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Assessing Food Security Scenario at the Ward Level in Nepal: An Analysis of Caloric Needs from Diverse Crops Based on Location-Specific Factors and Policy Implications

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Abstract

Food security means access to food along with food production and availability to every individual at a reasonable cost according to the calorific needs of people. To assure food safety to 30 million Nepali people, it is essential to utilize every piece of available farmable land in each geographic region of seven provinces. We analyzed individual household food intake, dietary energy adequacy, and nutritional status and needs at the ward level of Nepal. We used a decadal (2010-2020) average food production of different crops per unit of farmable area, and food needs for people living in that ward based on their gender and nutritional requirements to perform various activities in different geographic regions of seven provinces. We assumed three food consumption scenarios: a) traditional practices of meeting dietary needs only from major crops; b) consuming major and minor crops; and c) consuming major and minor crops and meat and fruit products. Our analysis revealed that it is essential for Nepal to implement policies that will encourage crop diversification comprising both major and minor crops and inform the public about the nutritional values of various crops that can be grown utilizing location-specific environments in different geographic regions of seven provinces. Our findings assist in policy instrumentation that will pursue farming communities to supplement their dietary needs with diverse crop products and suggest government set aside some matching funds to encourage remitters, who return to Nepal with knowledge and financial resources, to engage in agriculture. We also argue that crop diversification is needed to assure farm productivity if certain crops fail due to unforeseen environmental calamities.

Keywords: Food security, Nepal, policies, provinces, physiographic regions, major and minor crops

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1. Introduction

Once an exporter of agricultural products till late 1985 (Rai, 2019), Nepal has already faced shortages of food products and imports 20.95 per cent of food needs each year (Bhattarai, 2023). ChartsBin (2023) states that the average energy needs per person globally is 2,780 kcal/person/day. The calorie need per person is not consistent across the world. For example, people in developed countries consume 3,420 kcal/person/day whereas the consumption in developing countries is 2,630 kcal/person/day. Subsaharan African people consume 2,240 kcal/person/day and Central Africans limit their consumption to 1,820 kcal/person/day. Within Nepal, there are disparities in calorific consumption. People performing arduous work need high calorific values as compared to those who perform only white-collar jobs. However, some people must survive on poor-quality food either due to unavailability or due to unaffordability. Simply put, there are disparities in food consumption in Nepal.

The World Bank suggests that an adult with a normal health condition requires an intake of 2,200 calories each day for an active life. The calorie consumption as required depends on the availability of food. Thus, this paper takes an average of all the categories listed in ChartsBin (2023) for the purpose to calculate the average calorific need of Nepali per day and categorizes the food consumption under three scenarios for Mountains, Mid Hills and Tarai regions. The people who live in the Mountain region, in difficult terrains and poorly developed alpine conditions, almost in arctic conditions, and engage in arduous activities, are assumed to need 2,700 kcals/day/person for males and 2,500 kcals/day/person for females. In general, living conditions in the Mid Hills are not as arduous as in the Mountainous regions. However, due to the lack of developmental infrastructure, people still need to do menial jobs. Thus, the energy needs are assumed to be at 2,400 kcal/person/day for males and 2,200 kcal/person/day for females. For the Tarai region, the climatic conditions being sub-tropical and developmental infrastructure being relatively better, the calorific need for males is assumed to be at 2,200 kcal/person/day and 2,000 kcal/person/day (health.gov, 2015-2020) for females (Bhattarai and Conway, 2021; USDA, 2023).

In Nepal, 7.8 per cent of the Nepali population is at risk of a severe food crisis (Khabarhub, 2023; RSS,2023). There have been inequalities in food accessibility in different geographic regions of Nepal (Bhattarai and Conway, 2021). Nepal's 15th five-year plan states that 21 per cent population in Nepal still has no access to sufficient food (NPC, 2023). It states that only 48.2 per cent of households are basically food secure. Many lack quality food. In addition to the natural disasters and climate change impacts, artificial food shortages especially during the COVID-19 period and resulting fluctuations of food prices in the national and international markets have posed

uncertainty in the domestic food supply chain (Bhattarai, 2023). Likewise, the shortage of working human labour due to an exodus of the youth force needed for agricultural activities has also contributed to food security in Nepal (Bhattarai et al., 2020). According to World Food Summit 1996, food security exists when all people always have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. The World Bank defines the situation when the calorie intake remains under 1,800 per day per person as severe food insecurity. Nepal government's data shows that during 2020 (2078-2079 BS), the food production in the country was 369 kilos per person and it was estimated to be 257 kilos after deducting seeds, preservation for animal feed and the loss during the post-harvest stage (RSS, 2022). In the 2020 fiscal year (2078-79 BS), the annual food production in the country was 10 million 772 thousand metric tons and it was around 7,530,000 metric tons by deducing the seeds, livestock preservation and post-harvest stage losses. A recent study suggests that Nepal needs "around 5 million 867 thousand metric tons of processed food to meet the food requirements of its people" (Khabarhub, 2023; RSS, 2022).

Nepal imports a large quantity of food to address its daily demand. The consumption of fine-grain rice is on increasing trend, but there is a shortage of rice to meet the growing demand (FAO, 2022; Bhattarai and Conway, 2021). In some cases, the consumption of crops like millet, buckwheat and potato have been ignored despite their contributions to food and nutritional shortage as well as their importance to meet various micronutrients needed for humankind. Recently, however, some successful examples have been observed in some communities in Nepal and India to diversify crop production through the provision of matching funds to farmers (Gurung, 2016; Jain 2023) for growing minor crops to meet the demand for food.

There has been a growing trend of food demand with specific dietary cases – for instance, plant-based food for vegetarians (Malla, 2019) and also for those who try to avoid the meat base product despite the increasing trend of meat consumption with an increase in purchasing parity (Sitaula, 2021). We have assessed food security conditions based on both plant-based, mixed plant-based, and meat-based scenarios (USDA, 2023a; USDA, 2023b). Nepal's government claims that the country is self-sufficient in fish, meat, and egg while it is close to meeting the need for milk and meat. Improved irrigation facilities, availability of improved varieties of seeds and breeds and modernization in farming have helped improve productivity and the commercialization of agro-based products (The World Bank, 2019). However, the mass exodus of about 1,500 -2,000 working-age people each day has marred different agricultural activities in Nepal (Bhattarai et al., 2020). Since the issue of food security is not only linked to human security but also overall development, it is essential to

improve agricultural production and retain Nepal's working-age people within Nepal (Bohara, 2023). To retain the working age people within the country, "food becomes the basic requirement because it helps in maintaining a balance in quantity, price, and supply chain assuring every person to have physical and economic access to healthy and nutritious food as per individuals' needs" (UNHR & FAO, 2010).

The contribution of Nepali agriculture to its total GDP has decreased to 25 per cent in 2021 from 32 per cent in 2011/2012 (Dhakal, 2022). Almost "4.6 million Nepali people are food-insecure, with 20 per cent of households mildly food-insecure, 22 per cent moderately food-insecure, and 10 per cent severely food-insecure" (USAID, 2019). The situation is much more severe in rural areas of Nepal in general and Karnali Province in particular (Bhattarai and Conway, 2021). As a result, over "40 per cent of Nepalese children younger than five years of age are stunted and 10 per cent suffer from wasting due to acute malnutrition. Pregnant and lactating women (PLW) also suffer from malnutrition, as well as micronutrient deficiencies. Approximately 1.4 million PLW are malnourished, and 48 per cent suffer from anaemia" (USAID, 2019).

The COVID-19 global pandemic and the Russia-Ukraine war have impacted the food grain supply chain in Nepal. Even though the Nepali Constitution Section 3 Article 36 and Section 4 Article 51 rhetorically stress the food guarantee to every Nepali individual, food insecurity still affects more than half of Nepal's people. As a result, many people suffer from nutrition and micronutrient deficiencies. Over a quarter of children are underweight, and more than a third are stunted (Bhattarai and Thapa, 2022; Diao et al., 2022; WHO, 2021). The contrasts, however, are that several people suffer from anaemia, especially, women and children under five years old, while some suffer from increasing obesity and overweight in urban areas, especially, due to the consumption of fatty food (Timsina and Chowhan, 2023). Despite the fact that domestic production falls short of the population's dietary needs, the use of some cereal crops such as buckwheat, millet, barley, and potato are not considered as important as rice, wheat, and maize are, and therefore food imports have increased (Subedi et al. 2020). The low productivity of sloppy lands and inadequate infrastructure to improve land productivity have compelled many people to consume foods having low nutritional values. Even if many exuding people desire to live in Nepal, the lack of irrigation and infrastructure facilities, changing climate with erratic rainfall, long droughts period, and loss of soil fertility have further undermined food production (Liu et al., 2023) challenging the demand for adequate food.

Though food needs vary for different age cohorts and genders in different geographic regions based on their engagements in various types of activities, the scope of this article, however, is limited to the analysis of food security estimation based on gender for

different geographic conditions. Nevertheless, the database can also be used to estimate food requirements for different age groups in different geographic regions. In this paper, we assess the food sufficiency/deficiency at each ward of municipalities of various districts in different geographic regions of seven provinces. Moreover, this paper is mainly on food security based on the secondary data available from the Census Bureau of Statistics (CBS) and focused on the policy instrumentation based on the consumptive scenarios. Since the consumptive scenarios cannot be addressed without considering the land availability, we have focused on location-specific issues such as the types of crops grown and produced at the individual ward level of each village and municipal unit.

The paper first briefly presents the theory of food security, followed by the materials and methods. Then it analyzes food security scenarios using three models.

a. **Model A** food security scenario with the consumption of major crops such as maize, wheat, pulses, rice, milk, and fruit.
b. **Model B** consumption of major and minor crops such as millet, buckwheat, pulses, fruit, potato, and milk consumption.
c. **Model C** consumption of major, minor, milk, pulse, potato, fruit, egg, and meat.

Finally, this paper presents a discussion focusing on policy instrumentation for agricultural transformation in Nepal followed by a conclusion and recommendation.

2. Theory of food security:

The theory on food security emphasizes the need for guaranteeing the quality of food at every place on the earth to every individual at all times in all geographic regions that is economically affordable irrespective of race, socioeconomic conditions, ideological, religious, and political affiliations. To be more specific, Neo-Malthusian analyzes food insecurity from the perspective of food production; the techno-ecology theory sees food insecurity as being caused by improper and inadequate technology and human power; the modernization theory sees food insecurity as being the result of the lack of will of countries to use the most advance technology to enhance food production system; the dependency and the world system theory views food insecurity as a byproduct of world trade imbalance and politicization in the distribution of food resources; the urbanization theory assumes the root cause of food insecurity is due to rural and urban divide weakening the functional relationships between them; the social stratification theory argues food insecurity results due to social stratum; and the militarization theory states that food insecurity results when food is used as a weapon of war.

Though several superfood stores have been established in many places in many countries to help improve the food supply chains, none have guaranteed the supply chain. Climate change and environmental problems and the war in Ukraine have

created a shortage of food causing various health problems on one hand and increasing obesity on the other. In such environments, traditional agriculture practices will not be able to feed the growing population. It is time to switch to sustainable farming practices by engaging every individual to utilize the available land resources to grow new food sources while blending both indigenous and modern knowledge to improve the global food chain. In the case of Nepal, it is high time to think about the neglected micro crops such as barley, millet, potato, quinoa, grams, chickpeas, and others that contain micronutrients that are not available in major crop products such as rice, maize, and wheat and fulfil nutrient needs of people in different geographic regions. Barley, buckwheat, quinoa, and millet are considered pseudo-grains in Nepali society. Food products from these pseudo-grains have occupied precious positions in food items/chains in many five-star hotels after knowing their values that contain high micro-nutrients. Since these pseudo-grains require fewer fertilizers and can grow on inferior lands, Nepal can capitalize on their products to meet food needs.

Blending modern technology with traditional/indigenous knowledge helps to grow food on locally available land areas. Growing food locally helps in saving energy and emissions by avoiding long-distance hauling. It also makes farmers self-sufficient. The pseudo-grains like Kauno, millet, and buckwheat can be grown in different parts of Nepal that can grow in location-specific soil and microclimatic conditions. The positive aspects are that these crops grow even under climatic change conditions with the minimum amount of water and can supplement the food need with micronutrients. They are more resilient and better suited to new climate conditions. After all, farming is thinking about new generations. White revolution (increasing the production of milk through modern breeding) and increasing meat production not only will help in the circular economy but also will help in reducing trade deficits by reducing the import of packed food such as milk and meat products in rapidly urbanizing Nepal.

3. Materials and Methods

This paper assesses food security scenarios at the 6,618-ward level of 753 local political units of Nepal. It takes the population base of 2021 at each ward level. Agricultural lands were computed from 2021 Sentinel-2 at 10 x 10 m land use data available on the Esri website (https://www.arcgis.com/). Linking the population from the census record of 2021 to each ward level, we calculate the calorific needs of the population at each ward level based on their gender living in different geographic regions, such as Mountains, Mid Hills, and Tarai regions of six provinces[1] of Nepal (Fig. 1). It estimates food security conditions under three consumption scenarios. These

1 Madhesh Province is limited to the Tarai region. In this province food needs are assessed based on the subtropical climatic conditions where people involve in various activities partially using machineries because of its proximities to all weathered roads on mostly plain areas.

consumptive criteria include a) major crops such as maize, wheat, barley, pulses, rice, and milk; b) major and minor crops such as millet, buckwheat, pulses, potato, and milk; c) major, minor crops, milk, pulse, potato, and meat.

Land cover data for the year 2021 were extracted from global land cover Sentinel-2 surface reflectance at 10 m x 10 m resolution. These data were obtained from the Esri website (https://www.arcgis.com/) for UTM Zones 44 and 45 N. Satellite images were classified using a deep learning model that used over 5 billion hand-labelled Sentinel-2 pixels sampled from over 20,000 sites distributed across all major biomes of the world. Using a shapefile, only portions of Nepal's land use and cover datasets were extracted for the year 2021. Demographic information was obtained from the Central Bureau of Statistics (CBS) and the Election Commission, Nepal. The ward-level shapefile was obtained from the Ministry of land reform.

3.1 Methods

All demographic information was linked to the shapefile of Nepal with ward-level spatial information. Each ward was linked to available agricultural lands based on slope classes divided at 5 degrees intervals such as 0-4.99, 5-9.99, 10-14.99, 15-19.99, 20-24.99, 25-29.99, 30-34.99, 35-39.99, and 40 and above for the year 2021. Areas within 10 degrees slope and at the 5 km vicinities to the major rivers are considered as irrigated fields and others were considered semi-irrigated and rainfed agricultural land to grow different types of crops, but not irrigated paddy. Nutritional values for each crop were computed as in Table 1 to calculate the nutritional values available from different agricultural crops per unit of land.

Table 1: Crops grown in different regions, their calorific values and sources.

Crops	The geographic extent of production (Percent of agricultural land areas used to produce crops based on slope classes)	Nutritional values	Source
Maize	Tarai (65%) Mid Hills (100%) Mountains (50%)	1 ton = 3251595 calories Maize contains 10% husk.	Based on land use slope classes and CBS records. NIH: National Library of Medicine.
Wheat	Tarai (65%) Mid Hills (70%) Mountains (45%)	1 kg grain = 950 grams flour. 1 ton = 3083800 calories. Wheat contains 5% husk.	Based on land use slope classes and CBS records. WWF, QUORA. Traditional Oven (2023a)

Crops	The geographic extent of production (Percent of agricultural land areas used to produce crops based on slope classes)	Nutritional values	Source
Rice	Tarai (95%) Mid Hills (35%) Mountains (20%)	186 grams = 242 calories 1 gram = 1.31 calories 1 ton = 1180488 cal. Rice contains 72% rice and 28% husk.	Based on land use slope classes and CBS records. Rice Knowledge Bank. Verywellfit. IRRI Kit.
Millet	Tarai (15%) Mid Hills (60%) Mountains (70%)	1 ton = 1079017 calories Millet contains 10% husk	Based on land use slope classes and CBS records. Healthline, WebMed
Buckwheat including quinoa	Tarai (15%) Mid Hills (65%) Mountains (70%)	1 ton = 3111644 calories Buckwheat contains 15% husk.	Based on land use slope classes and CBS records. fatsecret. Good House Keeping. Fischer (2023).
Barley	Tarai (45%) Mid Hills (65%) Mountains (55%)	1 ton = 3208966 calories Barley contains 15% husk.	Based on land use slope classes and CBS records. Traditional Oven (2023b)
Potato	Tarai (45%) Mid Hills (65%) Mountains (70%)	1 ton = 680250 calories Potato contains 17.5% waste	Based on land use slope classes and CBS records. healthline
Pulses	Tarai (45%) Mid Hills (65%) Mountains (70%)	1 ton = 2670752 calories On average pulses contain 2% husk.	Based on land use slope classes and CBS records. Pulses and Nutrition
Milk	2.5 litres/household	1 liter = 628.98 calories Varies from sources such as cow, buffalo, goat, and yak. (Average is taken)	CBS records. INCHCALCULATOR, Nutritional Value of Milk, WebMD

Crops	The geographic extent of production (Percent of agricultural land areas used to produce crops based on slope classes)	Nutritional values	Source
Egg	0.25 eggs/household	1 egg =210 calories	CBS records, COVER CREEK FARM. Sparacie (2019). Onyenweaku et al. (2016)
Meat production	1.25 kg /household	1 kg meat = 2,500 to 3,500 calories	CBS records, COVER CREEK FARM, Our World in Data. Sparacie (2019).
Oil seed	Tarai (55%) Mid Hills (65%) Mountains (30%)	1 ton = 7709500 calories	The Features and Nutritive Values of Common Oil Crops Research Gate. De Lamo and Gomez (2018).
Sugarcane	Tarai (55%) Mid Hills (25%) Mountains (5%)	1 ton = 3401250 calories. Only 70 per cent of the product is usable	FITNigerian

Nutritional values are taken from the table above to calculate the average nutrition that can be obtained from different agricultural products. Nutritional values available from locally grown crops and food needs by everyone at the household level were determined to assess the food security situations under three models as discussed above. The average crop, milk, and meat production information was taken at the district level for a decade (2010 to 2020) from the Ministry of Agriculture & Livestock Development (MoALD, 2021). These values were averaged at the district levels and assigned to each individual polygon of each ward belonging to the municipalities of each district. Using the nutritional values from the above table, we calculated the calorific values for each agricultural product at each ward level. Energy needs for both males and females were computed as in Table 2 for each ecological region.

Table 2: Calorific values needed per person per day by region.

Ecological region	Calories need/day/person	
	Male	Female
Subtropical region (Tarai)	2,200	2,000
Temperate region (Mid Hills)	2,400	2,200
Alpine & artic (Mountain)	2,700	2,500
Average	2433	2233

3.2 3.2 Factors affecting food security situations in Nepal

The population distribution in three geographic regions belonging to six provinces and Madhesh Province belonging to the Tarai region is given in Fig. 1. People living in different geographic regions of seven provinces by gender require different calories. The population distribution in Nepal is not uniform across three geographic regions and across seven provinces as are the caloric needs of the people.

Many people live in the southern part—the Indo-Gangetic Plain. This is followed by the Mid Hills. The least number of people live in the Mountain region (Fig. 1). The agricultural land is more concentrated in the Tarai region followed by the Mid Hills. The Mountain region has the least areas of agricultural land (Fig. 2). Agricultural productivity also is higher in the Tarai region followed by the Mid Hills. Land productivity is very low in the Mountainous region. The elevation ranges increase from south to north (Fig. 3). As the elevation varies, different types of crops are grown at different elevational ranges and in different provinces. Since Nepal receives monsoon rainfall due to the orographic process from the storms originating from the Bay of Bengal, the amount of rainfall decreases from the east to the west and in different places (Fig. 4). Because of the variations in rainfall patterns (Fig. 4) and decreasing temperature from the south to the north (Fig. 5), different types of crops can be grown in Nepal.

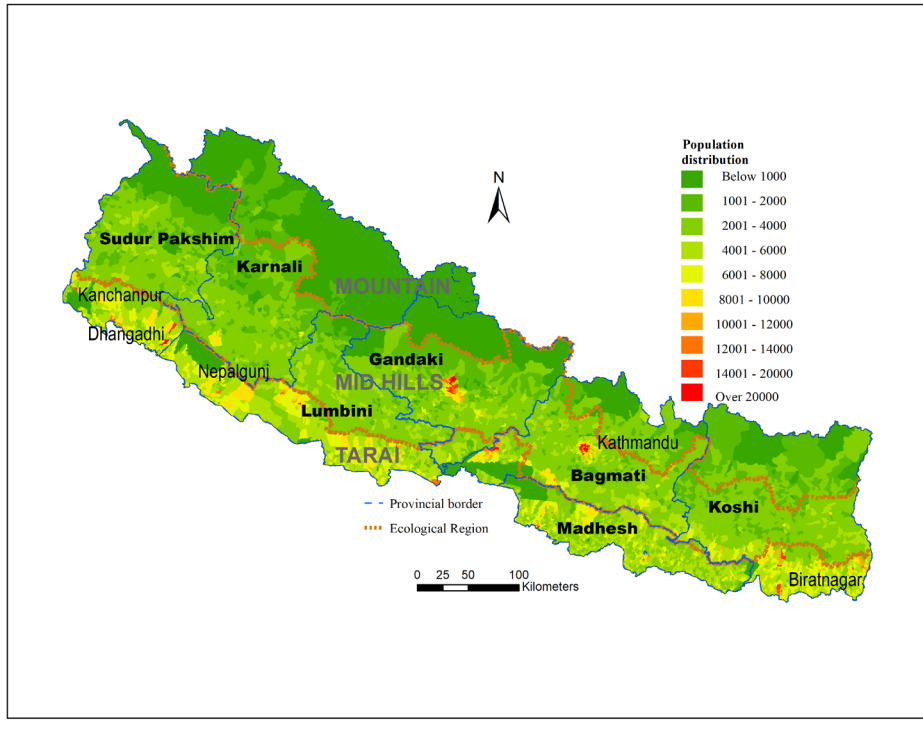

Fig. 1. Population distribution in Nepal based on Census 2021.

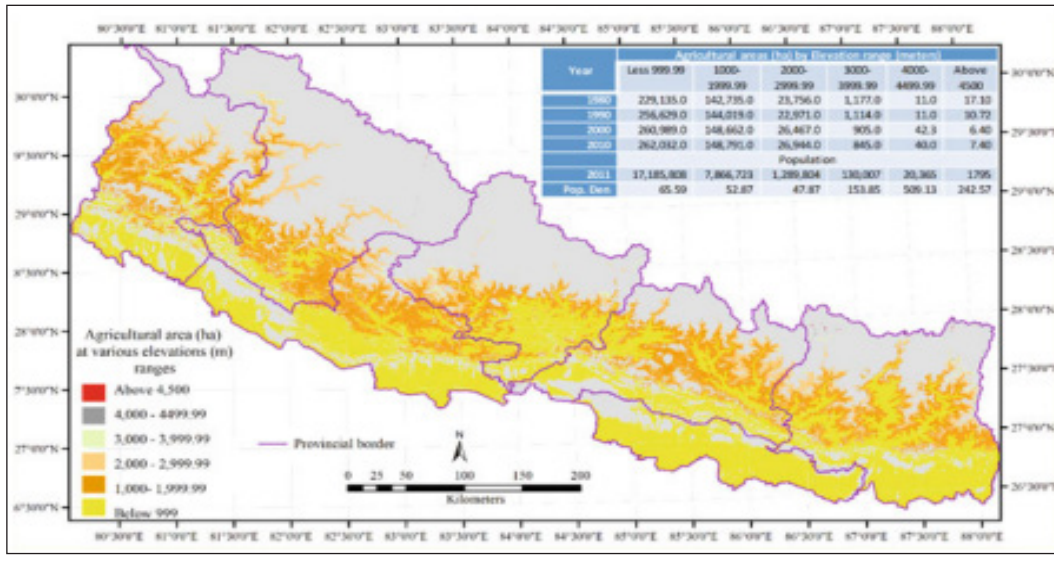

Fig.2. Agricultural land at different elevational ranges (Adapted from Bhattarai and Conway, 2021 with permission from the authors)

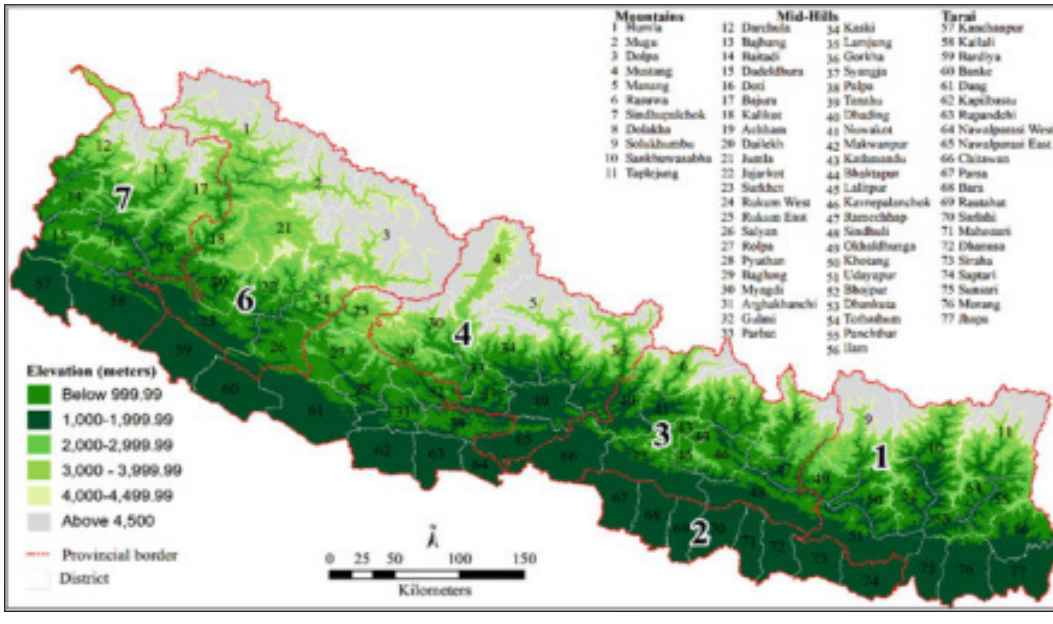

Fig. 3. Nepal- elevation range. [Map adapted from Bhattarai and Conway, 2021—with permission from the authors)

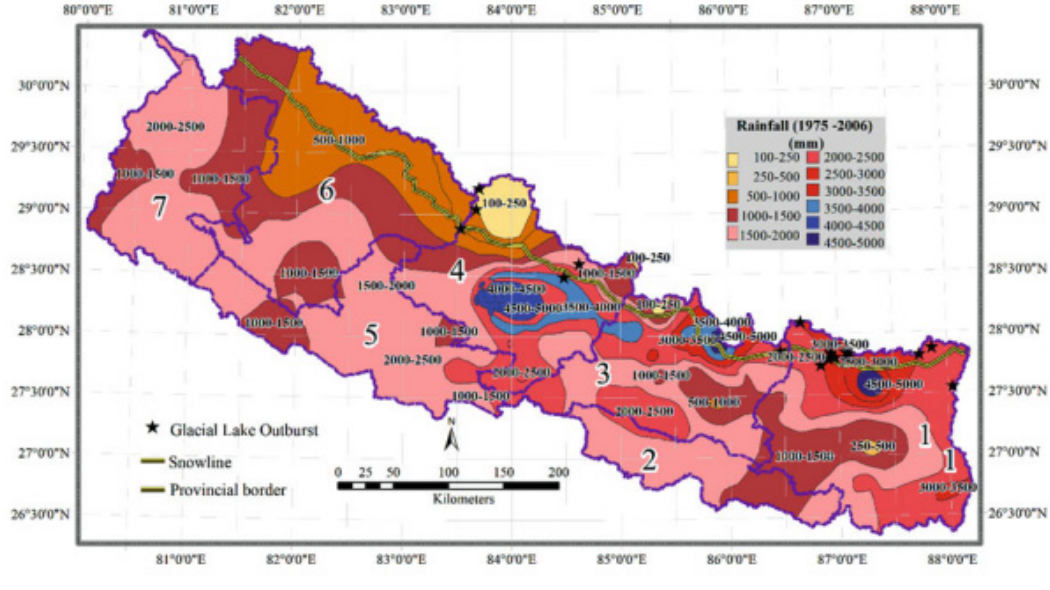

Fig. 4. Rainfall trends in Nepal (1975-2006). Adapted from Bhattarai and Conway with authors' permission.

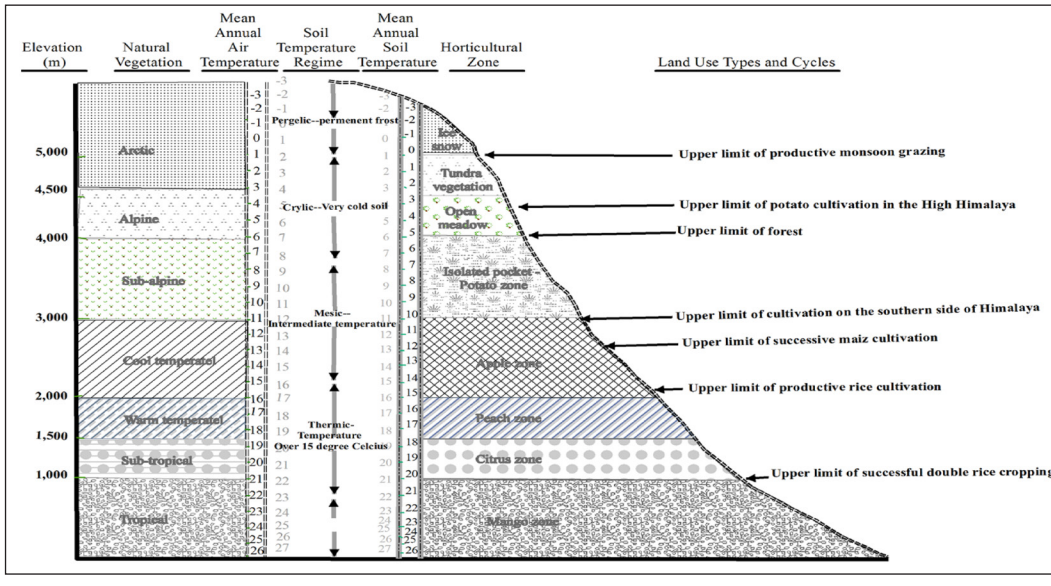

Fig. 5 Land use by elevation. Adapted from Bhattarai et al. (2020) with authors' permission.

The turnover rates of various crops are low in the mountainous region because of the alpine and arctic types of climates. Some areas with low slopes and elevation in the Mid Hills are as productive as in the Tarai region. These areas in the Mid Hills also have perennial irrigation facilities from local streams like in the Altiplanos of the Andean region of South America (Zubieta et al., 2021) despite their higher locations than the Tarai region. In the Tarai region, most of the agricultural areas are irrigated. Due to its subtropical nature, the turnover rate of various agricultural crops grown in this region is higher as compared to most of the Mid Hills region and can support more people per unit area of agricultural land than the Mid Hills and Mountainous region.

According to the Community Irrigation Project (RRP, NEP 38417-02) of the 2.60 million hectares (ha) arable land, 1.80 million ha is irrigated. Of the 1.8 million ha, 1.40 million ha is in the Tarai or plains. "The remaining 0.40 million ha is in river valleys, upland valleys, and terraces on hills and mountains." Almost 70 per cent of the command areas of surface water irrigation infrastructure is irrigated, with only 38 per cent of the agricultural land is irrigated perennially of which 75 per cent of the irrigation is managed by farmers and the government manages only 25 per cent. Shallow tube wells are used in irrigation in the Tarai region since the 1970s. Around 0.25 million ha is irrigated by groundwater in the Tarai region (ADB, 2009). Irrigation has helped to boost crop production and diversification.

We have taken these factors into consideration while evaluating the food security conditions in different geographic regions belonging to seven different provinces of Nepal.

4. Results

We have estimated the food security scenarios under three food consumption practices. Table 3, and presented the areas that face food scarcity in Figures 6, 7, and 8. It is assumed that maize is grown in 65 per cent of the agricultural land in the Mountainous region, 80 per cent in the Mid Hills and 55 per cent of agricultural land in the Tarai region.

Model A: Consumption of major crop such as maize, wheat, pulses, rice, potato, and milk.

a. **Model A**: Consumption of major crops produce such as maize, wheat, pulses, rice, and milk.
b. **Model B:** Consumption of major crop produce as in Model A (above) and minor crops such as millet, buckwheat, pulses, potato, and milk.
c. **Model C:** Consumption of major and minor crop produces (as in Models A and B above) and egg and meat products.

Table 3: Number of households and people by gender facing food deficits each day to meet their caloric needs per person and per household. The numerator number under the male and female columns are the numbers of males and females that face food shortages. The number in the denominators under the column males and females is the total number of males and females in Nepal. Also, on the household side, the denominators show the total number of households in each province. The numerator numbers represent the households that experience food shortages. Nutritious values are calculated based on Table 1. These nutritious values are taken to determine the calorific needs of both males and females.

Model	Number of people facing food deficit		Number of households facing food deficit each day to meet their required food calorie/day in each province under three models						
	Male	Female	Koshi	Mad-hesh	Bagmati	Ganda-ki	Lumbi-ni	Karnali	Sudur Pashim
Model A (Fig. 6, Table 4, Column 2)	3049257/ 12658606	3181622/ 13619480	38481/ 115069	22236/ 932087	596377/ 1269144	121454/ 584896	132594/ 881706	124715/ 300564	147522/ 469703
Model B (Fig. 7, Table 4, Column 3)	2954039	3083216	34241	22236	595454	115561	131522	112203	138139
Model C (Fig. 8, Table 4, Column 4)	2933920	3061473	34179	22236	588295	115086	130552	111054	138139

Figures 6 to 8 shows the geographical areas that face food shortages under different models.

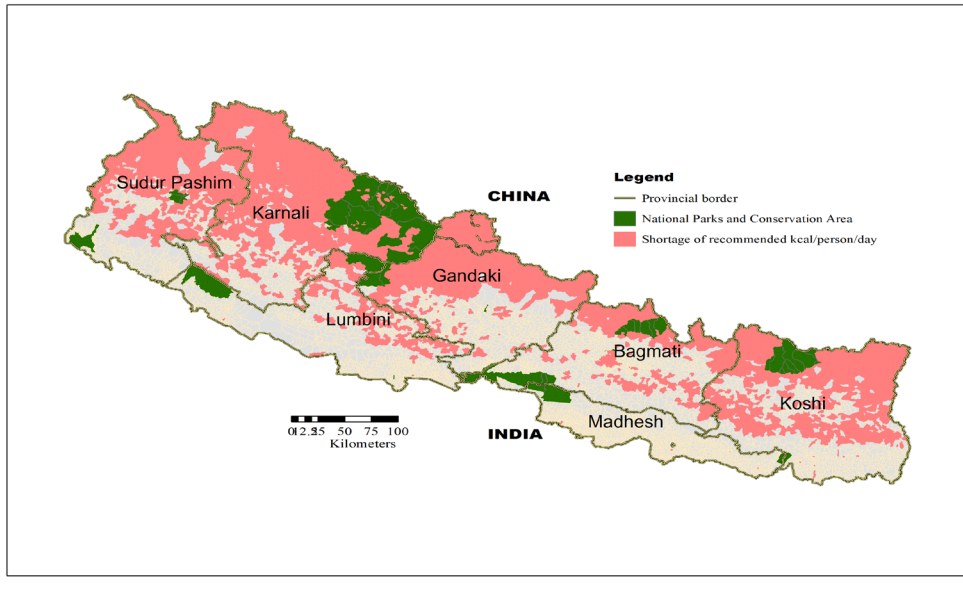

Fig. 6. Areas under scarcity as per Model A consumption of major crop produces. (Names of areas under food scarcity are given in Table 4).

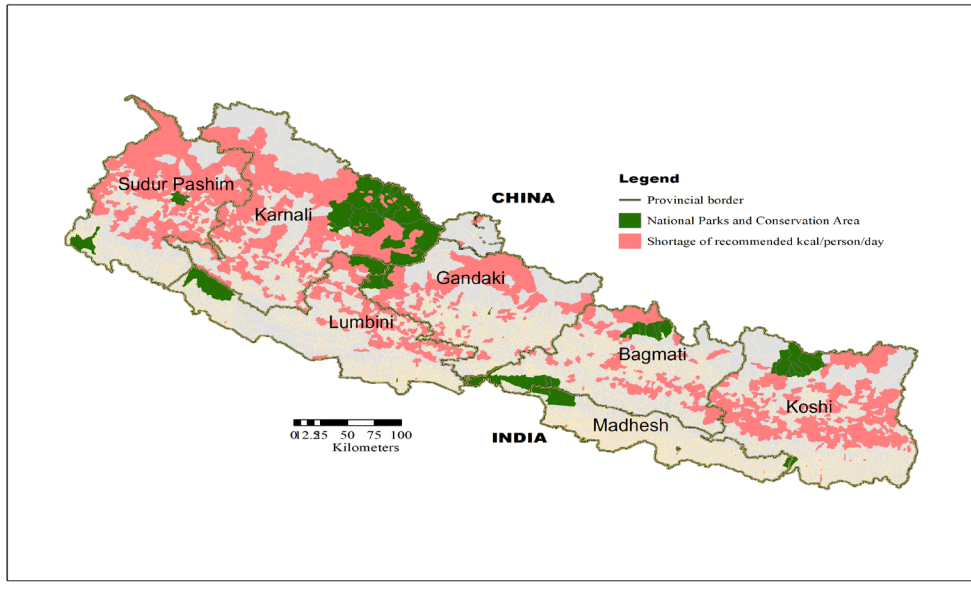

Fig. 7. Areas under scarcity as per Model B consumption of major and minor crop produces. (Names of areas under food scarcity are given in Table 4).

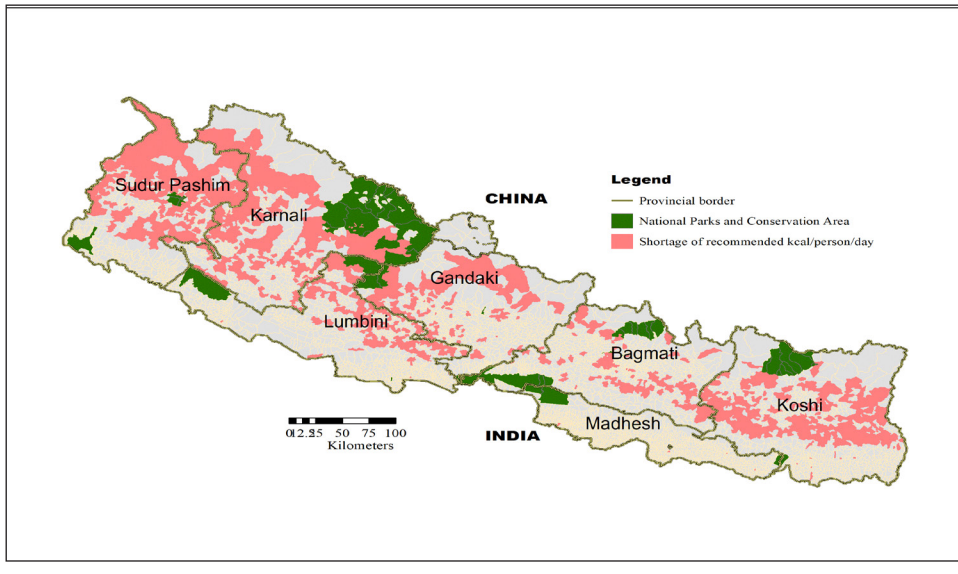

Fig. 8. Areas under scarcity as per Model C consumption of major and minor crop produces and egg and meat. (Names of areas under food scarcity are given in Table 4).

Table 4: Food shortage by provinces, districts and number of wards within the districts belonging to various rural and urban municipalities. The numerator numbers are food deficit wards in the district and the denominator numbers are the total number of wards in that district.

Province	Model A	Model B	Model C
Koshi	Taplejung (41/61), Terhathum (19/43), Udayapur (27/76)	Taplejung (39), Terhathum (10), Udayapur (22)	Taplejung (37), Terhathum (10), Udayapur (21)
Madhesh	Dhanusha (7/169), Parsa (10/114), Saptari (3/165), Sarlahi (2/200), Siraha (1/164)	Dhanusha (7), Parsa (10), Saptari (4), Sarlahi (2), Siraha (1)	Dhanusha (7), Parsa (10), Saptari (3), Sarlahi (2), Siraha (1)
Bagmati	Bhaktapur (18/34), Chitwan (4/99), Dhading (10/104), Dolkha (9/74), Kabhrepalanchok (31/135),	Bhaktapur (18), Chitwan (4), Dhading (9), Dolkha (7), Kabhrepalanchok (31),	Bhaktapur (18), Chitwan (4), Dhading (9), Dolkha (6), Kabhrepalanchok (30),

Province	Model A	Model B	Model C
	Kathmandu (101/138), Lalitpur (39/71), Makwanpur (7/104), Nuwakot (6/90), Ramechhap (29/64), Rasuwa (16/27), Sindhuli (15/79), Sindhupalchok (15/109).	Kathmandu (99), Lalitpur (39), Makwanpur (5), Nuwakot (6), Ramechhap (26), Rasuwa (12), Sindhuli (15), Sindhupalchok (7).	Kathmandu (100), Lalitpur (37), Makwanpur (5), Nuwakot (6), Ramechhap (25), Rasuwa (12), Sindhuli (14), Sindhupalchok (6).
Gandaki	Baglung (35/86), Gorkha (11/94), Kaski (23/83), Lamjung (16/75), Manang (25/28), Mustang (18/25), Myagdi (20/46), Nawalparasi East (6/93), Parbat (13/61), Syangja (19/97), Tanahu (6/85).	Baglung (35), Gorkha (10), Kaski (14), Lamjung (16), Manang (24), Mustang (16), Myagdi (20), Nawalparasi East (6), Parbat (12), Syangja (19), Tanahu (6).	Baglung (35), Gorkha (9), Kaski (14), Lamjung (16), Manang (23), Mustang (11), Myagdi (20), Nawalparasi East (6), Parbat (13), Syangja (18), Tanahu (6).
Lumbini	Arghakhanchi (25/61), Banke (6/81), Dang (2/100), Gulmi (44/93), Palpa (35/81), Nawalparasi West (1/74), Pyuthan (20/64), Rukum E (15/47), Rolpa (20/72), Rupandehi (15/156).	Arghakhanchi (25), Banke (6), Dang (2), Gulmi (34), Nawalparasi West (1), Palpa (35), Pyuthan (21), Rolpa (21), Rukum E (12), Rupandehi (15).	Arghakhanchi (25), Banke (5), Dang (2), Gulmi (34), Nawalparasi West (1), Palpa (35), Pyuthan (20), Rolpa (20), Rukum E (12), Rupandehi (15).
Karnali	Dailekh (36/90), Dolpa (55/76), Humla (39/44), Jajarkot (32/77),	Dailekh (36), Dolpa (55), Humla (37), Jajarkot (32),	Dailekh (36), Dolpa (55), Humla (36), Jajarkot (32),

Province	Model A	Model B	Model C
	Jumla (20/60), Kalikot (54/82), Mugu (33/45), Rukum West (29/62), Salyan (18/83), Surkhet (25/99).	Jumla (19), Kalikot (54), Mugu (33), Rukum West (29), Salyan (18), Surkhet (24).	Jumla (18), Kalikot (54), Mugu (33), Rukum West (25), Salyan (17), Surkhet (24).
Sudur Paschhim	Achham (47/92), Baitadi (54/84), Bajhang (73/95), Bajura (48/70), Dadeldhura (13/52), (Darchula (48/61), Doti (28/66), Kailali (4/82).	Achham (47), Baitadi (54), Bajhang (73), Bajura (48), Dadeldhura (13), (Darchula (47), Doti (28), Kailali (4).	Achham (46), Baitadi (54), Bajhang (73), Bajura (48), Dadeldhura (13), Darchula (47), Doti (28), Kailali (4).

5. Discussion and Policy Implications

Many districts in different provinces face food shortages. Within the district, some wards belonging to villages or municipalities are food sufficient while some wards face a food deficit. Table 4 shows the districts and the total number of wards (denominator) and the number of wards (numerator) facing food shortages. Districts with many urban areas face food shortages because urban areas do not produce the required amount of food. These areas need to import food from outside to meet their caloric needs.

Diversifying food consumption may help to improve the situation from food deficient to food sufficient ward. However, at the current rate of growth, there is no significant difference in various districts of the seven provinces that will improve food security situations even with crop diversification. Only a few wards and corresponding households in each district have been able to improve their food security situation with crop diversification that is growing both major and minor crops. Only a few wards are promoted to food sufficiency with crop diversification and consumption of both major and minor crops and meat and other food items such as eggs. Promoting large-scale production of minor and cash crops such as potato and quinoa will help improve the food security situation in Nepal.

The workforce always remains an invaluable asset for a country's economic growth, but food insecurity may obstruct the attainment of socioeconomic well-being of Nepali

people. Despite the fact that the Nepali constitution assures food security to every individual as per Part 3 Article 36 and Part 4 Article 51 of the Nepali Constitution, Nepal has not been able to achieve its food security. Policy instrumentation to pursue people to change eating habits based on the production possibilities of diverse food products that are healthy and nutritious to meet daily calorific needs may help make Nepal become food sufficient. Such adaption of dietary habits would help feed many people while growing food locally without importing much food from outside from long distances. The solution to sustainability and food security should integrate food safety considerations from the start considering what crops are supported by the physiographic conditions in different geographic regions of Nepal. Current agriculture production in Nepal is caught in a low equilibrium trap with low productivity of staples and supply shortfalls, low returns to farmers, and abandonment of farmlands due to various reasons including wild animal raids on crops and increasing exodus. It is high time for Nepal to unlock rural agriculture and learn from successful examples of agricultural revitalization efforts by capitalizing on the skills and resources that may be available from returnee migrants. Joining hands with various innovative organizations, such as "Nepal Innovation Center" and "Nepal Agriculture Research Council" implementing matching fund programs, may help engage the working age exuding human power to boost agricultural productivity. Delaying such efforts will be a lost opportunity for Nepal which will further suffer from severe food crises.

Planners and policymakers may utilize this information to craft policies to ameliorate food security. These include but are not limited to:

a. Promoting households to diversify their agricultural produces.
b. Providing incentives to start new crops that are suitable to location-specific agroecological conditions.
c. Encouraging remitters to start up new agricultural businesses by providing matching funds and guarantees of safe markets and preventing them from "falling prey to predatory lenders" (Bohara, 2023).
d. Encourage the diaspora to invest in agriculture with some matching funds as done in Mexico.
e. Collaborating with various innovation centres to practice new agricultural techniques.

6. Conclusion

In this paper, we utilized both spatial and aspatial data to analyze the food scenario in Nepal taking the decadal (2010-2020) average crop production information to

estimate the production of various crops at the ward levels of different municipalities of three geographic regions of seven provinces. We assessed farmlands at the ward levels and estimated the possible production scenarios for various agricultural crops and evaluated the nutritional values of each crop. We gathered calorific information for different crops and estimated the total amount of calorific nutrients that are available from each crop at the ward level. We computed the food energy needs by gender at each ward level and compared those needs with the available crop yields. We projected three scenarios: a) consuming only the major crops; b) consuming major and minor crops, and c) consuming major, and minor crops, fruit, and meat products. We also estimated the food calorific values that will be available under every three scenarios then we calculated the number of people facing food crises. We then decomposed the number of people at the national levels to provincial levels to municipal and to ward levels to assess how many households may face food deficits under three scenarios (Figs. 6-8, and Table 4). Finally, we concluded that food security follows three principles accessibility, availability, and affordability. Looking at the food deficit scenarios at each province, district, municipality, and ward, planners and policymakers need to develop policies that will intervene in the slow process of governance and start providing incentives or matching funds to engage exuding working-age people to vitalize the agricultural production of Nepal in order to improve food supply chain at the ward, village and municipalities, districts, provincial and national levels.

Authors Contribution

Keshav Bhattarai: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Application of statistical, mathematical, computational, or other formal; Conducting a research and investigation process, specifically performing the experiments, or data/ evidence collection; Report initial draft/review/ final draft polishing.

Shiva P Gautam: Review of final draft and polishing.

Buddhi R. Gyawali: Review of final draft and polishing.

Conflict of Interest

The authors declared no conflict of interest.

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