district and the country.

The average farm size of organic potato farmers was 1.17 hectares, with a minimum of 0.13 and a maximum of 6.88 hectares. The mean land holding in Bhutan was 0.89 ha, with higher landholding in rural areas (1.18 ha) than the urban area (0.42 ha) [6]. Most of the farmers (95.3%) were a member of the organic farmers' group – *Gasa Rangsin Sonam Detchen.* The majority of farmers (83.7%) depended purely on farming for their income. Takagi, Purnomo [29] also found out that the majority (89%) of the farmers were full time organic farmers.

More than half (72.1%) of the farmers frequently contacted the Agriculture Extension Agent for farming-related enquiries.

**Table II: Socio-demographic characteristics of organic potato farmers (n=43)**

| Item | Frequency | % | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|---|---|
| Gender | | | | | | |
| Male | 13 | 30.23 | | | | |
| Female | 30 | 69.77 | | | | |
| Age (years) | | | 52.35 | 13.90 | 26 | 84 |
| <40 | 10 | 23.26 | | | | |
| 40-50 | 10 | 23.26 | | | | |
| 51-60 | 13 | 30.23 | | | | |
| > 60 | 10 | 23.26 | | | | |
| Education level | | | | | | |
| Illiterate | 27 | 62.79 | | | | |
| Non-formal education | 4 | 9.30 | | | | |
| Primary School | 9 | 20.93 | | | | |
| Middle School | 1 | 2.33 | | | | |
| Lower secondary | 2 | 4.65 | | | | |
| Upper secondary | 0 | 0.00 | | | | |
| Marital status | | | | | | |
| Single | 0 | 0.00 | | | | |
| Married | 38 | 88.37 | | | | |
| Household members | | | 4.49 | 2.43 | 1 | 12 |
| ≤ 3 | 18 | 41.86 | | | | |
| 4-5 | 13 | 30.23 | | | | |
| ≥6 | 12 | 27.91 | | | | |
| Family labor (number) | | | 1.98 | 0.913 | 1 | 5 |
| 1-2 | 35 | 81.40 | | | | |
| 3-4 | 7 | 16.28 | | | | |
| ≥5 | 1 | 2.33 | | | | |
| Farming experience (years) | | | 31.05 | 19.81 | 5 | 70 |
| 1-10 | 9 | 20.93 | | | | |
| 11-20 | 9 | 20.93 | | | | |
| >20 | 25 | 58.14 | | | | |
| Attend farmers' training (number of times per year) | | | 1.65 | .923 | 0 | 3 |
| No training attended | 6 | 13.95 | | | | |
| 1 to 2 | 30 | 69.77 | | | | |
| 3 | 7 | 16.28 | | | | |
| Farm size (ha) | | | 1.17 | 1.07 | 0.13 | 6.88 |
| Membership in a farmers' group | | | | | | |
| Member | 41 | 95.3 | | | | |
| Non-member | 2 | 4.7 | | | | |
| Off-farm income | | | | | | |
| None | 36 | 83.7 | | | | |
| Yes | 7 | 16.3 | | | | |
| Consult Agriculture Extension Agent | | | | | | |
| Never | 6 | 14 | | | | |
| Frequently | 31 | 72.1 | | | | |
| Seldomly | 6 | 14 | | | | |

3.2 Constraints for organic farmers

Table III shows the constraints of the organic potato farmers. The first four constraints, as determined by the mean analysis, are main constraints, namely: no price premium for organic produce (mean 4.84), pest and disease problems (mean 4.02), crop yield is low (mean 4), and climate change affects production (mean 3.69). Other undecided constraints were the unavailability of farm labour (mean 3.14) and the inadequate supply of bio-pesticides in their place (mean 2.65). Rest items were not regarded as constraints by the farmers. Poor marketing strategies, unexplored marketing networks, lack of proper labelling and packaging materials, lack of understanding of the advantages of organic goods and production methods to customers, marketable yield reduction, and low purchasing power of consumers may all be factors preventing organic farmers from earning price premiums. The study also found that most organic potato farmers sold their crops to a middleman, who then purchased directly from the farmers in their place. Likewise, in Bhutan, [36] reported no premium price for organic rice. Since price disparities occur across different business channels, exploring better marketing channels would be helpful [28]. According to one report, the scale of organic farming adoption would be determined by the limited market size and willingness of customers to pay a price premium [37]. Pest and disease problems, which have been the second most problem identified by organic farmers, may influence crop yields. Wheeler [37] reported many agricultural professionals agreed that the second most vital obstacle to organic farming adoption is production difficulties and pest and disease problems. Climate change constraints may have led to lower organic potato crop productivity. An adverse impact of climate change on potato production has also been reported by many researchers [38][39][40]. Low yield in organic potato production has also been reported by other researchers: Ierna and Parisi [41] Maggio, Carillo [42] found that the organic potato cultivation was less productive than the conventional one. Organic hazelnut yields were also low, according to Coppola, Costantini [43], and grain yields were significantly lower in organic farming, according to Taube, Kelm [44]. This result contradicts [36], which found that rice grain yields between organic and conventional rice farms in Bhutan were statistically not different.

As a result, more research is needed to address pest and disease issues, lower crop yields, and climate change issues. Increasing the yield of organic potatoes in the Gasa District will entail adopting improved climate-resilient organic farming practices. Farm labour unavailability could have been contributed by less family labour with the organic farmers. The farm labor shortage is a growing problem in Bhutan, mainly resulting from an increasing rural to urban migration. Rural to urban migration is the highest as compared to the other flows of the migration stream. It accounts for 21.7% of all population born in Bhutan and almost half (44.2%) of all migrant population. The net migration rate of Gasa stood at 158 persons [6]. All the supply of pesticides and bio-pesticides are centralized by the Government agency considering the environmental contamination and health hazards these chemicals pose. Many imported bio-pesticides have a shorter shelf life, relatively expensive, and their efficacy have still been tested [45].

**Table III. Constraints of Organic farmers**

| Constraint | Mean | Interpretation | SD | Rank |
|---|---|---|---|---|
| No premium price for organic potato | 4.84 | Strongly agree | 0.5 | 1 |
| Pest and disease problems | 4.02 | Agree | 1.2 | 2 |
| Crop yield is low | 4 | Agree | 0.5 | 3 |
| Climate change impeding crop production | 3.69 | Agree | 0.6 | 4 |
| Unavailability of farm labor | 3.14 | Undecided | 1.2 | 5 |
| Inadequate supply of bio-pesticides | 2.65 | Undecided | 0.6 | 6 |
| Unavailability of bio-pesticides on time | 2.5 | Disagree | 0.9 | 7 |
| Competition of imported potato with local | 2.09 | Disagree | 0.6 | 8 |
| Inadequate supply of organic fertilizer | 2.02 | Disagree | 0.6 | 9 |
| Inadequate knowledge of potato production | 2.02 | Disagree | 0.3 | 10 |
| Wild animals' crop damage | 1.77 | Strongly disagree | 1.2 | 11 |
| Unavailability of organic fertilizers on time | 1.51 | Strongly disagree | 0.6 | 12 |
| Inadequate supply of potato seed | 1.49 | Strongly disagree | 0.6 | 13 |
| Unavailability of potato seeds on time | 1.39 | Strongly disagree | 0.5 | 14 |
| Unavailability to hire farm machinery | 1.07 | Strongly disagree | 0.3 | 15 |

## 4. Conclusion

An assessment of socio-demographic characteristics and constraints faced by the organic potato farmers of Bhutan's first and only organic district, Gasa, was carried out from August to October 2020. The primary data were collected from 43 organic potato farmers from Goenkhatoed *Gewog* under the Gasa District. The findings indicated that organic farmers had a higher female than the male population. The average age of the organic potato farmers showed an aging population. More illiterate farmers were there producing organic potatoes. An aging population, higher illiteracy rate, and more female gender observed with the organic potato farmers could affect crop yield and other farm outputs. The average family labor of organic farmers was half of the average household members. The study indicated that the organic farmers were experienced in their field. The average farm size of organic potato farmers was at par with the national average. Most of the farmers had joined the organic farmers' group of the district, and a majority of them depended purely on farming for their livelihood.

The lack of a price premium for organic potatoes was one of the most significant organic farmers' constraints. Pest and disease were also a problem, as were low crop yields and climate change concerns. The government's increased support for farm inputs and training for organic potato farmers reflected the government's efforts to encourage organic farming in Gasa and throughout the country. Nevertheless, there is still room to boost organic potato yields. Developing marketing strategies, investigating marketing channels, value additions, investing in proper packaging and labeling, raising awareness about the advantages of organic produce, and creating organic sales outlets will provide opportunities for a price premium. It would be helpful to invest in research to control pests and diseases in organic potato fields and adopt better organic farming practices resilient to climatic change and increase organic potato yield. Bhutan also needs to conduct reliable long-term scientific field research on organic potatoes. Organic potato farmers' socio-demographic characteristics and the various constraints they face, presented here, would hopefully aid policymakers in developing a vision for organic agriculture development in the country. It will evoke additional support from Agriculture officials and prompt the Department of Agriculture to begin necessary research. Assist farmers in making decisions about organic potato production in Bhutan.

## 5. Competing Interest Declaration

The authors declare that they have no conflicts of interest.

## 6. Acknowledgments

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## 7. References


1. International Federation of Organic Agriculture Movement [IFOAM], *Into the future. Consolidated annual report of IFOAM - organics international.* 2015. p. 24.
2. IFOAM, *Consolidated Annual Report of IFOAM - Organics International & its Action Group* 2018. p. 22.
3. D'Avanzo, C., *Mosby's Pocket Guide to Cultural Health Assessment - E-Book.* 2008: Elsevier Health Sciences.
4. Department of Agriculture [DoA], *National Framework for Organic Farming in Bhutan* D.o. Agriculture, Editor. 2006, Department of Agriculture, RGoB, Thimphu: Thimphu, Bhutan. p. 44.
5. National Organic Programme [NOP], *National Organic Program (NOP): Major achievements 2016-2017 (Annual report),* D.o. Agriculture, Editor. 2017, National Organic Programme, Dept. of Agriculture, Ministry of Agriculture and Forests, Royal Government of Bhutan: Thimphu. p. 7.
6. Population & Housing Census of Bhutan [PHCB], *Population & Housing Census of Bhutan (PHCB) 2017* 2017, National Statistics Bureau, Royal Government of Bhutan Bhutan.
7. National Statistical Bureau [NSB], *Bhutan Living Standards Survey Report 2017.* 2017, National Statistics Bureau (NSB), Royal Government of Bhutan: Bhutan. p. i-xvi, 210.
8. Feuerbacher, A., et al., *Is Bhutan destined for 100% organic? Assessing the economy-wide effects of a large-scale conversion policy.* PloS one, 2018. **13**(6): p. e0199025.
9. McCrae-Hokenson, M., *Organic Agriculture in Bhutan: Barriers Going to 100%.* 2014.
10. Seldon, P., *Nu 1 billion flagship program for organic farming with Sikkim in mind.* 2019, The Bhutanese.
11. Bajgai, Y., *Standard Evaluation Guideline for Potato Germplasm*, in *Standard Evaluation Guidelines for Field & Horticultural Crops*, Lakey, Editor. 2018, Agriculture Research & Extension Division (ARED), Department of Agriculture, Ministry of Agriculture & Forests, Thimphu: Thimphu. p. 27-39.
12. Ministry of Agriculture and Forests [MoAF], *Bhutan RNR Statistics 2018* 2019, Renewable Natural Resources Statistics Division, Directorate Services, Ministry of Agriculture and Forests, Royal Government of Bhutan Thimphu. p. 121.
13. Lhamo, P., *In Phobji and Gangtey, farmers compete to use more fertilisers*. 2019, kuensel.
14. Agriculture Research & Development Centre (ARDC)-Yusipang, *Annual report ARDC-Yusipang, Royal Government of Bhutan,* D.o. Agriculture, Editor. 2019, Research & Development Centre-Yusipang, Thimphu, Department of Agriculture, Ministry of Agriculture& Forests, Royal Government of Bhutan: Thimphu. p. i-x, 106.
15. Connor, D.J., *Organic agriculture cannot feed the world.* Field Crops Research, 2008. **106**(2): p. 187-190.
16. Dasgupta, S. and I. Roy, *Good Agricultural Governance: A resource guide focused on smallholder crop production.* 2011, Bangkok: Food and Agriculture Organization of the United Nations.
17. Ghimiray, M., et al., *Agriculture Research Strategy 2018-2028,* D.o. Agriculture, Editor. 2019, Agriculture Research and Extension Division (ARED), Department of Agriculture, Ministry of Agriculture and Forests, Royal Government of Bhutan Thimphu, Bhutan. p. 56.
18. ARDC-Bajo. *About ARDC Bajo.* 2020; Available from: http://rcbajo.gov.bt/bsws/by-laws/
19. NSB, *Annual Dzongkhag Statistics 2011 (Dzongkhag Administration Gasa),* N.S. Bureau, Editor. 2011, National Statistics Bureau. p. i-iii, 48.

20. Wangmo, S. and C.B. Iwai, *Performance of Organic Agriculture (OA) based on Emergent Properties of Agriculture System in Gasa, Bhutan.* way, 2018. **1985**(1986).
21. Kothari, C.R., *Research methodology: Methods and techniques*. 2004: New Age International.
22. Department of Agricultural Marketing and Cooperatives [DAMC] & DAS Gasa, *Gasa Dzongkhag leading the way in organic crop production*. 2016, MoAF: Thimphu.
23. Likert, R., *A technique for the measurement of attitudes.* Archives of psychology, 1932.
24. Rovinelli, R. and R. Hambleton, *The use of content specialists in the assessment of criterion-referenced test item validity: 1977.* Dutch J Edu Res, 1977.
25. Sharifi, O., et al., *Barriers to conversion to organic farming: A case study in Babol County in Iran.* African Journal of Agricultural Research, 2010. **5**(16): p. 2260-2267.
26. Best, J.W. and J.V. Kahn, *Research in education.* 8 ed. Vol. 8. 1998, Boston: Allyn and Bacon. 3-27.
27. Neuhoff, D., et al., *Organic agriculture in Bhutan: potential and challenges.* Organic agriculture, 2014. **4**(3): p. 209-221.
28. Suwanmaneepong, S., et al., *Cost and return analysis of organic and conventional rice production in Chachoengsao Province, Thailand.* Organic Agriculture, 2020: p. 1-10.
29. Takagi, C., S.H. Purnomo, and M.K. Kim, *Adopting Smart Agriculture among organic farmers in Taiwan.* Asian Journal of Technology Innovation, 2020: p. 16.
30. Andaregie, A. and T. Astatkie, *Determinants of technical efficiency of potato farmers and effects of constraints on potato production in Northern Ethiopia.* Experimental Agriculture, 2020. **56**(5): p. 699-709.
31. Nyagaka, D.O., et al., *Technical efficiency in resource use: Evidence from smallholder Irish potato farmers in Nyandarua North District, Kenya.* African Journal of Agricultural Research, 2010. **5**(11): p. 1179-1186.
32. Chemak, F., L. Allagui, and Y. Ali, *Analysis of the technical performance of potato growers in Tunisia, A non parametric approach.* New Medit, 2014. **13**(4): p. 72-80.
33. Houngue, V. and G.M.A. Nonvide, *Estimation and determinants of efficiency among rice farmers in Benin.* Cogent Food & Agriculture, 2020. **6**(1): p. 21.
34. Nguyen, H.D., et al., *The Role of Knowledge in Sustainable Agriculture: Evidence from Rice Farms' Technical Efficiency in Hanoi, Vietnam.* Sustainability, 2019. **11**(9): p. 10.
35. Panpluem, N., et al., *Measuring the Technical Efficiency of Certified Organic Rice Producing Farms in Yasothon Province: Northeast Thailand.* Sustainability, 2019. **11**(24): p. 16.
36. Tashi, S. and K. Wangchuk, *Organic vs. conventional rice production: comparative assessment under farmers' condition in Bhutan.* Organic Agriculture, 2016. **6**(4): p. 255-265.
37. Wheeler, S.A., *The barriers to further adoption of organic farming and genetic engineering in Australia: views of agricultural professionals and their information sources.* Renewable Agriculture and Food Systems, 2008. **23**(2): p. 161-170.
38. Bhatnagar, A., V.K. Dua, and S.K. Chakrawarti, *Scenario, implications and prospects of climate change on potato (Solanum tuberosum) insect pests: A review.* Indian Journal of Agricultural Sciences, 2018. **88**(9): p. 1331-1339.
39. Julio, G., I. Ruiz, and X. Cuesta, *EXPANDING THE AGRICULTURAL FRONTIER OF THE POTATO (SOLANUM TUBEROSUM L.) TO REDUCE THE EFFECTS OF CLIMATE CHANGE.* Revista Universidad Y Sociedad, 2018. **10**(1): p. 46-51.

40. Kimathi, S.M., O.I. Ayuya, and B. Mutai, *Adoption of climate-resilient potato varieties under partial population exposure and its determinants: Case of smallholder farmers in Meru County, Kenya.* Cogent Food & Agriculture, 2020. **7**(1): p. 18.
41. Ierna, A. and B. Parisi, *Crop growth and tuber yield of "early" potato crop under organic and conventional farming.* Scientia Horticulturae, 2014. **165**: p. 260-265.
42. Maggio, A., et al., *Potato yield and metabolic profiling under conventional and organic farming.* European Journal of Agronomy, 2008. **28**(3): p. 343-350.
43. Coppola, G., et al., *A Comparative Cost-Benefit Analysis of Conventional and Organic Hazelnuts Production Systems in Center Italy.* Agriculture-Basel, 2020. **10**(9): p. 16.
44. Taube, F., et al., *Resource efficiency as a regulation variable for the promotion of sustainable production systems: Are there priority areas for organic farming?* Berichte Uber Landwirtschaft, 2006. **84**(1): p. 73-105.
45. DoA, *Implementation framework and guidelines for supply of Bio-inputs in the country*, D.o. Agriculture, Editor. 2015, Department of Agriculture: Thimphu, Bhutan. p. 10.

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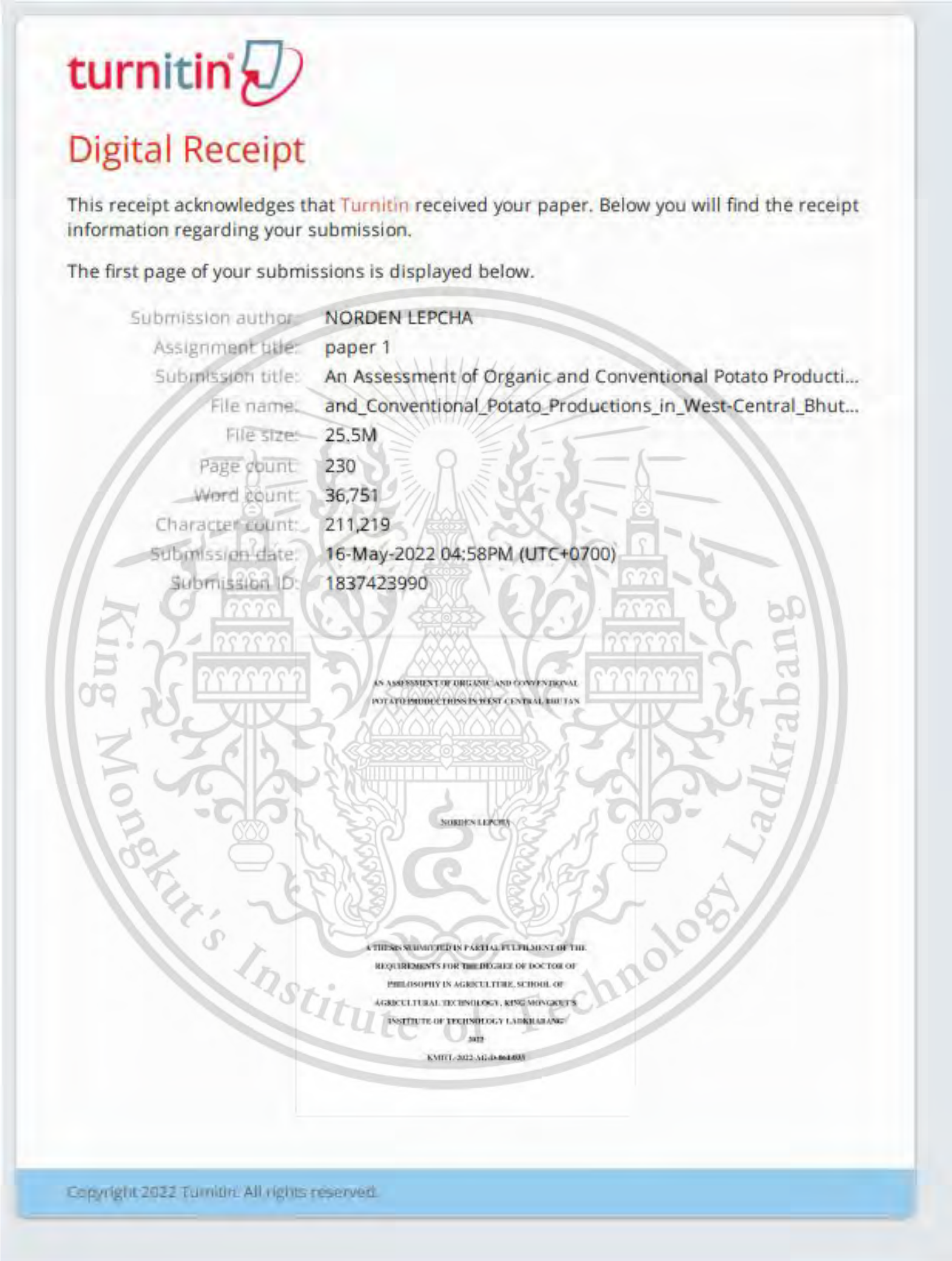

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AN ASSESSMENT OF ORGANIC AND CONVENTIONAL POTATO PRODUCTIONS IN WEST-CENTRAL BHUTAN

NORDEN LEPCHA

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN AGRICULTURE, SCHOOL OF AGRICULTURAL TECHNOLOGY, KING MONGKUT'S INSTITUTE OF TECHNOLOGY LADKRABANG

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## 7.6 VITAE

Mr.Norden Lepcha, a Bhutanese nationality from the Himalayan Kingdom of Bhutan, was born in Khamdang, in his country, in 1979. He obtained BSc. in Agriculture from the Acharya N.G Ranga Agricultural University, Hyderabad, India, in 2004 under the Government of India (GOI) Scholarship. In 2011, he received his MSc.Horticulture from the University of Philippines at Los Banos (UPLB) under the European Union – Agriculture Sector Support Project (ASSP), Bhutan. Currently, he is pursuing a Ph.D. in Agriculture under the mentorships of Assoc. Prof. Dr. Suneeporn Suwanmaneepong (advisor) and Assoc. Prof. Dr. Panya Mankeb (co-advisor) at the School of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang (KMITL), Bangkok, Thailand, under the KMITL's Doctoral scholarship.

He is currently working on his doctoral dissertation titled "An Assessment of Organic and Conventional Potato Production in West-Central Bhutan". The important objectives of the dissertation are 1) To investigate the farm and farmers' socio-demographic characteristics and production aspects of organic and conventional potato farmers in West-Central Bhutan. 2) To compare productivity and profitability of organic and conventional potato production in the region. Also, concisely determine the marketing aspects and constraints of organic potato farmers in the region. 3) To compare the soil properties impacted due to organic and conventional potato productions in the region. Additionally, determine any relationships between the soil properties and the potato productivity.

Before his Ph.D. study in 2019, he served as a Deputy Chief Agriculture Officer at the National Organic Programme, Agriculture Research and Development Centre–Yusipang, Department of Agriculture, Ministry of Agriculture and Forests, Royal

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1) Suwanmaneepong, S., Kerdsriserm, C., Lepcha, N., Cavite, H. J., & Llones, C. A. (2020). Cost and return analysis of organic and conventional rice production in Chachoengsao Province, Thailand. Organic Agriculture, 10(3), 1-10. doi:10.1007/s13165-020-00280-9
2) Lepcha, N., Mankeb, P., & Suwanmaneepong, S. (2021). Productivity and profitability of organic and conventional potato (Solanum tuberosum L.) production in West-Central Bhutan. Open Agriculture, 6(1), 640-654. doi:https://doi.org/10.1515/opag-2021-0044.
3) Lepcha, N., & Suwanmaneepong, S. (2021). Cost and return analysis of organic potato in Gasa district, Bhutan. Paper presented at the 9th International conference on integration of science and technology for sustainable development (ICIST) Bangkok, Thailand.
4) Lepcha, N. and Suwanmaneepong, S. (2022). Macronutrients (NPK) and other soil properties influenced by long term organic and conventional potato farming in West-Central Bhutan. International Journal of Agricultural Technology 18(3): 2630-0192 (online) (accepted to be published in May 2022).
5) Growth of and Antioxidant Production in Tsaang-Gubat (*Carmona retusa (vahl) Masam*) as influenced by Compost, 2011, pages: 118 (MSc.Horticulture Thesis).