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WFP Critical Corporate Initiative: Climate Response Analysis for Adaptation

Nepal

Alliance

Bioversity International
CIAT International Center for Tropical Agriculture Since 1967 Science to cultivate change
CGIAR RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security CCAFS

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Key messages

CONTEXT

- **Nepal is one of the countries that is most vulnerable to natural disasters and climate change. Climate change presents detrimental impacts on food and nutrition security.** To better respond to and anticipate the needs of Nepal's population in relation to current and future climate challenges, this report assesses projections of climate change's effects on food and nutrition security and vulnerability indicators. This report also outlines recommendations for climate adaptation programming for World Food Program (WFP) operations in three selected provinces of Nepal - namely Province 2, Karnali, and Sudurpaschim Province.

- **The government of Nepal's policy focuses on climate change and disaster risk response - yet gaps in implementation exist, especially at the province and district levels.** Insufficient funding, lack of capacity at the province and district levels, and administrative restructuring and decentralization due to the country's adoption of a new constitution in 2015 provide openings for WFP programming to support the government in addressing, designing, and implementing food and nutrition security policies for climate adaptation.

PROJECTED CLIMATE CHANGE IMPACTS THROUGH 2050

- **Projected climate impacts, as well as recommendations for adaptation, differ strongly between and within provinces.** While climate projections suggest a general warming trend across the whole country, precipitation will likely become more erratic and unpredictable. Some parts of the country are projected to receive more precipitation in the future, and other parts are projected to receive less precipitation in the future. These changes depend on season and elevation, which varies from 60 m above sea level in the south to over 8000 m above sea level in the north. Summer monsoon rainfall is projected to increase in amount yet shorten in duration. Short and medium-term projections for the years 2030 and 2050 predict more intense rainfall during peak summer months across all assessed provinces. Projections foresee lower and upper mountain elevations becoming drier during the winter, while mid-hill areas might become wetter. Increasing winter droughts are especially problematic for high mountain districts, which have significantly less access to irrigation sources as compared to lower elevation districts. Drier winters will likely severely impact agricultural productivity and food and nutrition security in remote mountain areas, such as Karnali and Sudurpaschim Province.

- **Climate change impacts specific locales through hazards such as floods, droughts, cold spells, and heat stress.** Most of these hazards are projected to become more frequent and extensive in the future, with the exception of cold spells, which will likely become rarer due to warming temperatures. In addition, the population of Nepal is highly vulnerable, with food insecurity, inequality, poor health, little access to cities, and out-migration prevailing across the three provinces. Accordingly, the projected increase in climate hazards will likely have a disproportionately strong impact in those vulnerable areas - most notably in southern and lower hill districts across Provinces 2 and Sudurpaschim Province respectively, but also to some extent in all three provinces.

- **While low elevation districts across Provinces 2 and 7 are currently highly suitable for cultivating maize and lentil, they are projected to become poorly suitable for maize cultivation and moderately to poorly suitable for lentil cultivation.** Rice cultivation in both lowland and upland regions will remain largely unchanged; lowlands are moderately to highly suitable for rice cultivation, and uplands are poorly suitable to unsuitable, with the slight exception of low to mid-hill areas of Karnali and Sudurpaschim Provinces. This means that responders will need to consider shifting to alternative stress-tolerant crops in areas where maize and lentil cultivation declines and choosing varieties that are better adapted to new climate conditions. Where suitable, production can shift to higher areas.

ECONOMIC ANALYSIS OF CLIMATE CHANGE IMPACTS OF AVAILABILITY AND STABILITY OF FOOD SUPPLY THROUGH 2050 (IMPACT)

- **According to an economic analysis based on a future with high global carbon emissions, few mitigation efforts, and improved technology, improvements in agricultural productivity and yield are projected to increase the availability and stability of food through 2050.** This is expected to decrease levels of hunger and undernourishment. While these gains are in line with socioeconomic trends, they are due to rapid industrialization, technological innovation, and improving education, rather than improving climatic conditions. On the contrary, negative climate trends will prevent the agricultural sector from reaching its maximum potential. Maize and other cereal crops face the gravest threat, although the production of pulses, millet, sugarcane, vegetables, cotton, and wheat will all be adversely impacted by climate change through 2050.

- **Improvements in productivity and yield may be distributed unevenly, leading to pockets of entrenched deprivation.** A geo-spatial analysis of eight dimensions of vulnerability has found different types of vulnerability occurring in tandem across all provinces, with Karnali and Province 2 most likely to face overlapping vulnerabilities. Without effective intervention, current vulnerability indicates a preponderance for future vulnerability, indicating that gains in agricultural productivity or socio-economic development may be felt less acutely in these areas.

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RECOMMENDATIONS AND OPPORTUNITIES FOR FUTURE WFP PROGRAMMING, PARTNERSHIPS, AND FUNDING STREAMS

- **WFP in Nepal already has a strong focus on incorporating climate adaptation response into its programming, with great potential for future expansion into new areas and building upon existing programs.** Existing programs include initiatives on early warning systems, forecast-based financing, agricultural and livestock insurance, climate smart agriculture training for farmers and value chain stakeholders, and helping local governments develop and implement action plans. Recommendations are formulated based on climate impact analyses. These recommendations address increasing drought and heat stress as well as floods and landslides in each of the three provinces and focus on specific technologies and practices that affect livelihood, landscape and supply chain levels (table 4). To provide an environment that can build adaptive capacity at a local level, these recommendations are accompanied by suggestions for adaptation options within institutional systems, processes,and policies , as shown in Table 5.

- **WFP has many opportunities to strengthen partnerships with both local and international organizations to support climate resilience programming in the country.** WFP's most important strategy is to strengthen its collaborations with different government agencies that work on agricultural development, climate change, and food security. However, enhancing climate adaptation programming also presents an opportunity for WFP to systematically build and strengthen partnerships with other UN agencies in the country, such as FAO and IFAD. These partnerships strengthen the UN's role as one actor with common objectives for the country. This will not only enhance the effectiveness of program implementation in Nepal, but also strengthen WFP's position in relation to other organizations with longstanding expertise in climate change programming, thus enhancing WFP's ability to win funding from international donors. Nepal hosts numerous international and national non-governmental organizations with expertise and experience in the climate change field, which can provide great value to WFP in terms of partnerships.

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Acronyms and abbreviations

ACLED	Armed Conflict Location & Event Data Project
AEZ	Agroecological zones
AF	Adaptation Fund
CC	Climate Change
CDaFN	Community Development and Advocacy Forum
CGIAR	Consortium of International Agricultural Research Centres
CIAT	International Centre for Tropical Agriculture
CLEAR	Consolidated Livelihood Exercise for Analysing Resilience
CSP	Country Strategic Plan
EU	European Union
FAO	United Nations Food and Agriculture Organization
GCF	Green Climate Fund
GDI	Gender Development Index
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HDI	Human Development Index
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
KIIs	Key Informant Interviews
KIRDARC	Karnali Integrated Rural Development and Research Centre
KVS	Koshi Victims Society
LAPA	Local Adaptation Plan of Action
LDC	Least Developed Country
LDCF	Least Developed Country Fund
Li-Bird	Local Initiatives for Biodiversity, Research and Development
MoFE	Ministry of Forests and Environment
NARC	National Agriculture Research Council
NGO	Non-Governmental Organization
ODA	Overseas Development Aid
PRO-C	Climate and Disaster Risk Reduction Programmes Unit
RAM	Research, Assessment and Monitoring Unit
RCP	Representative Concentration Pathway
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RIMES	Regional Integrated Multi-Hazard Early Warning System for Africa and Asia
SDGs	Sustainable Development Goals
SO	Strategic Outcome
SSP	Shared Socio-Economic Pathway
UK MET	United Kingdom Meteorological Service
UNFCCC	United National Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
WFP	World Food Programme

Introduction

The World Food Programme's (WFP) recent Zero Hunger Strategic Review has identified climate change as one of several new and complex drivers of hunger. This novel threat to global food and nutrition security requires new approaches in terms of both design and resourcing. The international funding mechanisms that provide resources for addressing climate change are often beyond the reach of specific climate change response programs. In response, the Critical Corporate Initiative seeks to broaden and enhance WFP programs through a collaboration between the Policy Development Department and the Partnerships and Advocacy Department. This effort will support the successful identification and pursuit of diversified financing opportunities.

As part of the Critical Corporate Initiative, WFP's Climate and Disaster Risk Reduction Programs Unit (PRO-C), in collaboration with the Research, Assessment, and Monitoring Unit (RAM) and the Alliance of Bioversity and CIAT and the CGIAR, has developed a gap analysis of climate risk management actions that can identify funding needs. The initiative was conducted in Burundi, Guinea, Guinea-Bissau, Haiti, Myanmar, Nepal, Niger, Pakistan, Somalia, and Tanzania. In close coordination with the national WFP officers, the Alliance of Bioversity and CIAT identified intervention areas, key crops, priority outcomes, and key climate and non-climate hazards for each country. Analysis was then conducted using a diverse methodology that included desk review, climate change modelling, the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) assessment, stakeholder workshops, and key informant interviews. The report begins with an overview of the national context, including geography, the county's socio-economic and food security situation, climate and development policy context, and national level climate projections. Section II of the report introduces the three selected areas of interest. In this case, the areas of interest are Province 2, Karnali, and Sudurpaschim Province. Section II provides a deeper analysis of the current and future threats of climate change and its impact on food availability , and compares these results with an analysis of the area's existing socio-economic vulnerability. Section III analyses current WFP activities and how these may be optimized in light of Section II's findings. Finally, the report offers recommendations for partnerships that may enable and enhance the programs.

PART 1.

National context

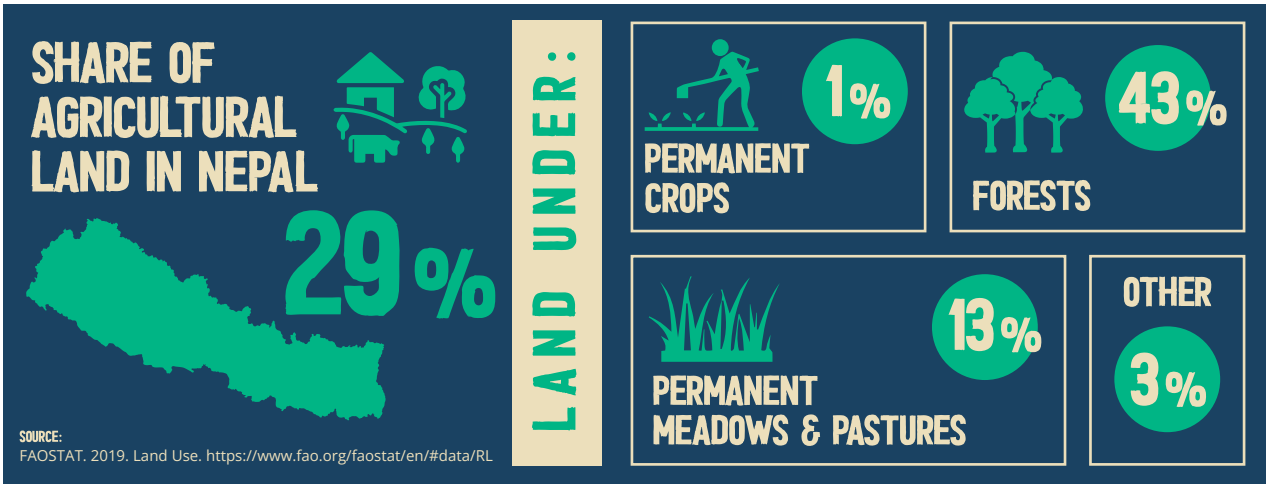
1.1 Geography

Nepal is a landlocked country in the central Himalayas. It borders India on three sides and China's Tibet Autonomous Region to the north. Its land area of approx. 147,000 sq. km expands over 885 km from east to west, and 193 km from south to north [1]. Nepal is divided into five physiographic regions that experience increasing altitudes between 60 m in the south to 8850 m in the north. These regions stretch from east to west. The regions are: Terai, Siwaliks, Middle Mountains, High Mountains, and High Himalaya. This creates a complex, steep and fragile topography with varied climates that range from subtropical in the south to alpine in the north [2].

Nepal is rich in natural resources, including many rivers with high potential for hydropower generation which represent important water resources for the country. The Karnali river in western Nepal, the Gandaki river in central Nepal, and the Koshi river in eastern Nepal are the county's most important water sources. All originate from the Tibetan Plateau and make their way south, with many tributaries flowing through deep gorges between massive mountains. They are complemented by numerous medium-sized rivers and small streams that flow across the whole country [3]. Fed from ground water springs and precipitation, the three large rivers are characterised by seasonal discharge, which can cause great damage to their banks every year [4].

Nepal underwent major restructuring after adopting a new constitution in 2015, and is now divided into seven provinces, 77 districts, and 753 municipalities [5], [6]. The capital Kathmandu is the main economic hub, located in the mid hills of Bagmati Province. Under the new constitution, the central government has awarded much authority and power to the local and provincial governments, establishing the federal democratic republic as a three-tier system that is coordinated within national, provincial, and municipal government units [7]. Forests make up 44.47% of Nepal's total land area. Of the remaining land, 21.88% is covered with cropland, 2.6% with grasslands, 1.22% with wetlands, 1.15% with settlements, and 28.68% with other land including bare soil, rock, ice, and all unmanaged land [8].

Nepal is also one of the countries that is most vulnerable to natural disasters, with earthquakes, flooding, landslides, snowstorms, droughts, and multiple other hazards and disasters striking every year [9]–[11]. Globally, Nepal is ranked ninth in terms of climate change risk. Nepal's 2020 risk index for earthquake and flood risks reached 9.9 and 6.7 out of 10 respectively [11], [12]. In 2015, a



large earthquake killed over 9,000 people and destroyed houses, infrastructures, and assets – which significantly set back the country's socio-economic development status [13]. Nepal's geology and geographic position are among the primary causes for natural disasters. Disaster risk in Nepal is augmented by climate change. Disaster risk reduction is a primary concern of the national government, as remote and poor rural areas are extremely exposed and vulnerable to impacts from natural disasters and climate change [14].

1.2 Agro-ecological characteristics

There are three main agro-ecological zones (AEZ) in the country, each with very different agricultural potential. Depending on the source, the AEZ delimitation can vary with different specified altitude levels. Khanal et al. (2018) specify the AEZ at following levels: The terai zone has an elevation of between 60 m and approximately 800 m and covers 23% of land area along the country's southern border. The Hills zone has an elevation of between 800 m and 4000 m and makes up 42% of Nepal's land area, while the Mountain AEZ has an elevation of above 4000 m and covers some 35% of land Nepal's area [15]. Agriculture in Nepal is mostly subsistence-based and is practiced in mixed crop and livestock systems. Growing seasons are determined by the monsoon rains that affect the entire subcontinent [1], [15]–[20].

The largely flat and fertile terai plains have the most production potential. With their tropical to sub-tropical climate, an annual rainfall of approximately 3000 mm, and their relatively fertile soils from fluvial deposits, the plains are frequently referred to as the "food basket" of the country. There are three growing seasons per year. The main crops are cereals, especially rice, wheat, and maize. The plains zone is the only zone that allows for double rice cultivation at elevations below 1000 m. Other crops include fruits and vegetables, lentil, sugarcane, jute, and tobacco for cash income. In addition, livestock farming is common - specifically, cow and buffalo for dairy, and goat or sheep for meat [17], [21], [22].

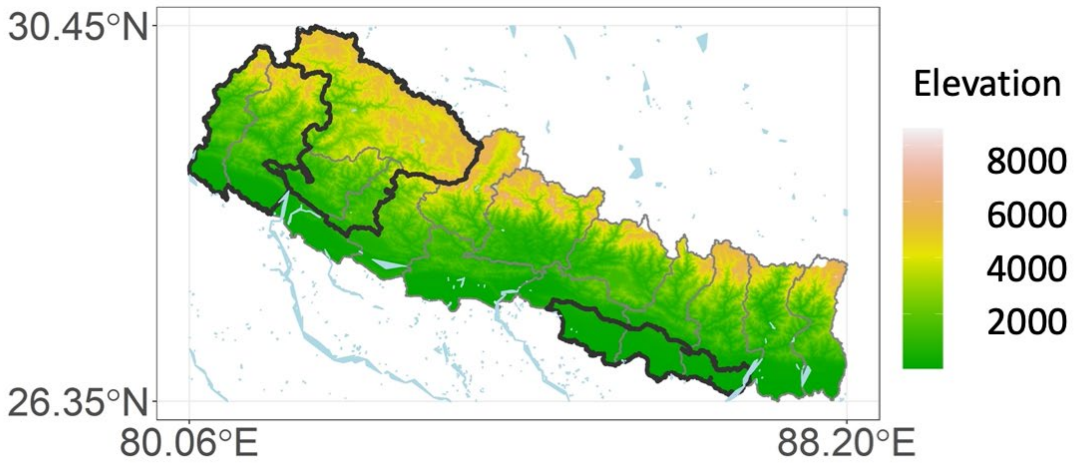


Figure 1: Elevation map of Nepal with borders of selected areas highlighted, displaying Province 2, Karnali and Sudurpaschim Province.

The hills are characterized by steep slopes, several small valleys, and a sub-tropical to cool-temperate climate. 40% of the country's forest resources are found in this agroecological zone. Agricultural production is important and usually practiced in complex systems that combine livestock husbandry, arable cropping, and forestry. Depending on altitude, there are typically two or three growing seasons per year. Crop cultivation is either irrigated or rainfed, whereas irrigated cultivation is usually practiced on terraced land along slopes. Maize and rice are the most important crops, but the area is also used for wheat, millet, barley, potato, mustard, and other minor crops, as well as vegetables and fruits like citrus. Rice is usually grown on irrigated, terraced land at altitudes below 1800 m, and maize is usually grown on rainfed land at an altitude of up to 2500 m [4], [22].

The mountain zone has a largely cool and alpine climate and constitutes only 7% of the county's cultivated area. Annual rainfall ranges between 600 mm in the western mountains and 2200 mm in the central mountains, while soils are shallow and often rocky. With its inhospitable climatic and physical environment, this zone experiences only one main growing season during summers; few crops are able to withstand also the winter conditions, with the exception of potato. Cultivation is mostly practiced in lower slopes and valleys, along riverbanks. The principal crops grown are maize, wheat, and rice, whereas in higher elevations, millet, barley, buckwheat, and potatoes predominate. The area is also conducive to temperate fruits and nuts such as apple, walnut, plum, and apricot. Given the limitation of crop production, rural populations in higher mountain zones are dependent on livestock for their income. In fact, the sheep population is highest in this zone, with an average of 6.8 animals per farm. Other livestock in this zone are goat, yak, mules and horses. Farmers in this zone rely on transhumance systems: they migrate in search of grazing areas during the summer, when pasture resources are abundant [22], [23].

	RICE	MAIZE	WHEAT
AREA COVERED AS A SHARE OF AGRICULTURAL LAND	10%	7%	5%
ANNUAL YIELD IN TONS/HA	3.7 T/HA	2.8 T/HA	2.8 T/HA

LIVESTOCK POPULATION	CATTLE	GOATS	SHEEP
	7,385,035	12,283,752	798,889

SOURCE: FAOSTAT. 2019. Crops and livestock. https://www.fao.org/faostat/en/#data/QCL

1.3 People and livelihoods

1.31 Socioeconomic characteristics

Nepal is a largely undeveloped country that is characterized by slow economic development, socio-economic challenges, and little human development. The national population is 29.1 million people, of which around 54% are female and 46% are male. Nepal boasts high cultural and ethnic diversity, with over 126 ethnic groups and 123 languages spoken as reported in the census of 2011 [24]. Around 79% of the population lives in rural areas.This percentage has steadily declined over past years.

Agriculture is considered a major driver of Nepal's economy in terms of income, employment, and food security. In 2020, agriculture accounted for 27.7% of Nepal's GDP and 60.4% of national employment [25]. Nevertheless, Nepal's agriculture is mostly subsistence based, with farms averaging 0.7 ha in size. According to a 2011 living standard survey, farms are considered small if they operate on less than 0.5 ha of land, and large if they use over 2 ha of land. According to this definition, 53% of farms in Nepal are considered small. These small farms take up only 18% of the country's agricultural area. On the other hand, the 4% of Nepal's farms that are considered large occupy 22% of the country's land. The unequal land distribution is reflected by Nepal's Gini concentration index for agricultural land, which is 0.51. Around 95% of Nepalese farmers own at least some of their land, while 5% of farmers are considered landless [26]. Crops, vegetables, and fruits contribute 46.1%, 13.2%, and 10.4%, respectively, of the country's agricultural GDP, with rice alone contributing 7% of the total GDP [4], [27], [28].

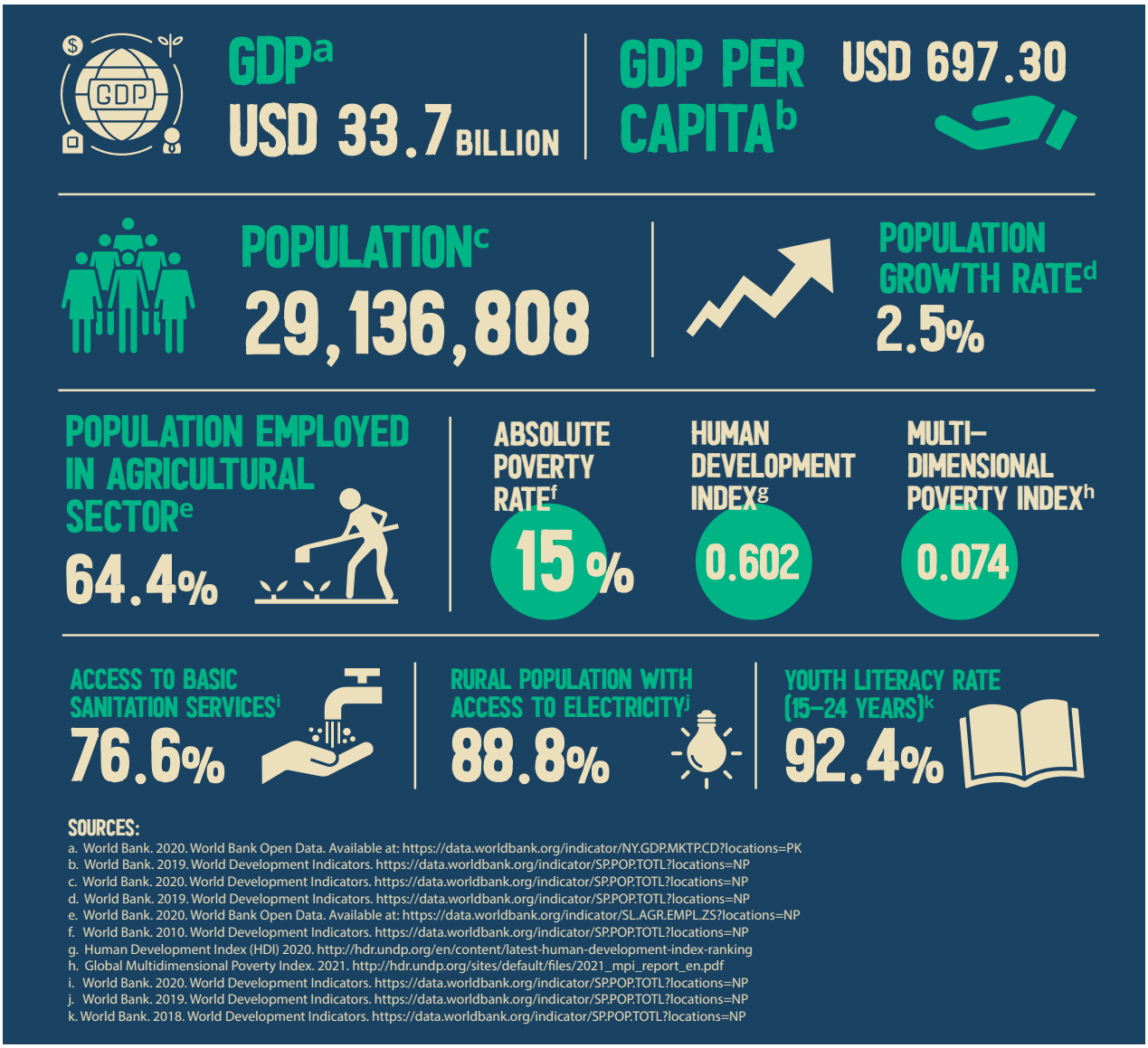
Livestock production is important and contributes around 25.7% of Nepal's agricultural GDP. 7.2 million cattle, 5.1 million buffalos, 9.5 million goats, and over 72 million chickens, among other livestock, account for an annual production of 1.6 MT of dairy and 0.3 MT of meat [29]–[31]. Nepal's livestock sector is key to food and nutrition security because it provides milk, meat and eggs. The livestock sector generates income through markets for raw materials such as wool and hides, and the animals provide draught power and manure.

1.32 Socioeconomic challenges

Nepal's socio-economic status has been greatly impacted by its turbulent political past. In 2006, the country came out of a 10-year conflict that had long hindered economic development and cost human lives. Recent years have seen a complex and lengthy transition phase that ended in 2015 with the adoption of a new constitution. While the new federal government gave the country newfound political stability and economic growth, the shift also poses many challenges to socio-economic development [32].

Despite this promising outlook, Nepal still experiences many socio-economic challenges. Around 18.7% of the population still live in absolute poverty. Nepal's human development index (HDI) lies at 0.58, which puts the country in 142nd place out of 189 countries. Nepal is behind most other South Asian countries in terms of development: the average HDI score in South Asia is 0.624 [33], [34].

The people of Nepal have little access to basic services. In 2011, only 45% of households in Nepal had access to piped drinking water. In rural areas, the percentage is 41%, compared to 58% in urban areas. In the Karnali and Sudurpaschim

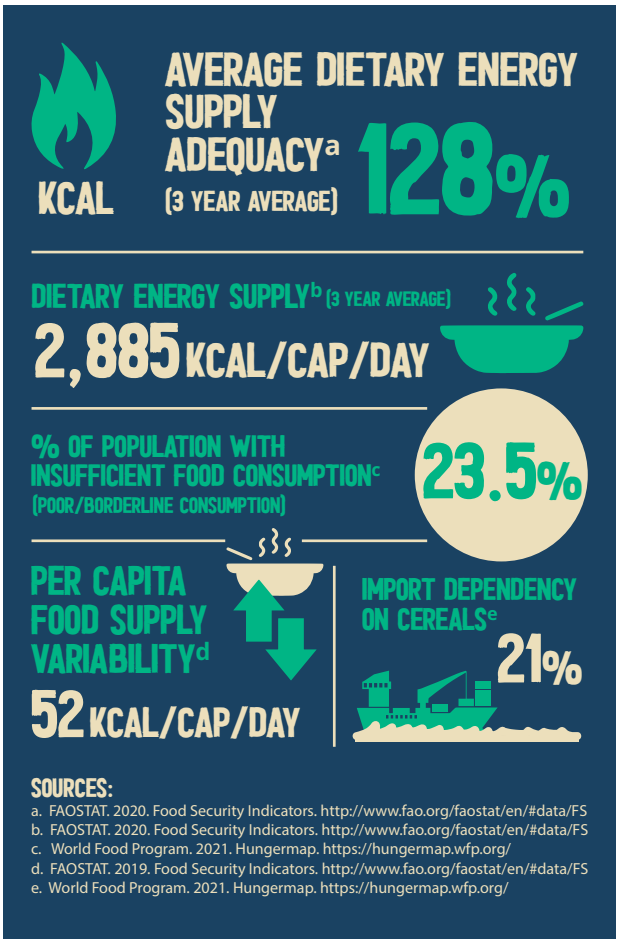


Province, this value drops to 34%, while in the Tarai zone only 14% of households have access to piped drinking water [35], [36]. Weak road and services infrastructure limit rural access to health care, education, and markets. Only 43% of Nepalis have access to paved roads, and some villages in the remote western parts of the country can only be reached after several days of hiking. This limits socio-economic development and increases food insecurity and geographic and socio-economic exclusion, especially for women. Accordingly, increasing productivity and improving road and market infrastructure are key goals of Nepal's national development plans [37], [38].

In Nepal, gender inequality is high and especially pronounced in remote, rural areas. The Gender Development Index (GDI) places female HDI at 0.549 compared to male HDI at 0.669, resulting in a GDI value of 0.88 [34]. GDI values differ across the country, with the lowest value, found in Province 2, lying at 0.786. The female literacy rate is only 57.4%, compared to 75.2% for men. Female employment is at 37.7%, compared to 62.7% for men. Over past years, Nepal has taken tangible steps towards eliminating traditional harmful practices and violence against girls and women. Nevertheless, women and girls still face various forms of discrimination and violence at the physical, sexual, social, political, psychological, cultural, and economic levels [34].

Dalits are much more affected by poverty than non-Dalits. Caste discrimination remains a problem in Nepal, and Dalits often constitute the poorest and most food insecure segments of the population. Dalits are often excluded from land ownership, education, and basic care, and often engage in daily wage labour activities with low job security and pay.

The lack of income-generating opportunities in rural areas has driven many young, able workers to seasonally migrate abroad in search for work. In most families, at least one member spends more than six months abroad, often in India. Remittances have thus become an important source of livelihood for much of the population. In 2015, 32% of Nepal's GDP came from international remittances, making Nepal the country with the highest share of personal remittances to GDP [39], [40].



1.33 Food and nutrition security

In 2021, approx. 22% of Nepal's population, or 6.5 million people, are considered food insecure. Nepal experiences a moderate to high level of food insecurity. Among children below 5 years, 36.5% are affected by chronic malnutrition and are considered stunted, and 9.6% are affected by acute malnutrition and are wasted [41]. The highest prevalence of food insecurity is found in the hills and mountains of the remote western provinces, while people in the terai districts generally have more access to food. Even if food is available, many households may not be able to afford it. This makes poverty a direct contributor to food insecurity. In 2015 and 2016, the average household spent 53.8% of their income on food. Food consumption is 1.7 times higher in urban areas as compared to rural areas [42].

Seasonal poverty and food insecurity is highest between May and August, just before the annual harvest, and lowest between October and January, after the annual harvest. Most rural households only produce enough food for several months of the year and are required to bridge the gap through purchasing food at markets. Fluctuations in cereal harvests and food prices can further impact access to food. The number of months in which households are able to grow food to feed themselves is generally higher in terai districts and lower in hill and mountain districts. The average yields of key crops such as rice, maize, and wheat remain below potential, with a yield gap of between 45 and 55%. Rice, maize, and wheat had yield rates of 3.17, 2.35 and 2.29 tons/ha respectively in 2013 and 2014

[28], [29], [43], [44]. Accordingly, Nepal continues to have a negative cereal trade balance, with the cereal import dependency ratio at approximately 19% in 2021 [27], [41]. The cereal deficit is highest in the mountains and the hills, whereas terai regions generate a cereal surplus. This indicates that the food deficit in mountainous regions is often caused by difficulties in food transportation and distribution.

Farm size directly correlates with food security status in Nepal. The government estimates that a farm household in the mountain region needs 0.64 ha of land to subsist, a farm household in the hills needs 0.52 ha to subsist, and a household in the terai needs 0.42 ha. This estimation varies according to family size, as data suggests that larger rural households experience poverty more frequently. Given that the majority of farms are subsistence-oriented and operate on less than 0.5ha, increasing yields and production will be effective in reducing food insecurity in the country [27].

One of the greatest challenges to food and nutrition security in Nepal is limited nutritional knowledge. Nepalese diets often lack diversity and many important nutrients. Children and women who have reached reproductive age are disproportionately affected by wasting, stunting, and anaemia. The lack of healthy dietary habits has also resulted in an increase of many non-communicable diseases, especially among the remote, rural poor [27].

1.4 National climate profile

Climate varies across Nepal depending on elevation and agro-ecological zone (AEZ). With elevations ranging from below 100m in the southern terai zone to over 8000m in the northern upper mountain range, the annual minimum and maximum temperature vary from -4 to 19°C and 4 – 30°C, respectively. Temperatures are generally highest in the southern plain terai areas, and lowest in the high mountain zones of western Nepal.

The climate is affected by two major weather systems. The summer monsoon season lasts from June to September and is the main rainy season. This season generates 80% of total annual precipitation and is strongest in the south-east. The westerly circulation lasts from November to May and is responsible for winter precipitation, which is most pronounced in the north-west. Precipitation varies ranging from an aggregated 2021mm/year in the hills of Gandaki Province to an aggregated 622mm/year in the high mountain of Karnali Province. Generally, the western provinces receive less annual precipitation than the eastern provinces[1], [45], [46].

Depending on their AEZ, areas experience either one, two, or three growing seasons. These seasons are a pre-monsoon season, a monsoon season, and a dry winter season. The terai generally has three growing seasons, while the upper mountain districts have only one growing season. For this analysis, we aggregate seasons into broadly monsoon, which lasts from April to October, covering mostly the winter season, which runs from October to May. The seasons' onset and duration, however, differentiate depending on elevation and agro-ecological zone.

Comparison of historical data and future projections indicate that while average temperatures are expected to increase gradually and evenly over the next decades, precipitation is projected to concentrate towards the peak of the rainy season. May and September are projected to become drier, with less precipitation projected for both months in the 2030s and 2050s. July and August are expected to become much wetter through 2030 and up to 2050 (Figure 2). Temperatures are projected to become slightly higher in the first half of the year compared to the last six months. The last half of the year is projected to become warmer after 2030. In the next chapter, future climate and hazard projections will be further explored.

1.5 Economic analysis using IMPACT model

This economic analysis uses the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT), an exploratory tool for assessing links between agricultural policy, climate change, and technology in agricultural systems. The socioeconomic basis for the results presented in this chapter is Shared Socioeconomic Pathway 5 (SSP5), a policy, population, and GDP trajectory characterized by rapid industrialization, high levels of technological innovation, improving education, and little effort to mitigate the impacts of climate change [47].[1] Assumptions regarding future temperature increases are captured in different Representative Concentration Pathways (RCPs), which account for long-term changes in temperature and precipitation, but not for changes in climate or the incidence of extreme weather events [47]. This study assumes an RCP of 8.5. This value reflects a pessimistic carbon concentration scenario which projects an average

1 IMPACT does not account for perturbations resulting from the COVID-19 pandemic.

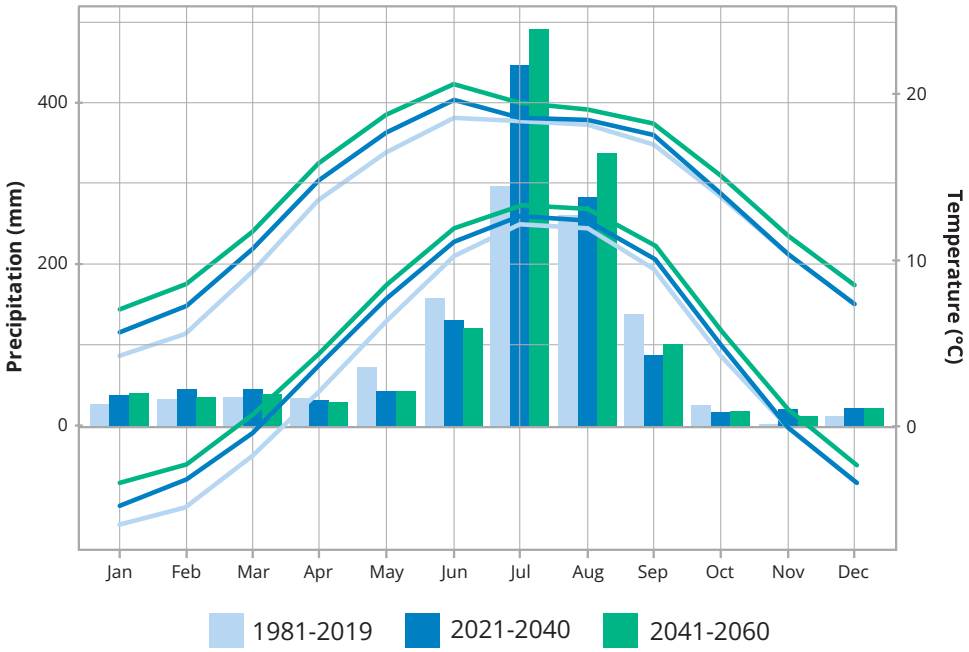


Figure 2: Historical and future projected monthly mean maximum and minimum temperature and precipitation in Nepal

temperature rise of 1.4 to 2.6 degrees Celsius by 2050. The combination of SSP5 and RCP 8.5 envisions a bleak outlook, although some of the worst impacts on food availability are partly offset by an increase in technology and education. A "no climate change" scenario is also modelled as a benchmark against which to compare the impacts of climate change. This scenario is written as "No-CC" in accompanying figures and text.

In IMPACT, yield is modelled as a function of both biophysical and economic factors, meaning that negative climate impacts can be offset by technological improvements and economic incentives for farmers to invest in inputs. Conversely, economic incentives can exacerbate yield loss if price signals lead investments elsewhere, or if farmers switch to more profitable alternative crops. These impacts then translate into a rebalancing of the comparative advantages or disadvantages of commodities and of the nations trading these commodities. This rebalancing shapes the price signals that drive changes in economic yield and productive decisions at the farm level.

Because IMPACT results are reported at the country level and not disaggregated by livelihood zone or demographic, their relevance lies in the context they provide for local decision making. Identifying strong and weak points within Nepal's agricultural sector equips policy makers to make decisions at the national level. This is critical information that can help form strategies to address climate hazards at the province zone-level, which typically involve investments in infrastructure and institutions.

IMPACT outputs present one possible future scenario in order to provide general guidance on policy and development. Below, IMPACT climate change (CC) projections for the supply, demand, and food availability of key crop and livestock commodities are compared against their respective no-climate change (No-CC) benchmarks. This comparison is made to identify strong and weak points in Nepal's agricultural sector.[2] The focus is chosen by in-country experts based on the country's diet and farms.

2 "Raw" CC trajectories, without comparison to No-CC trajectories, are provided in Annex

1.51 Supply-side impacts of climate change

Comparing climate change scenarios against the no-CC benchmark scenario offers insight into how vulnerable or resilient crops are to the effects of climate change. IMPACT allows farmers to adjust input levels and switch to new crops in response to price signals, thereby altering yields and farming area. Yields and area may rise, despite climate change-related biophysical setbacks, if the corresponding investment in inputs is profitable to the farmer. Conversely, the market forces modelled by IMPACT can also exacerbate yield loss.

In Nepal, production of key crops is projected to decrease by 4-13% in 2030 and 10-26% in 2050 (Figure 3). This decrease is especially pronounced for maize, lentils, and sugarcane. IMPACT attributes the lower production to lower projected yields. In some cases, reduced area is also projected to play a small role. Production of temperate fruit like apples and oranges, vegetables, rice, wheat, and other cereals besides maize is projected to be resilient in the face of climate change, with production levels roughly equal to those of the No-CC benchmark. Potato production is projected to increase under climate change in comparison to the No-CC benchmarking area is also projected to play a small role. Production of temperate fruit (including apples and oranges), vegetables, rice, wheat, and other cereals besides maize is projected to exhibit

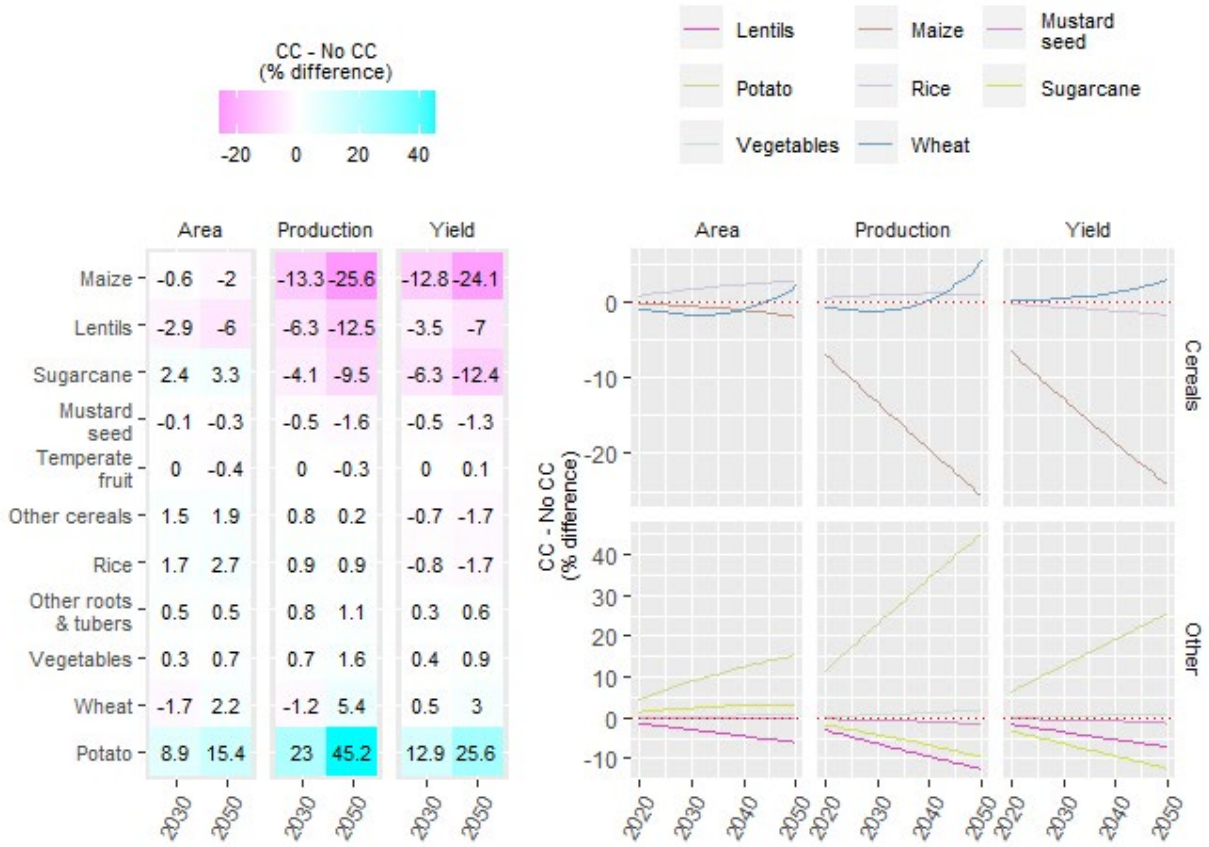


Figure 3: Difference between the climate change scenarios for the production, area, and yield of the main crops. For each year, the difference is calculated as the percentage difference between the CC value and the No-CC value.

resilience in the face of climate change, with production levels roughly equal to the No-CC benchmark. Potato production is projected to be substantially higher under climate change than under the No-CC benchmark.

Resilience to climate change may be due to the crop's intrinsic biophysical resilience, but it may also be because climate change damages to alternative crops are more severe. The resulting scarcity of alternative cropscreates demand for certain crops and increases prices such that farmers are willing to invest in the inputs necessary to offset the loss resulting from climate change.

1.52 Climate change impacts on diet

Diet trajectory is defined as the number of calories that different crops provide, given consumption levels. The diet trajectory of key crops is projected to decrease under climate change (Figure 4). Lower calorie availability is especially pronounced for cereal, potato, and mustard seed. The projected impact on pulse and fruit & vegetable calorie availability, on the other hand, is less severe. Lentil calorie availability, in particular, exhibits resilience in the face of climate change.

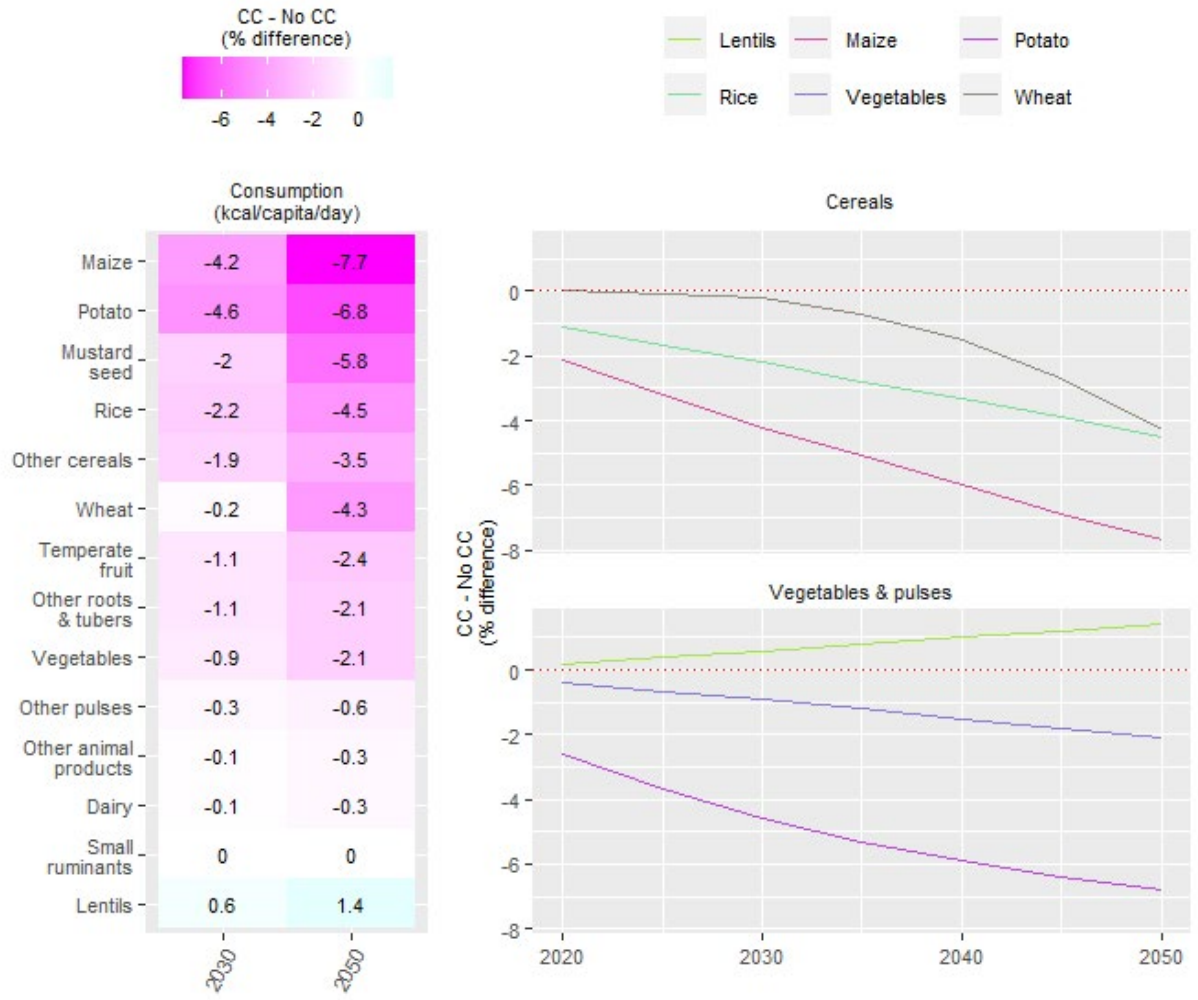


Figure 4: Percentage difference between expected consumption of key products (kcal/capita/day)under climate change and consumption without climate change.

1.53 Climate change impacts on hunger and malnourishment

The risk of hunger is projected to be slightly higher under CC than under the no-CC benchmark. The CC projection of number of undernourished children in 2030 is just over 1% higher than the no-CC projection, but the difference increases to over 3% by 2050 (Figure 5, left panel). This is consistent with the diet trajectory data seen above. Import dependence for wheat and lentils is projected to be 5 percentage points higher under climate change than under the no-CC benchmark from 2030 onward. Import dependence for potato is projected decrease under CC by more than 10 percentage points (right panel).

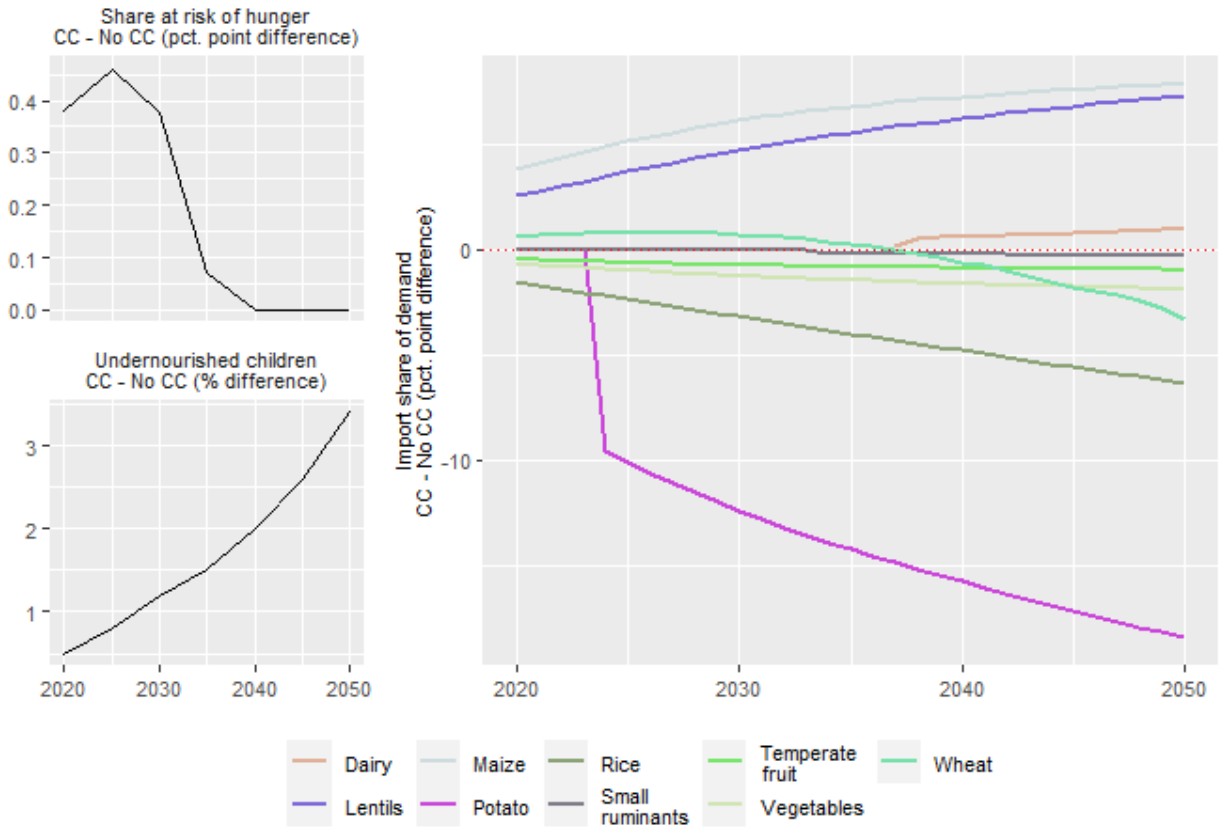


Figure 5: Differences in projected trajectories for key food security indicators and commodities with and without climate change

1.54 Conclusions and recommendations based in the IMPACT analysis

While maize, lentil, and sugarcane exhibit vulnerability to climate change, crops including temperate fruit, vegetables, rice, wheat, and other cereals besides maize are projected to exhibit resilience in the face of climate change. Potato production might even benefit from a changing climate, inviting expansion in production and planted area. This suggests that continued investment in fruits, vegetables, rice, wheat, and other cereals, as well as potato, could be key to ensuring future food availability, especially considering the role of rice and wheat as staple crops.

Calorie availability and diet trajectory is projected to decrease under CC for almost all crops except lentils. This is partly due to lower imports and partly due to lower production. This projection highlights the importance of making investments in the R&D of key value chains, as well as improved transport and market infrastructure to allow access to important food products.

Negative climate trends such as winter drought or summer flooding can disrupt food supply and reduce incomes, which underlines the importance of income diversification in rural areas. This is relevant not only for market-oriented and subsistence farmers, but also for landless agricultural wage labourers who risk losing income opportunities if crop production enterprises are destroyed by negative climate events. Nevertheless, the population at risk of hunger is only slightly higher under CC than under a no-CC scenario.

1.6 National climate change policies and development strategies

A desk review of climate-related policies and strategies has been conducted in order to realize a demand-driven process that ties in with government priorities. WFP goals have been mapped against current investments by the government, multilateral donors, bilateral donors, International Financial Institutions (IFIs), and the private sector, in order to highlight gaps and opportunities for WFP programs in alignment with national objectives (SDGs 2, 13 and 17). This effort was undertaken through a literature review, discussions with the WFP country offices, and key informant interviews (KIIs).

1.61 National climate strategies and finance mechanisms

The Government of Nepal is at the forefront of climate change response in relation to social and economic development objectives. The government adopted its first National Climate Change Policy in 2011 and approved an updated version in 2019. The country also ratified the Paris Agreement and submitted a Nationally Determined Contributions report in 2015 as well as a revised second versionin 2020. In 2015, Nepal started developing a National Adaptation Plan to build resilience among climate-vulnerable communities, which builds upon a Local Adaptation Plan of Action (LAPA) planning framework from 2011 that has already been piloted in over 100 local governments [48], [49]. Nepali villages have conducted community-based adaptation plans. Since the adoption of the new constitution in 2015, the government has put an strong emphasis on mainstreaming climate change in planning and budgeting processes and has given sectoral and provincial level ministries the opportunity to prioritize, allocate, and track climate finances. Under Nepal's national climate policy, 80% of mobilized climate finance is expected to be delivered for implementation at the local level [50]–[52].

Many policies, strategies, and plans are formulated to target disaster risk reduction and climate change adaptation. By 2013 and 2014, 11 out of 27 ministries had a climate-related allocation in their annual budgets [53]. The government recently launched the National Disaster Risk Reduction Policy and Strategic Action Plan 2018-2030 and committed to implement the new Sendai Framework for Disaster Risk Reduction 2015-2030. In its second Nationally Determined Contributions report, the government pledged to accelerate its decentralized adaptation efforts such that by 2030, all 753 local governments will benefit from the development and implementation of locally-tailored climate-resilient and gender-responsive adaptation plans. The plan puts special emphasis on the most vulnerable groups, including women, differently-abled people, children, senior citizens, youth, Indigenous Peoples, economically deprived communities, and people residing in climate-vulnerable geographical areas [54], [55].

1.62 National development strategies and finance mechanisms

The Government of Nepal has formulated a long-term development agenda, "Prosperous

Nepal and Happy Nepali", that envisions Nepal as a developed country within 25 years. This agenda is presented as a roadmap to 2043 that outlines 10 overarching goals, including human development, sustained economic growth, equality, inclusiveness, environmental resilience, and good governance. The government's 15th five-year plan is well aligned with this ambition: the plan commits to the country's 2030 agenda and plans for Nepal to graduate from least developed country (LDC) status by 2024 [34], [38].

At the sectoral level, Nepal puts a strong emphasis on agricultural and rural development in order to eradicate hunger and poverty. Legally enshrined into the constitution through the Right to Food and Food Sovereignty Act from 2018, numerous policies, frameworks and programs targeting agricultural development and food and nutrition security support this ambition [27], [42]. Climate change response is mainstreamed across nearly every policy document and plan.

The Agriculture Development Strategy 2015-2035 of 2016 and the Nepal Biodiversity Strategy and Action Plan of 2014 prioritize highly productive, competitive, inclusive, and environment-friendly farming systems and pledge to develop several projects to promote climate resilient agriculture, livestock, fisheries, and forestry sectors [54]. Strategic priority is given to programs that combat food and nutrition insecurity through measures like agricultural insurance, credit for rural women, nutrition support programs, and social safety nets. Numerous programs target producer groups and strengthen value chain development, including improved services for processing, storage, transportation and logistics, finance, marketing, research, and extension. Emphasis is also put on breeding, enhancing the productivity of crops and livestock, and developing and disseminating drought-tolerant, flood-resistant, and pest-and-disease-resistant crop varieties [42].

1.63 International alliances and finance mechanisms

Since 2017, Nepal received an annual average of 1.4 billion USD in gross overseas development aid (ODA). Nepal's top ten donors are the International Development Association, the Asian Development Bank, the United States, Japan, the United Kingdom, EU Institutions, Germany, Switzerland, Norway, and UNICEF. 23% of each donor's bilateral ODA is directed towards projects related to economic and social infrastructure, 13% is directed towards the education sector, 11% is directed towards health and population, 8% towards production, 7% towards humanitarian aid, and the remaining money is spread across multisector targets, programme assistance, and other topics [56].

With regards to climate finance, the national climate change strategy plans to mobilize funds from bilateral and multilateral international financial mechanisms as well as from the private sector. Important international and multilateral funds include REDD+, Green Climate Fund (GCF), Global Environment Facility (GEF), Adaptation Fund (AF), and Climate Investment Fund, while private sector targets are Green Bond, blended finance, result-based financing, carbon offset, and corporate social responsibility [51]. In addition, the national government has steadily increased the national budget allocation for actions against climate change. The share of the government's total budget that is allocated for climate change-related actions increased from 10% in 2013 to 27% in 2018, and increased almost sevenfold from NRs. 53 billion, which is approximately USD 450 million, to NRs. 350 billion, or approximately USD 2.9 billion, during that time [50].

Nepal already accessed most of the funds established under the United Nations Framework Convention on Climate Change (UNFCCC). Accordingly, multiple internationally-funded climate adaptation projects are already being implemented in Nepal. For example, 22 national and 12 regional projects that concern Nepal have been granted funding from the GEF. These projects have a total value of USD 224 million in direct funding and USD 344 million in co-financing. The Least Developed Country Fund (LDCF) granted USD 46 million in direct funding and USD 200 million in co-financing to 7 national and 2 regional projects.

1.64 Gaps and opportunities

While numerous policies, frameworks, strategies, and plans exist to guide Nepal in its path towards inclusive and sustainable socio-economic development, the implementation of these policies and plans remains challenging. Given the relatively young age of the Nepalese constitution, the government's current efforts are concentrated towards institutionalizing the federal system. This requires huge restructuring in every sector. "Creating a coherent enabling environment of policy commitment and coordination, robust capacities, sound data monitoring systems and accountability" has proven difficult [38].

Policy gaps that concern climate change and food and nutrition security often exist at the province level. Of the three targeted provinces in this analysis, only the Karnali province's government is currently pursuing initiatives to mainstream climate change-related action into local policy plans. A major problem is a lack of human resources, quality education, and skills that can help develop and implement budget plans. Yet, the national government's goal is to develop and implement local plans for agricultural development and climate change adaptation across all 753 municipalities. This creates opportunities for WFP to provide support at the province level [57]–[59]. In fact, WFP Nepal is already pursuing successful activities in this regard, through a climate adaptation project in Karnali that can serve as a model to be replicated in other provinces.

PART 2.

Context within selected areas

2.1 Intervention areas and crops

This study focuses on WPF's three priority intervention areas in Nepal. These areas were selected based on WFP's priorities as established in accordance with the national government, as well as the socio-economic, food and nutritional status, and needs of the selected regions. Three administrative provinces were selected: Province 2, Karnali, and Sudurpaschim Province. These three provinces are at the tail end of human development in the country: Province 2 has the lowest HDI in Nepal, followed by Karnali and Sudurpaschim Province. All three also lag behind in economic development, as they have the highest unemployment rates, lowest per capita incomes, and highest poverty rates in Nepal.

PROVINCE 2

Province 2 is comprised of 8 districts that are all located in the terai zone. This province is found in south-eastern Nepal and borders India to the south. It has highly fertile soils and high agricultural production potential, yet agricultural productivity is low due to traditional practices and little mechanization. The province's main crops are rice during summer and wheat or pulses during winter. Several parts of the province use double rice cropping systems. These farms grow spring rice from February or March to June before re-planting a second rice crop during the main monsoon season. This province's rice is mostly rain-fed, as less than 25% of its agricultural area is irrigated [57], [60]. Lately, the province has seen an increase in horticultural production, which has improved the nutritional status of its residents. Occasionally, farmers also grow sugarcane for cash income.

With an HDI value of 0.51, Province 2 has the lowest human development in Nepal. The average household size is 7, compared to 5.27 across all terai districts. Generally, the poorer a family, the larger the household size in Nepal. The low socio-economic status of this province is related to traditional cultural practices as well as poor road systems that hinder development [57]. Accordingly, vulnerability and food insecurity are high in this province. In Province 2, women and people from lower castes, especially Dalits, are particularly disadvantaged [61].

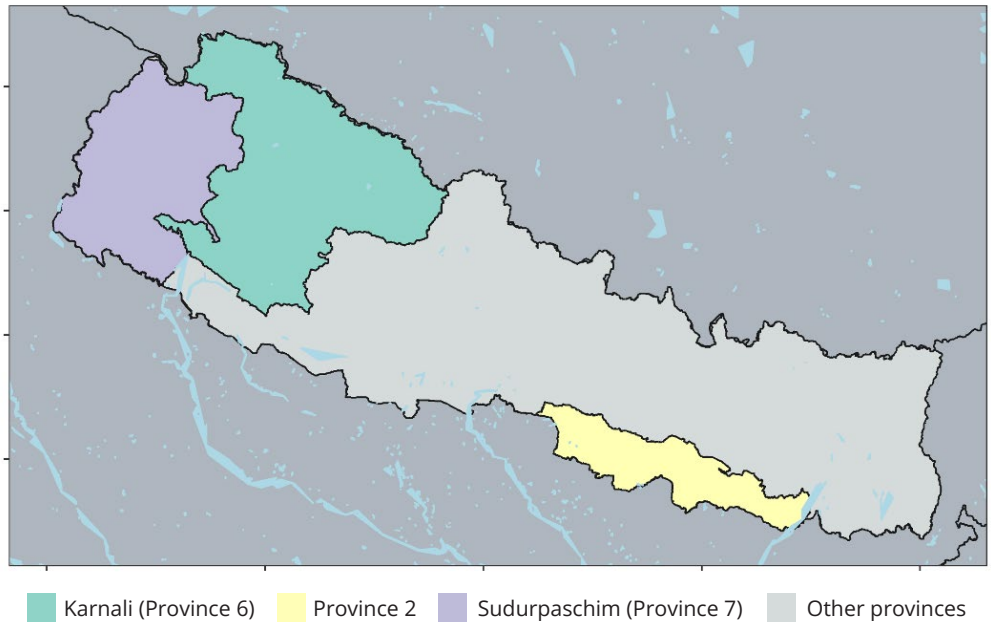


Figure 6: Map of Nepal and the selected provinces.

Province 2 is prone to climate-related disasters like river flooding, recurring droughts in spring, and cold waves in winter [46], [57], [62]. Many rivers cross the province. The largest one is the Koshi river, which divides Province 2 from Province 1 in the west. Given the low gradient of the land, yearly monsoon precipitation leads to recurrent flooding and water erosion, which affects households and settlements near river banks and regularly washes away or waterlogs summer crops. Flooding also destroys houses and affects livestock health and productivity. A study among local populations in western districts of this province revealed that many suffer from floods every year, yet there is little help available. More than 80% of respondents reported that more than 50% of their cropland gets inundated by more than 1 meter of water for more than 3 days in a row each year [63]. High rates of deforestation and weak disaster risk management contribute to the flood problem. In 2008, Province 2 experienced the worst river flood in the history of Nepal, which led to huge economic and human losses [63], [64].

KARNALI

Karnali province is located in the western part of Nepal. It has ten districts. 6 districts are located in the hill area, and 4 are located in the high mountain area. With its complex mountain topography, Karnali is among the most food insecure in Nepal [58].

Economically, Karnali is the poorest province of Nepal. It contributes only 3.4% of the national GDP. Bagmati Province, the wealthiest province, contributes 41.4% of the GDP [34]. Some 30% of Karnali's population are economically deprived Dalits. The province has 3 districts that are relatively food secure. The remaining are considered food insecure, with the population hardly producing enough food to be sufficient for 3-6 months. While Karnali agriculture generally produces enough vegetables and fruits to satisfy demand, cereals and rice have to be imported from terai districts of other provinces [58].

Two types of farming systems predominate in this province. The lower hill districts, with their more favorable climates, typically grow three crops every year. The cropping system is dominated by maize, followed by rice, wheat, and some indigenous crops like finger millet. Some districts also grow tropical fruits, especially citrus and mango. Lower districts in Karnali are famous for their goats, which are kept for commercial purposes. Around 90% of farm households have an average of 5-6 goats, and most households also have one cow or buffalo for milk. Some farmers keep more cows or buffalo, and poultry is becoming increasingly commercialized in lower districts. Production in the lower districts is generally higher, and the area is also more suitable for mechanization. The majority of Karnali's population lives in the lower districts [65].

The upper mountain districts experience mild summers and harsh winters, which limits crop cultivation to 1-2 seasons per year. Most crops are grown between April and August. The crops are mainly maize, barley, buckwheat, chino, kaguno, and finger millet. All mountain districts grow temperate fruits such as apples, walnuts, plums, and peach, which generate cash income. Given the province's limited ability to grow crops, sheep and yak farming are important sources of livelihoods. Almost 50% of households in this province have at least 10 sheep: some households have up to 150 sheep. Collecting non-timber forest products like medicinal plants is an important income source. The high mountain districts have small populations, as it is difficult to access them. Some of the world's most remote villages are found in this province [58], [66].

Karnali Province is vulnerable to climate change and is frequently exposed to climate hazards. As elsewhere in Nepal, flooding is one of the most prominent hazards. Intense monsoon rainfall and unstable, steep slopes result in high rates of soil erosion and landslides. This causes a high sediment load in rivers and large deposits of sand and gravel in lower catchments of the terai

plains. This disrupts local livelihoods, particularly subsistence agriculture, and has devastating effects on assets and infrastructure.

The province has also experienced increasing droughts, especially during winter. Higher districts have observed less snowfall during the winter months. This affects winter and spring crops like wheat and barley, as well as the pasture productivity of livestock [67], [68]. The shift in temperatures has also caused an increase in new pests and diseases, such as rice blast. Climate change has also resulted in some positive impacts, as higher temperatures have made wheat production possible in higher districts and some lower districts even during winters [58], [66], [68].

SUDURPASCHIM PROVINCE

Sudurpaschim Province is located in the far west of Nepal. It borders India to the south and west, Lumbini Province to the east, and Karnali Province to the east and north. Sudurpaschim Province is constituted of nine districts. Two of these districts are located in the terai zone, four are located in the hill zone, and three are located in the mountain zone.

The districts of Sudurpaschim Province span all three AEZ. Therefore, the province shares many agricultural characteristics with Provinces 2 and Karnali. The terai districts are the most productive zones, with three growing seasons of mostly rice and wheat. Dairy production is also important, with many farms keeping at least 2 or 3 cows or buffalos for home consumption or sale. Hill districts predominately grow maize and wheat. Hill districts also grow considerably less cereals than terai areas and focus instead on vegetables, fruits, and goat and sheep rearing. Sudurpaschim Province's mountain districts are similar to those in neighbouring Karnali, and focus on apple, walnut, peach, plum, and sheep and yak rearing [59], [69].

Given Sudurpaschim Province's proximity to India, remittances from seasonal migration is an important income source for the rural population, especially in the hill districts. Almost 50% of households in the hills have at least one member who migrates to India for several months each year. Sudurpaschim Province is as poor as neighbouring Karnali, as it contributes only 7% of the national GDP. As in Province 2 and Karnali, Sudurpaschim Province's per capita income is far below the national average. 33.9% of Sudurpaschim Province's population lives below the absolute poverty line [34], [59], [69], [70].

This province is highly vulnerable to climate change. Sudurpaschim Province is subject to summer floods and landslides as well as spring and winter droughts. Major and damaging floods occur almost every year in the Karnali river basin, which affects terai areas in Sudurpaschim Province. In 2014, three days of torrential rain led to a devastating flood that left 222 people dead and over 120,000 others affected by damaged houses, properties, and infrastructures [2]. In lower districts of terai zones, heat waves are increasingly common. Increasing temperatures have brought slightly more favourable growing conditions to higher areas in Sudurpaschim Province.

2.2 Climate risks by province

This section has several key goals. First, it provides an understanding of Nepal's current and future climate trends and hazards, including droughts, flooding, flash flooding, cold spells, and heat stress. Next, it assesses climate change impacts through assessing the suitability of selected crops like rice, maize, and lentil. Finally, it discusses potential risks to food security, taking into consideration nutrition, poverty, gender, market access, education, and other variables of interest by identifying co-occurrence between

climate hazards, climate impacts, and these variables.

We assessed climate change in Nepal by analysing historical data on and future projections of mean temperature and precipitation. The historical analysis focused on the period from 1981 to 2020. To assess future climate trends and hazards, we focused on 2021 through 2040 and 2041 through 2060. This analysis focuses on Representative Concentration Pathway (RCP) 8.5 and Shared Socioeconomic Pathway (SSP) 5. This RCP–SSP combination is close to the world's current emissions trajectory. This analysis focuses on 2030 for short-term planning purposes, but extends to 2050 so as to assess post-2030 trends, and because by 2030 the difference between RCPs is not substantial.

2.21 Mean climate projections

Generally, findings indicate that the selected provinces of Nepal are becoming warmer and both wetter and drier, depending on season and location. Temperatures will continuously increase across the country, while precipitation projections vary. These findings align with those of existing publications from the Government of Nepal [46], [71].

Future projections of annual mean temperature across selected provinces show a steadily increasing trend in all provinces, as shown in Figure 7. Compared to the historical baseline year 2000, the average annual temperature will continuously increase during both the monsoon season and the dry season. The highest temperatures will continue to occur in the terai districts of Province 2 and Sudurpaschim Province.

Total annual rainfall is projected to increase in the near future across all selected provinces during the monsoon season, while the winter season will be more mixed. From 2030 to 2050, low to middle elevation areas in Karnali and Sudurpaschim Provinces will see drier winters, while higher elevations will see wetter winters in the near future and both wetter and drier winters in the upper mountain areas by 2050. Province 2, which is entirely located in a low terai area, will see a wetter monsoon season but a drier winter, especially in the east: the west will get slightly wetter, as shown in Figure 8.

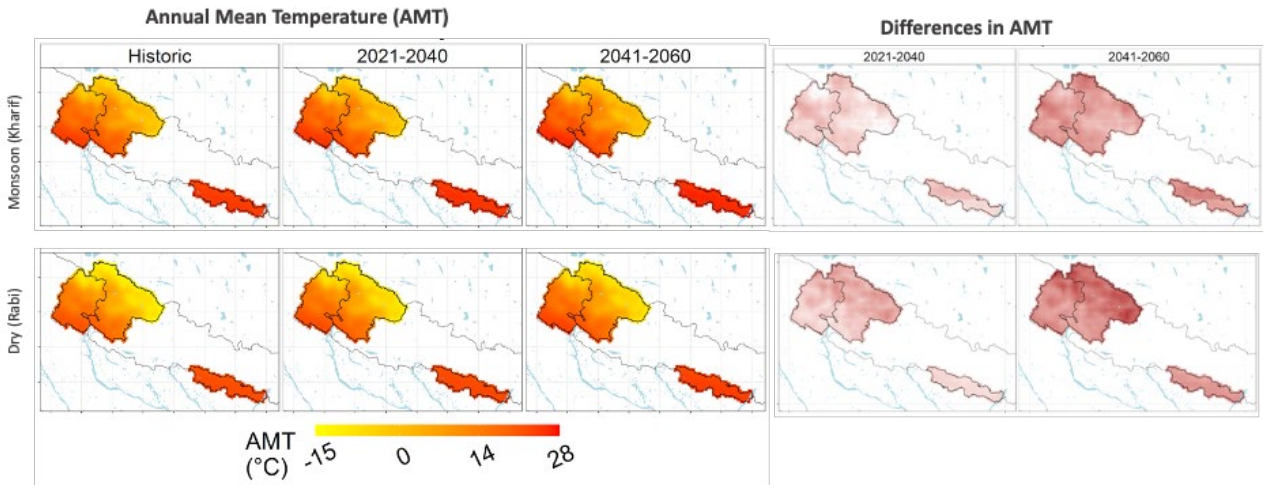


Figure 7: Historical trends and future projections of annual mean temperature and change in annual mean temperature during monsoon season and dry season by 2030 and 2050.

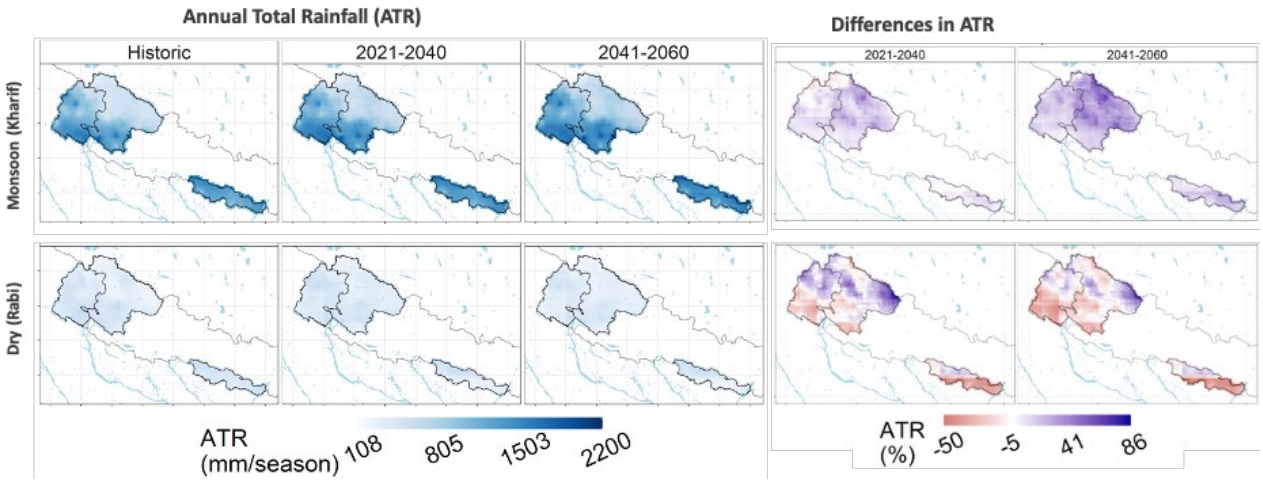


Figure 8: Historical trends and future projections of annual total rainfall and change in annual total rainfall during monsoon season and dry season by 2030 and 2050.

2.22 Climate hazard analyses

The climate hazards that are most detrimental to agricultural production in Nepal include droughts, flooding, flash flooding, cold spells, and heat stress. These events affect crops and livestock, as well as the ability to work productively, and therefore hinder agricultural production and development. According to a recent report by the Ministry of Forests and Environment (MoFE), climate hazards such as drought, floods, and erratic rainfall are responsible for 90% of crop loss, and 10 to 30% of overall production loss for crop, livestock, and fisheries in Nepal. Drought has the highest impact, accounting for 38.9% of losses. Floods accounted for 23.2% of losses between 1971 and 2007 [46]. The climate hazards analysed here have varying effects across Nepal, with impacts that largely depend on elevation and AEZ. Below, projected future trends for each hazard are presented by elevation level.

DROUGHT RISK

Drought risk is high across all elevation zones during dry winter season and from October to May, with higher severity in low and mid-elevation zones. Data from MoFE calculates the average duration of drought to be 102 days, or

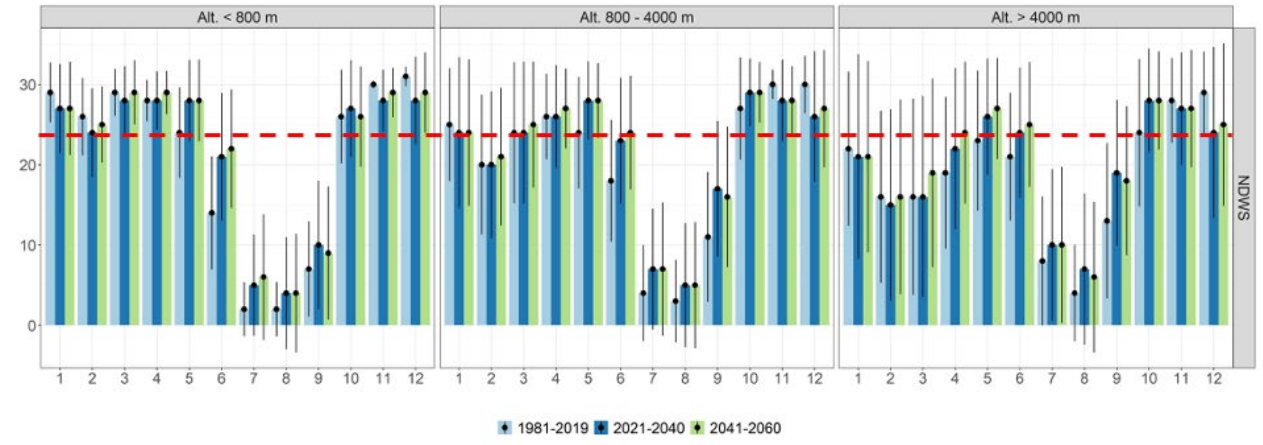


Figure 9: Monthly variation in drought risk at different elevation levels. The red line represents the threshold above which water stress has a detrimental impact on agricultural production.

3.4 months, per year, with 56% of the country's land area being affected [46]. As the graphic below suggests, drought risk is likely to become more serious under future climate conditions during the spring, and slightly decrease during the winter.

FLOOD AND FLASH FLOOD RISK

Historically, flash flood risk is concentrated around the peak monsoon season for all altitudes, with more severity in low and mid elevation zones. As indicated in figure 10 below, flash flood risk is likely to increase during the months of July and August and decrease slightly during the months of June and September across all elevation zones in 2030 and 2050. High mountain areas, which historically experience low flash flood risk, are projected to see equally elevated risks during July and August under future climate scenarios. Flash flood risk is similar to regular flooding risk, based on the maximum 5 day running average rainfall.

COLD SPELL

Generally, cold spell risk is low across the country. A cold spell is defined as an extended period of days with temperatures below 5°C. A recent report by the Ministry of Environment and Forests [46] highlights that historically, cold spell risk has concentrated in the terai districts of eastern Nepal and especially in Province 2. As temperatures increase across the country, cold spell risk is likely to decrease, indicating a positive development for agricultural and livestock production. However, it will be tempered by an increasing risk of heat stress across low elevation zones, which poses new challenges for crops and livestock.

HEAT STRESS

Levels of heat stress on animals are assessed with the THI, or thermal-humidity index. The index captures coinciding levels of temperature and humidity in shaded areas. Research has shown that crossing a certain THI threshold has a direct impact on livestock productivity and mortality [72].

Future projections indicate that heat stress risk will remain relevant only in low elevation zones. In mid-elevation zones, occasional heat waves will become slightly more possible, yet still unlikely, during June and July, as seen in figure 12. In terai districts, heat stress risk will shift by one month: while risk has historically been high from April onwards, it is now projected to decrease in April and June and increase in October, where it was historically low.

CO-OCCURRENCE OF HAZARDS

Drought and heat stress are especially damaging to agricultural production when

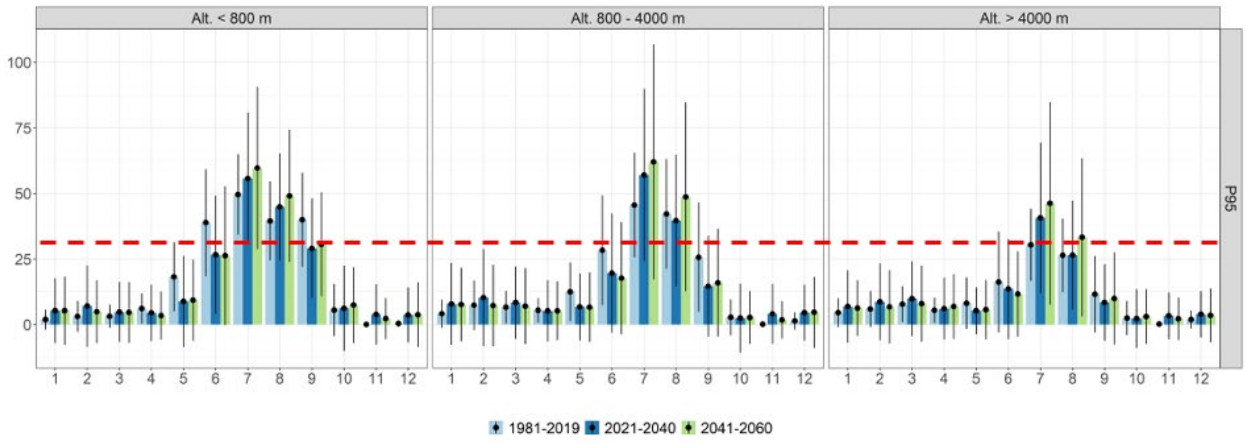


Figure 10: Monthly variation in flash flood risk at different elevation levels. The red line represents the threshold above which flood risk becomes critical.

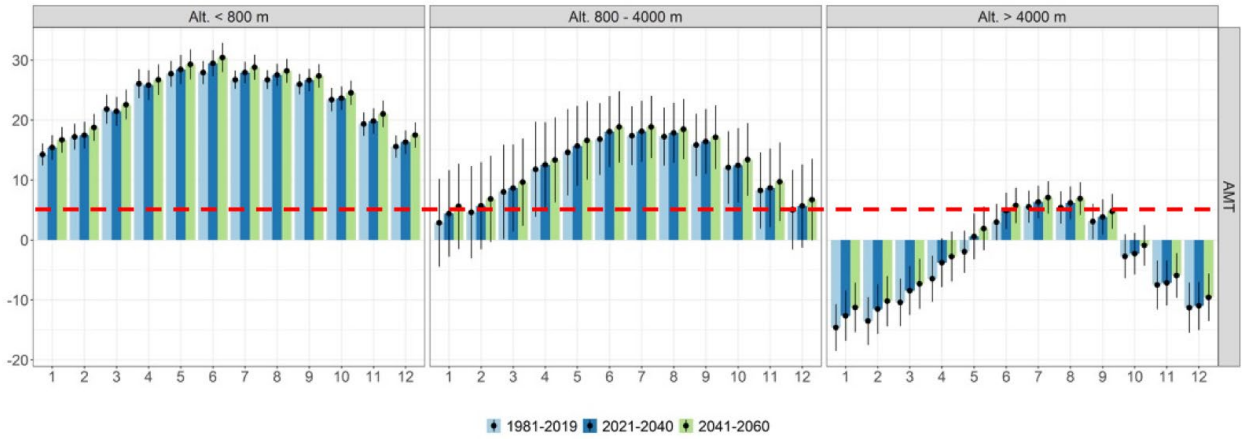


Figure 11: Monthly variations in temperature at different elevation levels. The red line represents the temperature threshold of a cold spell.

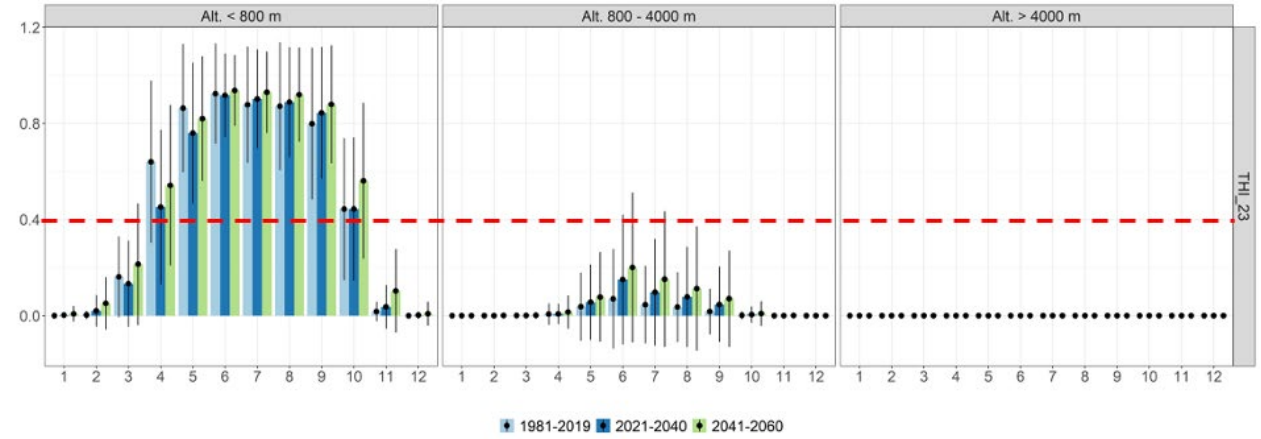


Figure 12: Projections on the probability of heat stress by elevation zone.

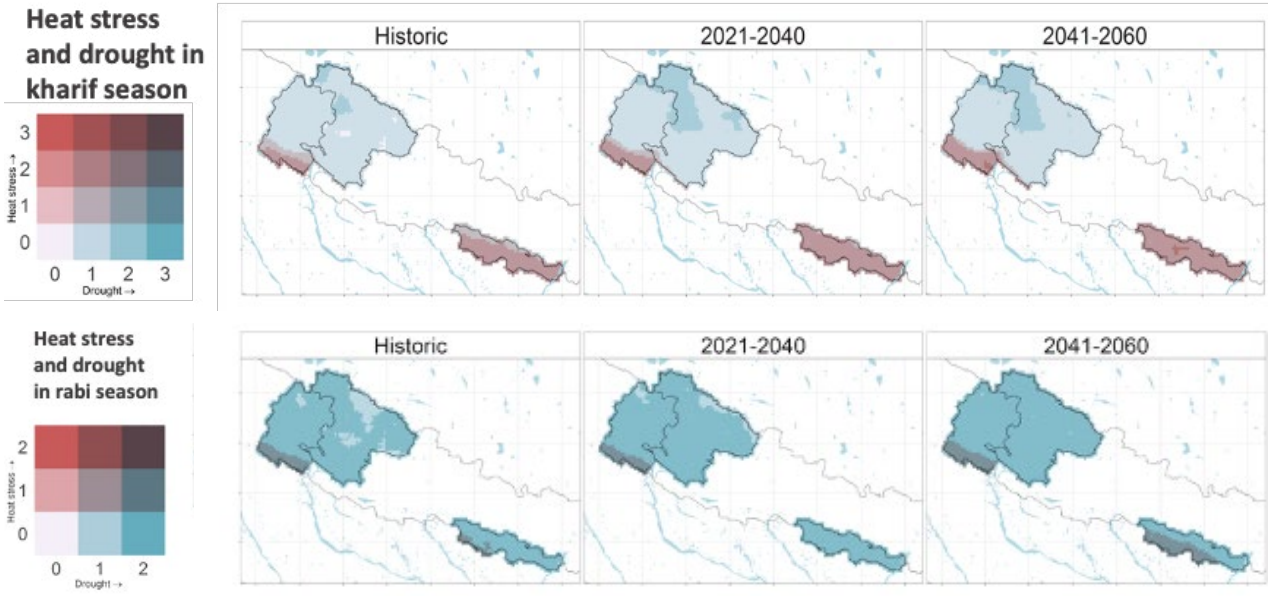


Figure 13: Projections of the co-occurrence of drought and heat stress during kharif season and rabi season. The darker the color, the more severe the hazard.

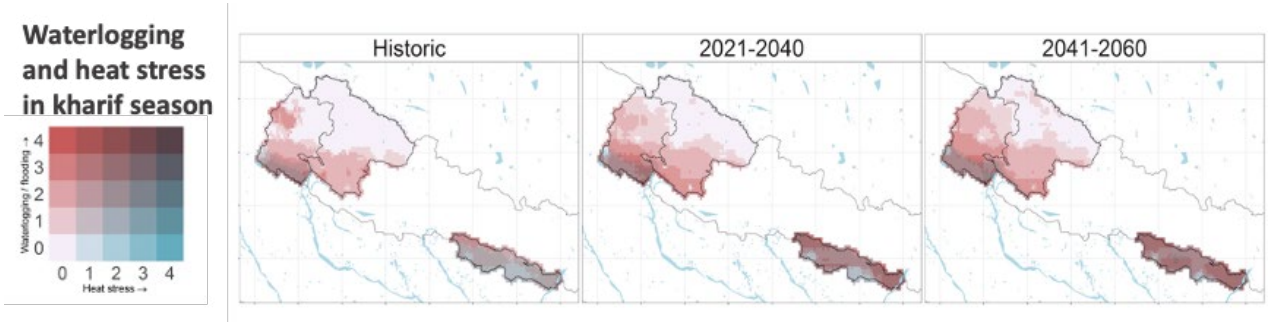


Figure 14: Projections of the co-occurrence of waterlogging and heat stress during kharif season.

experienced in tandem. Their co-occurrence is expected to grow in intensity by 2050, particularly during the kharif season in the low elevation zones of Province 2 and Sudurpaschim Province. The high mountain district of Karnali is expected to witness an increase of drought risk in the future, while heat stress risk remains low. Heat stress is less pronounced during the cooler rabi season. However, drought risk is increasing across all provinces, especially among the upper districts of Karnali and Sudurpaschim Provinces.

The co-occurrence of flooding and heat stress has historically been concentrated in lower elevation zones in Province 2 and Sudurpaschim, while Karnali has seen moderate flood risk and no risk of heat stress. While heat stress risk will remain high and relevant in terai districts only, flooding and waterlogging risk will increase by 2030 and 2050. By the 2030s, flood and waterlogging risk will become moderate to high across the upper hill districts in Sudurpaschim Province and the mid-hill districts of Karnali. In Province 2, flood risk will shift from strong to severe by 2030, and extreme by 2050s.

2.3 Current and future crop suitability

The EcoCrop model was used to find the areas that are suitable for crop production under current and future climate conditions in Nepal. EcoCrop has been used in numerous research projects to conduct crop suitability assessments and understand the impacts of climate change. The model uses crop-specific parameters such as minimum, maximum, and average temperature and cumulative precipitation during the growing season that are estimated across a spatial resolution of 5 x 5 km. Nepal's suitability analysis was carried out for the staple crops of rice, maize, and lentil.

RICE

Crop suitability for rice differs between lowland and upland rice, as shown in Figure 15. Historical analysis indicates that the most suitable growing areas for both varieties are in lower elevation levels. The suitable area for upland rice is generally larger than it is for lowland rice. Province 2 and the terai districts of Sudurpaschim Province are highly suitable for upland rice, and highly or moderately suitable for lowland rice, with only a small share of Province 2 deemed poorly suitable for rice. The mid and high elevation areas of Karnali and Sudurpaschim Province are mostly unsuitable for both rice varieties. Future projections show no significant changes in suitability for both lowland and upland rice in the terai districts of Province 2 and Sudurpaschim Province, but suitability in low to mid-hill elevation zones of Karnali and Sudurpaschim Province will be improved by increasing rainfall and temperatures. Nevertheless, poor land access will remain constraints, preventing the full use of these potential positive changes.

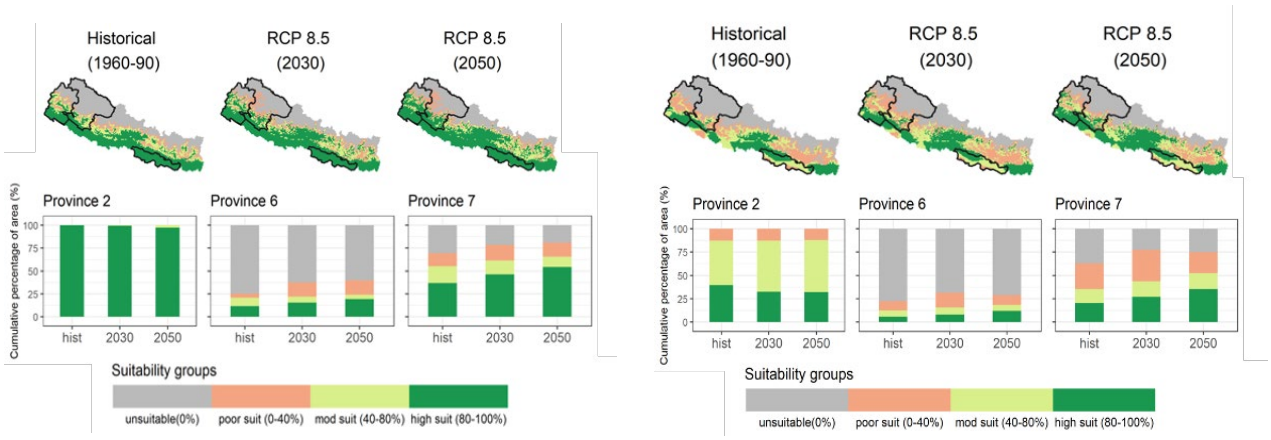


Figure 15: Crop suitability of lowland rice and upland rice.

MAIZE

Whereas maize cultivation has historically been highly suitable for low and mid-elevation zones, low elevation areas will become considerably less suitable for maize cultivation in the future, as shown in Figure 16. 60% of Province 2 will be poorly suitable for maize by 2030, and almost 90% will be poorly suitable by 2050, with a similar trend in the terai districts of Sudurpaschim Province. Overall, projections indicate that a less suitable area will increase in the future, likely due to temperature increases in lower areas. Karnali will become more suitable, as higher areas become more suitable. The increase could be related to higher rainfall and shifting temperatures.

LENTIL

More areas will become suitable for lentil in the future, as shown by Figure 16. Historically, the most suitable areas are concentrated across the lower and upper hill districts, whereas terai districts were only moderately suitable. By 2030 and 2050, suitable area will decrease, but higher elevation zones will become slightly more suitable. This shift could be related to increasing temperatures during lentil's winter growing

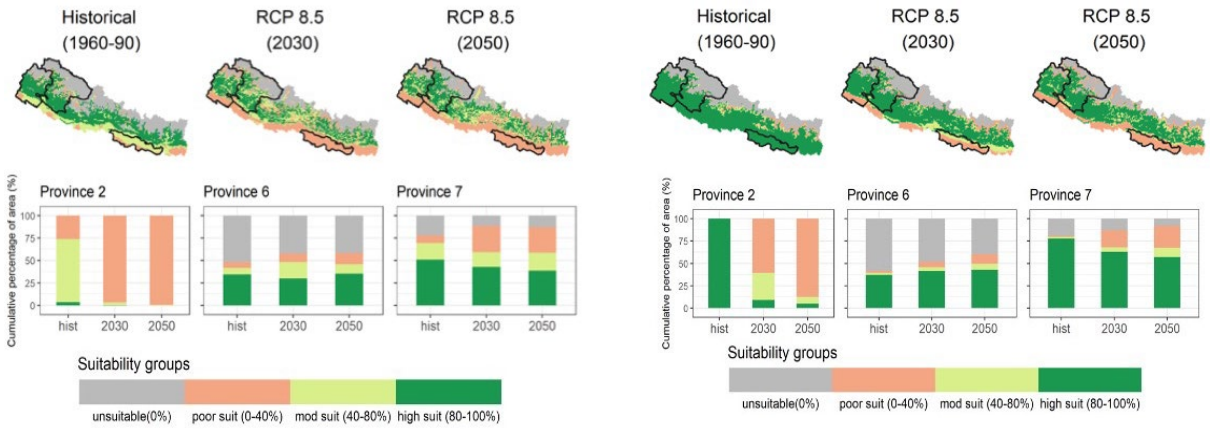


Figure 16: Crop suitability of maize and lentil across selected provinces.

season.

2.4 Hotspots of risk co-occurrence

METHODS

Below, we assess the spatial distribution of vulnerabilities across selected provinces and identify areas prone to co-occurrence. For this section, data on a set of indicators was compiled and then mapped. These indicators were selected to best represent three primary pillars of vulnerability as shown in Table 1. The indicators include food insecurity and nutrition, inequality, and poor health. Food security and nutrition was based on direct estimations of food insecurity, food consumption scores, and estimates on child development and nutrition. Inequality was represented by education and education-based gender indicators. Nutrition and health was represented by a combination of disease prevalence and mortality rates. The indicators were then tested to determine whether values that related to the livelihood zones showed sufficient spatial variability to meaningfully contribute to the vulnerability hotspots map. For those variables that did meet these criteria, values were sorted into two groups, according to a threshold used to categorise values demonstrating 'high' vulnerability. The resulting data was then summed to show the prevalence of indicators displaying high vulnerability, shown in Figure 17, and aggregated to show the combinations of food security and nutrition, gender-based educational inequality, and poor health that contribute to societal vulnerability. A similar process was used to produce maps that show vulnerability hotspots using the additional indicators in our analysis, although no aggregation was performed due to the

Table 1: Indicators that were used to derive the vulnerability hotspot maps in Figures 16-17. All included indicators are identified as such and the reason for any exclusions is given.

Variable specificity	Variable grouping	Variable	Inclusion status
Primary	Food insecurity & nutrition	Food insecurity	Included
		Prevalence of wasting	Included
		Prevalence of stunting	Excluded (insufficient variation)
		Number of underweight people	Included
	Gender and educational inequality	Males' years of schooling	Included
		Females' years of schooling	Included
		Gender education gap	Included
	Health	Plasmodium falciparum incidence rate	Included
		Plasmodium vivax incidence rate	Included
		Under-5 mortality per 1000 live births	Included
		Prevalence of diarrhea	Excluded (insufficient variation)
Additional	N/A	Net migration	Included
		Accessibility to cities	Included
		Active fires	Excluded (insufficient variation)
		Predominant ethnic group	Excluded (insufficient variation)

diverse nature of these variables. In both Figure 17 and Figure 18, 'no areas of high vulnerability' indicates that the indicator values in this area did not exceed a predetermined threshold of 'high' vulnerability. All variables that were used in the spatial analysis are shown as 'included' in Table 1 and further methodological explanation and data sources are detailed in Annex 2.

RESULTS

There is a strong distinction in the number of vulnerability measures classified as 'high' between provinces. Provinces 7 and 2 display large numbers, especially in the south, as seen in Figure 17 (a). By comparison, Karnali displays small numbers. In fact, parts of Karnali show no areas of vulnerability, although high inequality is prevalent across much of this province. Poor health and food security also percolate the southern part of the province.

Food insecurity is almost ubiquitous across both Sudurpaschim Province and Province 2, although some areas to the north of Province 2 are absent of food security hotspots, as seen in Figure 17 (b). Poor health appears to be spread across the southern part of Sudurpaschim Province and the majority of Province 2, with the exception of the north and northwest. Inequality is scattered across Provinces 7 and 2, with the exception of the eastern area of Province 2 and southwestern part of Sudurpaschim Province. Almost all areas within Provinces 2 and 7 are subject to at least one of the three vulnerability classifications of food security, inequality, and poor health.

Additional vulnerability indicators include out-migration and accessibility to cities, as illustrated in Figure 18. As the data suggests, the entirety of Sudurpaschim Province is free of high

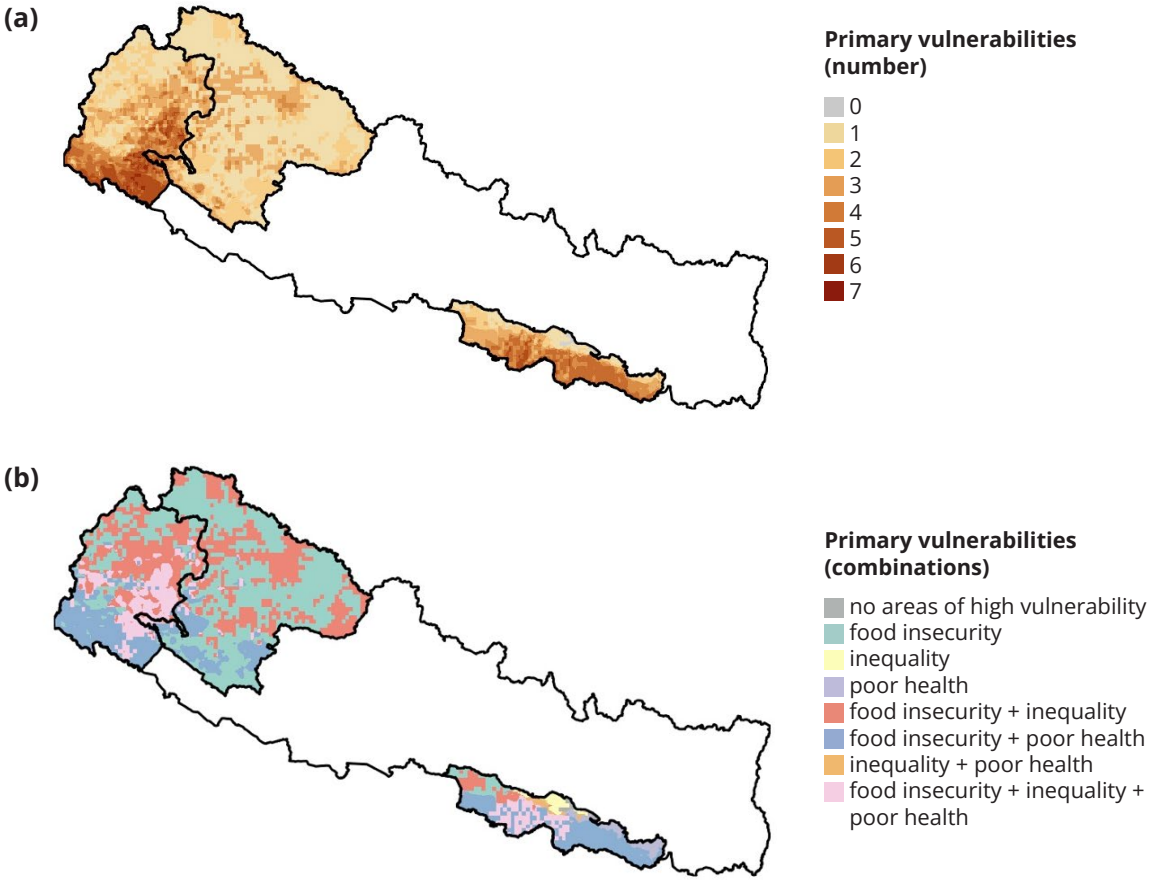


Figure 17: (a) Total number of the high vulnerability metrics of food security and nutrition, health, and inequality; **(b)** Food security and nutrition, inequality, and health hotspots across the livelihood zones, shown as combinations of vulnerability metrics. The specific vulnerability metrics used are marked as 'included' in Table 1.

out-migration. The majority of the province also seems to have adequate accessibility to cities, with the exception of two areas in the north[3]. High out-migration co-exists with low accessibility to cities in Karnali. These two vulnerabilities seem to be concentrated in the north. Province 2 has access to cities, but the west does show high out-migration.

2.5 Summary by province

PROVINCE 2

- Most negative impacts could be observed in lower altitudes, so Province 2 is expected to be more affected by climate change in the future.
- Waterlogging and flooding are the most threatening to agriculture and rural livelihoods. The risk will increase especially from July to August in terai regions.
- Increasing temperatures and associated heat stress in terai areas is a concern for livestock, especially cattle and buffalo. Its co-occurrence with drought will slightly increase in the future during kharif season. On the other hand, increasing temperatures will make cold spells less likely in the future.
- Maize will shift from very suitable to poorly suitable for the entire province, and lentil suitability will decline from moderately suitable to poorly suitable overall. Rice suitability will remain high.
- This province is particularly vulnerable,

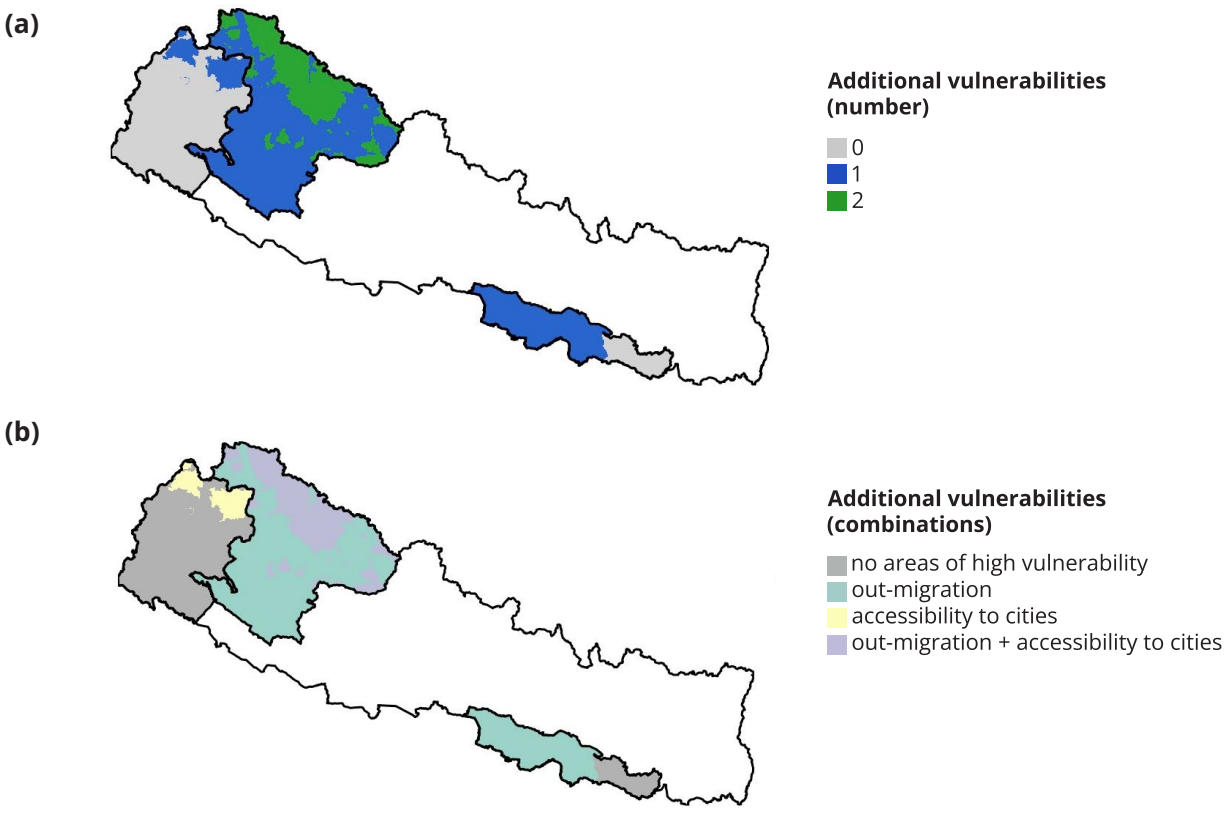


Figure 18: (a) Total number of additional vulnerability metrics classified as 'high' in a given area; **(b)** Combinations of additional vulnerability hotspots across selected livelihood zones. The specific vulnerability metrics used are marked as 'included' in Table 1.

3 Since the maps show hotspots, they merely reflect spatial variation and areas of particular vulnerability within the country; it therefore cannot be assumed that areas not represented as hotspots would not be classified as vulnerable when compared with data on a wider scale (e.g. globally).

specifically in regards to combined food insecurity and poor health in the south, as well as combined food insecurity and high levels of outmigration in the west.

KARNALI

- More projected summer rainfall in mid- to higher altitudes can be beneficial for crop production, but is also likely to lead to flooding and landslides
- Winter conditions will remain largely unchanged, except for a slight increase in droughts at high altitudes. These droughts will add to existing concerns about water scarcity for winter and spring crop production.
- Lower rainfall during winter is also expected to impact pasture productivity and water availability for livestock. It may lead to increased and earlier migration to lower areas as people and animals search for feed and water.
- Some parts of the province are projected to receive less rainfall in mid-term projections and more rainfall in long-term projections. Adaptation measures need to consider both scenarios.
- Suitability for maize and lentil will shift to higher altitudes, expanding slightly in net area. Rice suitability will remain largely unchanged.
- Karnali is especially affected by food insecurity, inequality in the north, and poor health in the south. However, Karnali is less vulnerable than Provinces 2 and 7. In addition, Karnali is quite strongly affected by outmigration and low accessibility to cities, especially in the north.

SUDURPASCHIM PROVINCE

- Sudurpaschim Province combines low, mid and high altitudes and experiences impacts across all levels.
- Impacts in the terai districts are similar to those in Province 2. Increased flooding and water logging risk during the monsoon season will be problematic, especially for summer crops, and will threaten human lives and livestock. Increased heat stress will be problematic, especially for livestock production. Maize and lentil crops will shift from very suitable to poorly suitable in terai districts.
- Mid- to high hill districts will experience an increase in precipitation and higher risk of landslides and water logging during monsoon season. Maize and lentil suitability will decline slightly, yet this trend will not be as pronounced as it is in terai districts. Rice may become suitable in some higher hill areas.
- The south is particularly vulnerable to poor health, while the northern parts are vulnerable to food insecurity and inequality. Several parts in lower hills are affected by all three vulnerability indicators, while some pockets in the north suffer from low access to cities.

PART 3.

Review of World Food Program activities and recommendations

In light of the aforementioned climate risks, climate impacts, current policies, and funding mechanisms, several high-potential food security interventions came to light in alignment with the WFP mandate. These interventions were validated through key informant interviews and an online workshop, and offer insight into the most impactful potential next steps for WFP .

3.1 Review of current relevant WFP activities and program recommendations

WFP has established itself as the government of Nepal's trusted partner in achieving zero hunger, in accordance with the new federal structure and the constitutional mandate on right to food. With its 2019–2024 Country Strategic Plan (CSP), WFP pursues six strategic outcomes (SO) that are implemented through nine different activities that target nutrition, school meals, institutional support for food security and nutrition monitoring, resilience building among smallholder producers, emergency preparedness, and crisis response (see Table 2; [38], [73]). on the plan emphasizes gender-transformative approaches, poverty reduction, and education for empowerment among the rural poor and socially disadvantaged.

The current CSP reflects WFP's focus on climate resilience in Nepal [38]. WFP plans to "develop and improve risk-resilient infrastructure and strengthen local capacity to identify climate risks and implement adaptive strategies". A key aim of this SO is to increase resilience to climate change among vulnerable farmers in the central terai districts of Province 2, including the Koshi river basin, and in the Karnali Province in western Nepal. WFP is also supporting efforts to mainstream climate-change adaptation measures within local policy frameworks. These adaptation measures focus on preparing for climate shocks and early-warning systems. At the institutional level, WFP also explores and pilots programs that promote weather-indexed insurance for smallholder farmers. One of the CO flagship projects in this context is the CAFS project in Karnali province that trains and supports local government stakeholders as well as farmers with regards to climate risk information, development, and climate smart agriculture technologies and practices [66].

WFP further provides "technical assistance to enable the government to strengthen the food security monitoring, analysis and early-warning system and align it with the federal governance system". WFP has already implemented many innovative programs, including forecast-based financing against flood risk in terai districts [74]. In addition, WFP has also been working towards realizing one of its flagship climate resilience programs, Consolidated Livelihood Exercise for Analysing Resilience (CLEAR), in Provinces 6 and 7. CLEAR assesses livelihood zone profiles, climate projections, and adaptation options together with the provincial government and local stakeholders. The activity is intended to raise awareness and generate evidence on the impact of climate change at local levels on livelihoods and food security.

Table 2: WFP Nepal Country Strategic Plan 2019-2023

WFP Nepal Country Strategic Plan 2019-2023	
Strategic outcome 1: Affected populations in Nepal have timely access to adequate food and nutrition during and in the aftermath of natural disasters and other shocks.	**Activity 1:** Provide food assistance for targeted shock-affected people, including food and cash-based transfers (CBTs) and specialized nutritious foods and related services for the treatment and prevention of malnutrition in children aged 6-59 months and pregnant and lactating women and girls.
Strategic outcome 2: Food-insecure people in targeted areas have improved nutrition throughout the key stages of their lives by 2025.	**Activity 2:** Provide gender-transformative and nutrition-sensitive school meals and health packages in chronically food-insecure areas and strengthen the government's capacity to integrate the national school meals programme into the national social protection framework.
	Activity 3: Provide technical support to the government for the development of a rice-fortification policy framework and supply chain system for use in social safety nets.
	Activity 4: Support the strengthening of national nutrition-sensitive, gender-responsive social safety nets for vulnerable populations and provide specialized nutritious foods, technical assistance, logistics and social behaviour change commuication for the prevention of malnutrition.
Strategic outcome 3: Vulnerable communities in remote food-insecure areas have improved food security and resilience to climate and other shocks by 2030.	**Activity 5:** Develop and improve risk-resilient infrastructure and strengthen local capacity to identify climate risks and implement adaptive strategies.
Strategic outcome 4: The government has strengthened capabilities to provide essential food security and nutrition services and respond to crises by 2023.	**Activity 6:** Provide technical assistance to enable the government to strengthen the food security monitoring, analysis and early-warning system and align it with the federal governance system.
	Activity 7: Strengthen preparedness capacity, establish emergency logistics and institutional platforms and improve access to food reserves to enable government and humanitarian partners to respond rapidly to crises.
Strategic outcome 5: Government efforts towards achieving zero hunger by 2030 are supported by inclusive and coherent policy frameworks across all spheres of government by 2023.	**Activity 8:** Provide technical asistance and support evidence generation for government and multi-sector partners to enhance right-based food security and nutrition plan, policies regulatory frameworks and service delivery.
Strategic outcome 6: Humanitarian and development partners have access to reliable common services by the end of 2023.	**Activity 9:** Provide on-demand service provision to all stakeholders in the country in order to support effective humanitarian response.

3.2 Program recommendations for WFP

Effective adaptation involves "both building adaptive capacity, thereby increasing the ability of individuals, groups, or organisations to adapt to changes, and implementing adaptation decisions, i.e., transforming that capacity into action" [75]. Various intervention options can reduce risk, impact, and vulnerability across different levels. Activities can target either structural and physical, social, or institutional adaptation, focus on specific hazards, or strengthen adaptive capacity in general [76]. Recommendations for WFP are thus structured according to different levels of intervention and designated to different SOs and existing activities.

PROGRAM RECOMMENDATIONS AT THE LIVELIHOOD, LANDSCAPE, AND SUPPLY CHAIN LEVELS.

At the livelihood and community level, WFP activities within SO2 and SO3 represent the ideal venues for integrating climate adaptation activities into national programming. While SO2 provides opportunities for strengthening climate education, SO3 provides opportunities for promoting and installing climate smart technologies and interventions at the farm, landscape, and supply chain levels.

SO2 activities in relation to nutrition support and education can raise awareness and educate vulnerable populations on climate change. For example, the Social Behavior Change Communication program of Activity 2 involves training modules that teach adaptation behavior at the individual and household level. This is an opportunity to build the adaptive capacity of Nepal's most vulnerable population and educate children, who can act as multipliers by bringing knowledge to their families. Education modules should focus on resilient nutrition choices, health risks from climate change and how to cope, and well as on good agricultural practices in drought or flood risk zones.

In addition, the school meal and health programs of Activity 3 can incorporate climate considerations into local meal plans. Current interventions promote climate-friendly cooking stoves, yet no specific consideration is given to selecting food in response to climate change. Upper hill and mountain districts should develop meal plans with highly nutritious, locally adapted, and drought resistant crop varieties, while lower terai districts should integrate nutritious and flood- and waterlogging-resistant foods.

SO3's focus on climate resilience for poor and vulnerable rural communities allows ample room for piloting different climate resilience projects in Nepal. These projects have been implemented under Activity 5. WFP could expand its geographic scope and portfolio of activities promoted under this SO. The table below shows recommended adaptation options, identified through stakeholder discussions and literature review, that WFP could integrate or systematically strengthen under SO3 and Activity 5.

Table 3: Adaptation measures for selected hazards in Province 2, Karnali, and Sudurpaschim Province.

Hazard type	Intervention level	Adaptation options
Province 2		
Flood and waterlogging	**Livelihood level**	• Leasehold farming models with CSA interventions for landless people • High value cash – vegetables, seed production • Cropping calendar adjustment to reflect changes in rainy season onset and duration as well as temperature increases • Flood and water logging resistant rice varieties, spring paddy • CSA technologies for maize, rice, sugarcane, groundnut • Agricultural enterprises with water tolerance – like buffalo, fish, duck farming • Livelihood diversification, e.g., seed business, rural enterprises • Planting of cash crops
	Landscape level	• Chure conservation activities – increasing water retention and recharging capacity • Riverbank protection • Constructing sedimentation retention dams • Water harvesting ponds in Chure, upland • Promoting agroforestry
	Supply chain level	• Distributing seeds and subsidizing governance improvement • Resilient local infrastructure, including food storage structure, seed banks, and emergency livestock shelters • Access to real-time market information like price developments • Improved market access, access to finance and credits • Linking farmer groups and cooperatives to seed production • Stockpiling and pre-positioning to prepare for disasters
Drought and heat stress	**Livelihood level**	• Climate-Smart agriculture technologies for drought, e.g., conservation agriculture practices for rabi crops, relay crops • Selecting suitable crops for drought and heat tolerance, e.g. promoting mung crop, oilseed, sunflower in summer, and drought resistant varieties in winter • Promoting small and micro-irrigation, water-smart irrigation technologies including solar-based and drip irrigation • River-bed farming • Planting trees for shading

Hazard type	Intervention level	Adaptation options
Province 2		
Drought and heat stress	**Landscape level**	• Chure conservation activities – increasing water retention and recharging capacity • Water source protection scheme
	Supply chain level	• Improving supply chain for drought resistant seed varieties • Improving supply chain for irrigation technology
Karnali Province		
Flood and landslide	**Livelihood level**	• Slope stabilization activities, e.g., terracing, contour hedgerows, contour stone bunds, tree plantation • Soil management activities, e.g., compost and manure, mulching, cover crop, intercrop, crop rotation, legumes • Promoting perennial crops, e.g., Bains, Bamboo, Amriso • Establishing nurseries for tree planting • Food for work linked to fruit farming • Participatory plant breeding
	Landscape level	• Planting in open lands • Proper drainage systems • Forest management • Installing check dams, retaining walls, and gabion walls
	Supply chain level	• Installing improved foot trails for market connection • Improved storage facilities such as rustic stores
Drought	**Livelihood level**	• Crop diversification, introducing drought tolerant crops, including climate-resilient and genetically diverse local species • Water efficient technologies such as drip irrigation, sprinkler irrigation • Innovate and promote 'forest for food' concept in order to cultivate/harvest food from the forest, including that of wild food • Integrated pest management • Promoting kitchen gardens • Water and snow harvesting techniques e.g., recharge ponds
	Landscape level	• Irrigation canal, lift irrigation system • Installing community water supply systems
	Supply chain level	• Improving market access and availability of inputs for improved crop management
Sudurpaschim Province		
Flood and landslide	**Livelihood level**	• Livelihood diversification, e.g., alternative agricultural enterprises with water tolerance like buffalo, fish, duck farming • Promoting agroforestry, e.g., fruit farming • Promoting waterlogging tolerant varieties and crops, e.g., promoting sugarcane in flood-prone areas
	Landscape level	• Terrace management, slope stabilization, hedgerows, contour stone-bunds • Planting perennial crops, forest protection and reforestation in upper and exposed areas to protect from landslides in lower zones • Installing proper drainage system around fields that are prone to waterlogging
	Supply chain level	• Installing foot trails, improved roads to connect remote areas • Improved and elevated storage facilities with flood protection • Establishing food banks that target the hill and mountain districts

Hazard type	Intervention level	Adaptation options
Sudurpaschim Province		
Drought and heat stress	**Livelihood level**	• Cropping in riverbanks during dry season • Diversifying with drought tolerant crops, including climate-resilient and genetically diverse local species • Rainwater and snow harvesting, e.g., ponds • Promoting water efficient use technologies e.g., drip or sprinkler irrigation • Integrated pest management • Promoting kitchen gardens
	Landscape level	• Irrigation canal, lift irrigation system • Installing community water supply systems
	Supply chain level	• Improving market access and availability of inputs for improved crop management

PROGRAM RECOMMENDATIONS AT THE INSTITUTIONAL AND POLICY LEVELS

Nepal has a well-established regulatory and institutional framework for social, environmental, and climate change challenges. However, institutional adaptation and resilience capacities at the province and municipal levels are still weak. Because of the devolution process that was initiated with the new constitution in 2015, much of the provincial level government is still in the consolidation phase. While national level policy frameworks for climate response are also valid at a provincial level, local governments have thus far given little priority to establishing locally-tailored climate change policies and adaptation plans. One reason for this is lack of resources, technical expertise, and specialized staff. Budget plans often prioritize much-needed investments in physical infrastructure such as roads and markets. Despite annual climate hazards, response to climate change has been mostly ad-hoc, reactive, and poorly coordinated.

Opportunities include providing capacity development, organizing training and awareness activities with key stakeholders around a number of specialized topics, accessing international climate finance, and further integrating scientific insights into local plans and objectives. Given WFP's expertise, positioning, and well-established, unique access to the most food insecure and vulnerable communities, it is well-placed to support policy makers and adjacent international development organizations. In fact, several of WFP's current engagements are already aligned with national policy objectives and WFP can build upon its experience to expand these activities in the future.

Besides the previously-listed recommendations, a number of cross-cutting adaptation options that WFP can help develop and implement are identified here. These options are listed in the table below with links to current WFP programs.

Table 4: Cross-cutting adaptation interventions at the institutional and policy levels

Intervention level	Adaptation option	Link to WFP programming
Institutional systems and processes	• Emergency fund establishment for DRR and response • Training on disaster response • Collaborate with governments to establish/set up evacuation centres in the flood disaster prone areas	SO1 – Act01
	• Promoting weather index-based crop insurance to compensate for the loss caused by extreme weather events, increasing the local presence of insurance companies • Establishing a mechanism for credits from micro-finance institutions and support cooperatives to invest in profitable agricultural activities • Enhancing local extension systems and service delivery, integrating climate change adaptation	SO3 – Act05
	• Establishing local agrometeorological information centers and distributing agricultural management advice that targets smallholder and marginalized farmers, disseminating information through local radios, SMS services, and information boards at village centers • Developing and strengthening early warning systems and linking to forecast-based action	SO4 – Act06
	• Training and raising awareness on climate change risks and adaptation, linking to nutrition and food insecurity	SO4 – Act07
Policy level	• Integrated sector-wise climate change adaptation and food security plans should be developed in line with the Right to Food and Food Sovereignty Act to ensure public sector buy-in • Rural municipality level food security strategy • Preparing plans such as Local Adaptation Plan of Action (LAPA) and DRR plans • Integrating DRR and CCA into existing policies and plans • Establishing a Farmer ID card, linking with subsidy and social security systems • Localizing the national agricultural policy • GESI integration, identifying vulnerable groups • Giving higher policy priority to the agriculture and food security sector at the local and province levels • Integrating DRR plans into one single plan to avoid confusion	SO5 – Act08

3.3 Scoping of WFP programmatic partnership opportunities

Several partnerships with national and international organizations have been identified as helpful to WFP's work in Nepal. WFP's most important partnerships involve continuing and strengthening alignments with different government agencies . These agencies include the Ministry of Agriculture and Livestock Development (MoALD), the Ministry of Forests and Environment (MoFE), the National Disaster Risk Reduction and Management Authority, and the National Planning Commission (NPC) and its provincial and local level counterparts, such as Provincial Ministries of Land Management, Agriculture & Cooperative (MoLMAC).

Furthermore, other UN agencies, including Rome-based agencies such as the Food and Agriculture Organization (FAO), add great value to WFP programming through their climate expertise. FAO and WFP have an existing partnership - however, a lot of the engagement is project based. Enhancing climate adaptation programming represents an opportunity for WFP to build and strengthen partnerships with other UN agencies. WFP and other UN agencies should seek to overcome one-on-one interaction and reconsider the UN's role as one actor with common objectives for Nepal. This will enhance the effectiveness of programs in Nepal and strengthen WFP's position and ability to win funding.

Besides national government agencies and UN organizations, a number of other NGOs and research centres have the potential to collaborate on climate adaptation programming. These organisations include:

- Regional Integrated Multi-Hazard Early Warning System for Africa and Asia Nepal (RIMES) Nepal and the UK Met Service with expertise on weather information and early warning systems
- The German Agency for International Cooperation (GIZ) for expertise on value chain development in the agriculture and forestry sectors
- The CGIAR research centres that were previously active as separate centres such as CIMMYT/ CCAFS, CIAT, or Bioversity International, but are currently in the process of combining. They boast with wide expertise in climate resilient technologies and crops, including the development of climate smart villages
- National research centres such as the National Agriculture Research Council (NARC) and the province-level Regional Agricultural Research Stations (RARS)
- National NGOs like Local Initiatives for Biodiversity, Research and Development (Li-BIRD) for climate resilient agriculture activities, Karnali Integrated Rural Development and Research Centre (KIRDRAC) or Koshi Victims Society (KVS) and Community Development and Advocacy Forum (CDaFN) for disaster risk reduction and preparedness activities

3.4 Potential funding mechanisms

WFP is well-placed to apply for most of the relevant funds for climate finance that the Nepalese government has targeted for in-country programming. These include international and multilateral funds such as REDD+, Green Climate Fund (GCF), Global Environment Facility (GEF), Adaptation Fund (AF),

and Climate Investment Fund. Further sources include bilateral donors such as UK Aid from the United Kingdom, AusAID from Australia, GIZ from Germany, JICA from Japan, or USAID from the United States. WFP can also seek strategic partnerships with private sector companies and apply for blended finance projects funding by applying for state or international donor support in reducing investment risks for private sector actors that are active in climate resilience and mitigation. WFP can obtain further funding from international development banks including World Bank, Asian Development Bank, the International Fund for Agricultural Development (IFAD), and the Central Emergency Response Fund (CERF).

PART 4.

Synthesis

Nepal is already among the countries that are the most vulnerable to and affected by natural disasters and climate change. Projections indicate that climate events will become more extreme in the future, with generally warmer temperatures, a shorter and more intense rainy season, negative drought trends, erratic rainfall, floods, and landslides. These events are expected to negatively affect agricultural and livestock production, as shifting precipitation patterns and temperatures complicate growing conditions. A comprehensive framework of policies, programs, and social protection schemes are in place to address these climate hazards. However, given Nepal's recent adoption of a new constitution, the local implementation of these policies is often hindered by administrative and political restructuring at the province, district, and municipality levels. As a result, social protection schemes remain limited and disintegrated. Though many programs exist, they are not coherent or interlinked, creating a major gap that needs to be addressed. This creates opportunities for WFP programming to support the government in addressing, designing, and implementing food and nutrition security policies and programs with strong social protection and climate adaptation linkages.

WFP in Nepal already focuses on mainstreaming climate adaptation response into its programming, with high potential for future expansion. Existing programs support numerous projects, including early warning systems, forecast-based financing, agricultural and livestock insurance, climate smart agriculture training, and local climate action plans of action. Given the results of the climate impact analysis, addressing increasing drought, heat stress, floods, and landslides will be key in each of the three provinces. Here, WFP can support local and provincial governments by raising awareness and promoting specific technologies and practices.

Recommended climate change adaptation practices are relevant across all provinces. The specifics of these practices will differ depending on AEZ and elevation. Lower areas such as terai and lower hill districts are likely to experience frequent and intense flooding and landslides during summer, while increasing temperatures in these districts will likely lead to heat stress in livestock and decreased crop suitability. Adaptation suggestions are thus focussed on addressing these phenomena. Higher areas, especially the high mountains of Karnali and Sudurpaschim Province, are expected to experience increasing winter and spring droughts. Adaptation suggestions for these provinces therefore evolve around technologies like water and snow harvesting, irrigation systems, and drought-tolerant crop varieties. These recommendations are accompanied by further suggestions for adaptation options within options within institutional systems and governmental policies. These suggestions include revising of disaster management plans and expanding early-warning systems and weather-index based insurance programs.

To successfully support the government of Nepal, WFP can strengthen partnerships with local and international organizations. WFP's most important strategy is continuing and strengthening collaborations with different government agencies that work on agricultural development, climate change, and food and nutrition security. However, enhancing climate adaptation programming also represents an opportunity for WFP to systematically build and strengthen partnerships and engagement with other UN agencies like FAO and IFAD, allowing these organizations to strengthen the UN's role as a unified force for change. This will enhance program effectiveness and strengthen WFP's position among other development organizations, thus enhancing WFP's ability to win funding from funds and donors. Nepal hosts numerous international and national non-governmental organizations with vast expertise and experience in the climate change field that can provide great additional value to WFP if engaged in partnerships. The table below summarizes the findings from this review.

Table 5

	Province Name		Province 2	Karnali	Sudurpaschim Province
Analytical Insights	Current climate hazards	Drought	X	X	X
		Heat Stress	X		X
		Flood	X	X	X
		Cold spell	X		
	Projected climate changes through 2050	Temperature	Hot and increasing across all seasons, with higher risk of heat stress, especially during summer	Warm to mild in mid- to higher altitudes, increasing across all areas and seasons	Hot in terai plains, warm to mild in higher elevations, increasing across all areas and seasons
		Precipitation	Shift to later rainy season onset and earlier end, with concentration and higher intensity towards July-August	Shift to later rainy season onset and earlier end, with concentration and higher intensity towards July-August	Shift to later rainy season onset and earlier end, with concentration and higher intensity towards July-August
		Pluvial flooding	High and increasing flood risk during peak monsoon months	High and increasing flood and landslide risk during peak monsoon months, especially in mid-hills	High and increasing flood and landslide risk during peak monsoon months, severe flood risk in terai districts
		Heat stress	Severe during kharif and will remain so	Low risk of heat stress throughout the year, will remain that way	Severe during kharif in terai districts, low risk in higher districts, will remain that way
		Drought	Erratic precipitation and rainy season onset can lead to more frequent occurrence of dry periods in late spring and autumn and winter	Increasing risk of winter droughts in mountain districts	Increasing risk of winter droughts in mountain districts
		Cold spell	Risk of cold spell will decrease due to overall temperature increase	Risk of cold spell will decrease due to overall temperature increase	Risk of cold spell will decrease due to overall temperature increase
	Hotspot analysis of current non-climate vulnerabilities	Primary vulnerabilities	• Food insecurity • Poor health	• Food insecurity • Gender-based educational inequality • Poor health	• Food insecurity • Poor health
		Additional vulnerabilities	• Out-migration	• Conflict	• Outmigration • Low organic carbon content in soil

	Province Name		Province 2	Karnali	Sudurpaschim Province
Analytical Insights	IMPACT Analysis of climate change on food access and stability through 2050	Availability considerations	+ High gains in potato productivity under CC invite expanded production + Production for temperate fruit, vegetables, rice, wheat, and other cereals, except maize, is projected to exhibit resilience in the face of climate change - Yields for other crops are generally lower under climate change than under a no-climate change scenario, especially for maize, lentil, and sugarcane - Calorie availability and diet trajectory is lower under CC for almost all crops except lentils, partly due to lower relative imports and partly due to lower relative production		
		Stability considerations	- Negative climate trends like winter droughts and summer flooding can disrupt food supply and reduce incomes from agriculture. This highlights the importance of income and livelihood diversification - The population at risk of hunger is slightly higher under CC than under a no-CC scenario		
Cross-cutting recommendations	Partnership opportunities		• **International:** UK Meteorological Service, UN Food and Agriculture Organization, International Fund for Agricultural Development; German Agency for International Cooperation (GIZ), CGIAR research centres • **National:** Ministry of Agriculture and Livestock Development (MoALD), The Ministry of Forests and Environment (MoFE), the National Disaster Risk Reduction and Management Authority, the National Planning Commission (NPC); Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES), National Agriculture Research Centre (NARS), Local Initiatives for Biodiversity, Research and Development (Li-BIRD), Community Development and Advocacy Forum (CDaFN) • **Province-Level:** Provincial Ministries of Land Management, Agriculture & Cooperative (MoLMAC), Karnali Integrated Rural Development and Research Centre (KIRDRAC), Koshi Victims Society (KVS)		
	National-level policy support		• National Adaptation Plan (NAP) • National Climate Change Policy + Implementation Framework		
	Province-level policy support		• Rural Municipality level food security strategy, Local Adaptation Plan of Action (LAPA), provincial level disaster risk reduction strategies		
	Institutional capacity strengthening		• Support the identification of climate-vulnerable beneficiaries for national and provincial social protection programs and systems; Support creating a coherent enabling environment of policy commitment and coordination, robust capacities, sound data monitoring systems, and accountability		
	Climate resource mobilization	Bilateral development partners	• UK Aid (United Kingdom), AusAID (Australia), GIZ (Germany), JICA (Japan) or USAID (United States)		
		Multilateral development banks	• World Bank, Asian Development Bank, International Fund for Agricultural Development (IFAD		
		International/ multilateral funds	• REDD+, Green Climate Fund (GCF), Global Environment Facility (GEF), Adaptation Fund (AF) and Climate Investment Fund, Central Emergency Response Fund (CERF)		

	Province Name		Province 2	Karnali	Sudurpaschim Province
Programmatic recommendations	Climate adaptation	Flooding, waterlogging, and landslides	Recommendations linked to SO3 – Act 5 (table 5)	Recommendations linked to SO3 – Act 5 (table 5)	Recommendations linked to SO3 – Act 5 (table 5)
		Drought and heat stress	Recommendations linked to SO3 – Act 5 (table 5)	Recommendations linked to SO3 – Act 5 (table 5)	Recommendations linked to SO3 – Act 5 (table 5)
	Institutional systems and processes		Recommendations linked to SO1 – Act 1, SO3 – Act 5, SO4 – Act 6, SO4 – Act 7 (Table 6)		
	Policy level		Recommendations linked to SO5 – Act 8(Table 6)		

PART 5.

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PART 6.

Annexes

Annex 1: IMPACT results

YIELD, HARVESTED AREA, ANIMAL NUMBERS, AND PRODUCTION

In Nepal, production is projected to increase for most key crop and livestock commodities. In the case of rice, lentils, and wheat, this is due to a projected increase in yield while harvested area remains the same or declines slightly. In the case of sugarcane, this is due to a projected increase in area harvested while yield stagnates. Increased production outlooks for potato, temperate fruit (including apples and oranges), vegetables, mustard seed, and small ruminants are due to a mixture of projected increases in both yields and harvested area/numbers of animals. Maize production, on the other hand, is projected to remain at its current level out to 2035, and then to decline slightly thereafter. This outlook is due to a projected decrease in both maize yield and harvested area (Figure 19).

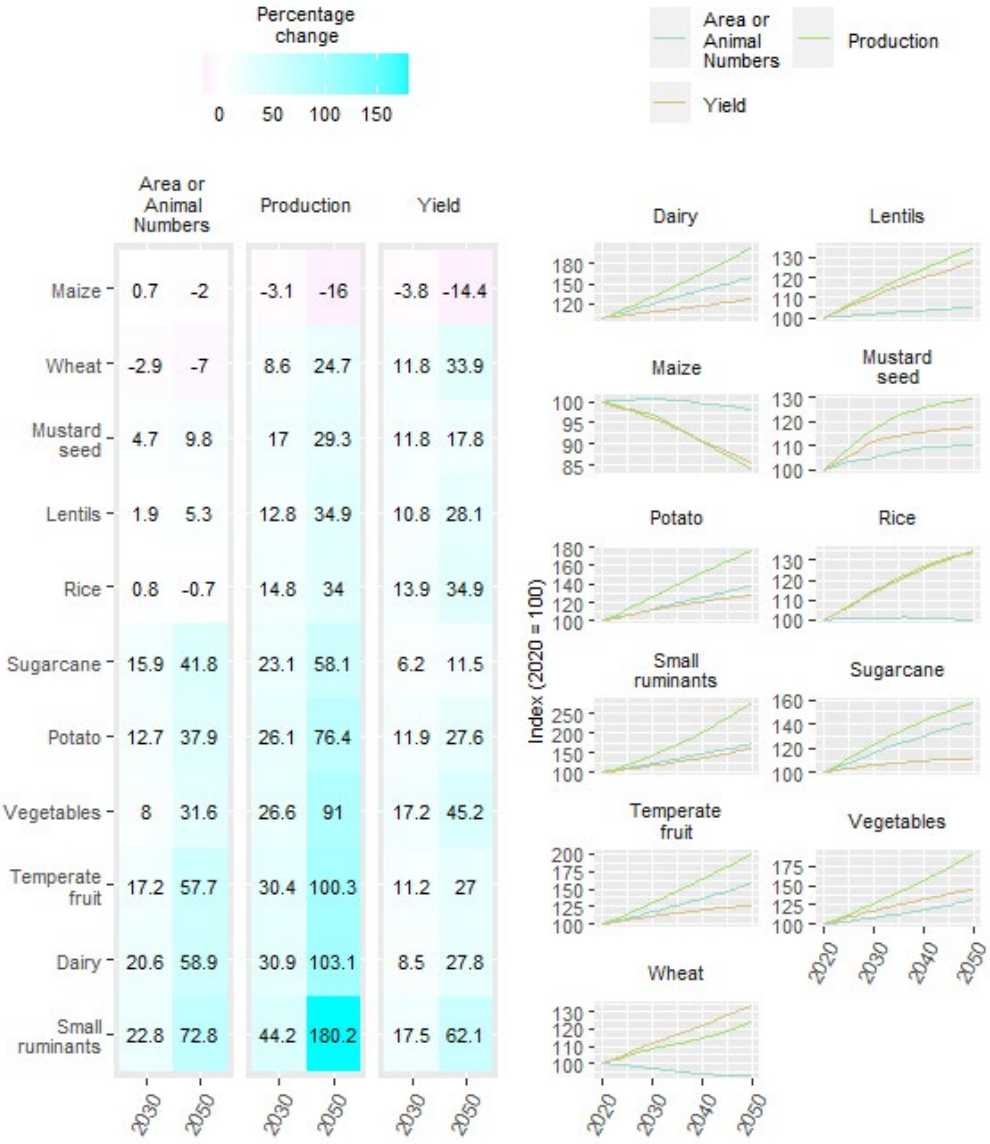

Figure 19: IMPACT 2020-2050 projection of percentage changes in yield, production, and area or animal numbers for key crop and livestock commodities.

Future projections in terms of percentage changes can present a misleading picture of the relative prevalence of commodities if not interpreted against their underlying baseline and future magnitudes. This is especially true if the baseline magnitudes are small. For this reason, a companion table of projections expressed as magnitudes is provided below (Figure 20) and a more detailed view of harvested area shares is presented in the next section.

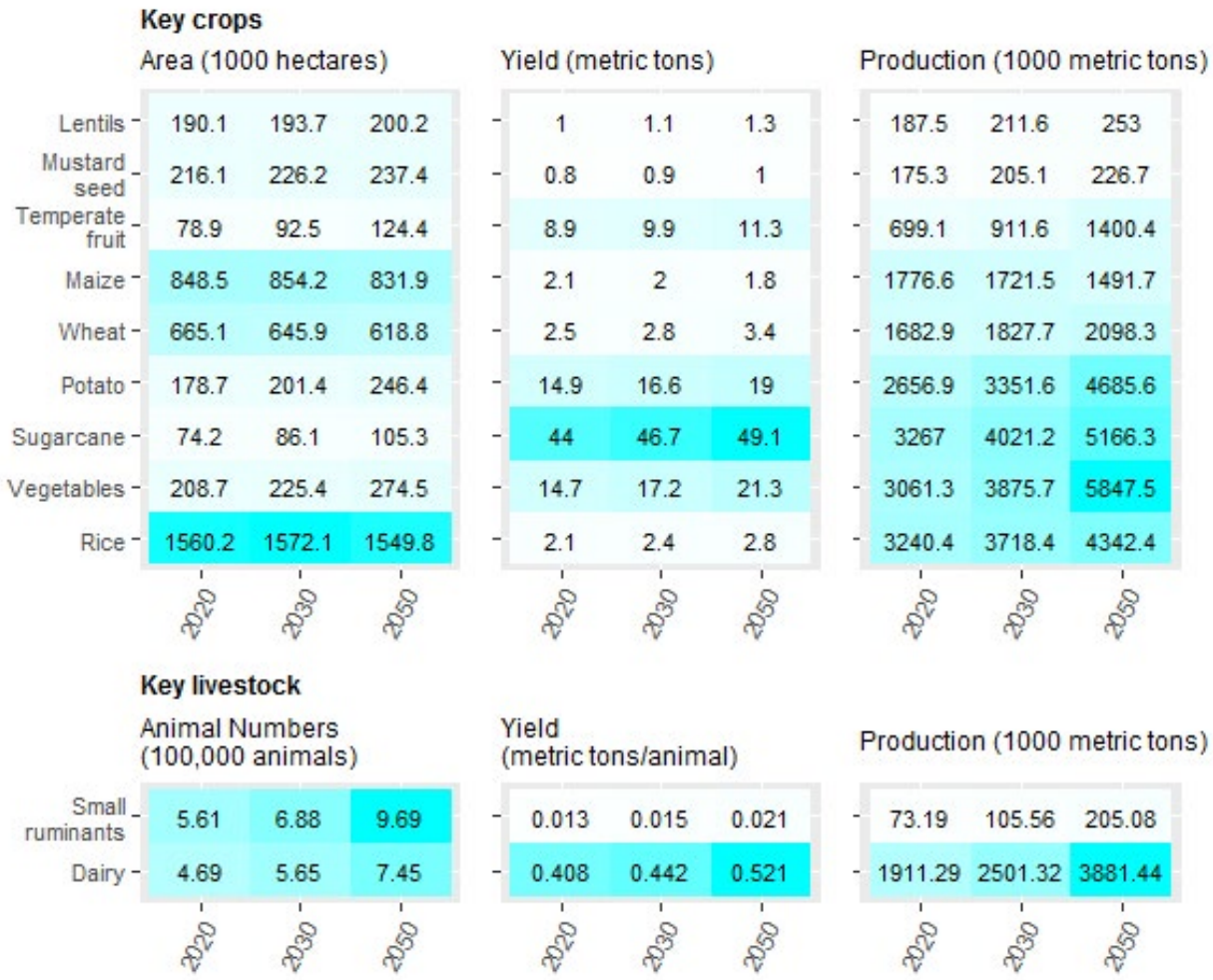

Figure 20: The yield, production and area or number of animals projected by the IMPACT analysis for the main plant and animal commodities in 2020, 2030 and 2050.

CROPLAND USE TRAJECTORY

While overall cropland is projected to expand, the cropland shares allocated to key commodities are projected to change very little, with cereals projected to occupy the largest share of harvested area out to 2050. Vegetables and mustard seed are projected to occupy the second largest share of cropland, followed by potatoes, lentils and other pulses, and sugarcane (Figure 21).

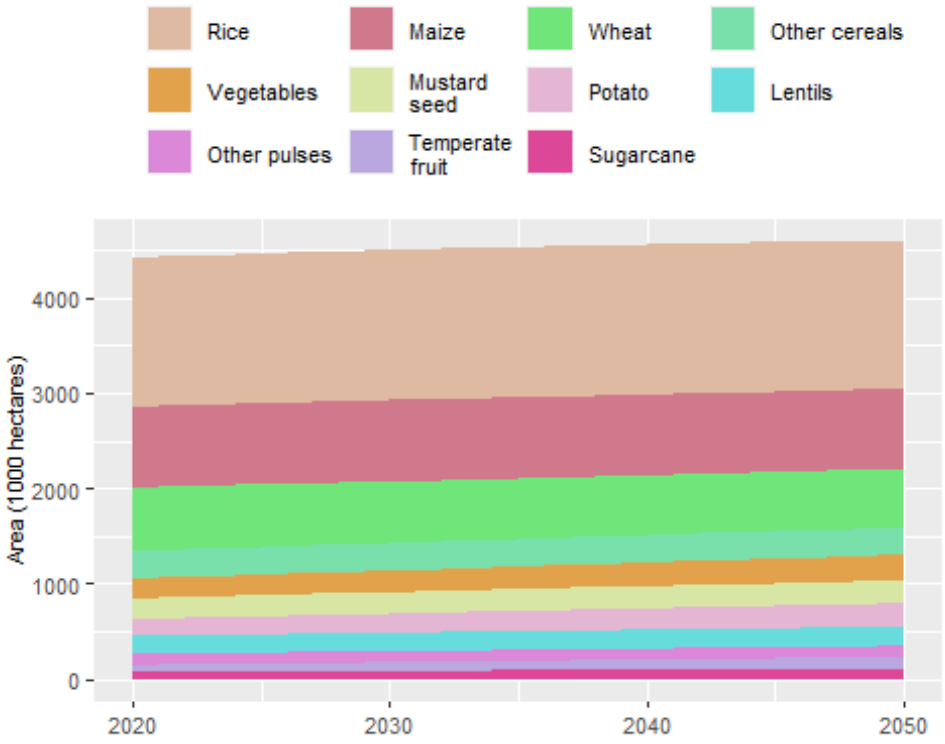

Figure 21: IMPACT 2020-2050 projection of harvested area for key crops and residual categories.

TOTAL AND DISAGGREGATED DEMAND

Demand for key crop and livestock commodities is projected to grow considerably out to 2050 (Figure 22). In most cases, this is projected to come mostly in the form of increased rural household demand. Industrial/seed demand ("other demand") is projected to play an important role in the case of potato, wheat, rice, and, to a lesser extent, maize. A substantial portion of maize demand is projected to come in the form of feed demand. Demand for mustard seed and sugarcane is projected to come entirely from processing plants ("intermediate demand"). A small fraction of potato demand is projected to be in the form of export demand.[4]

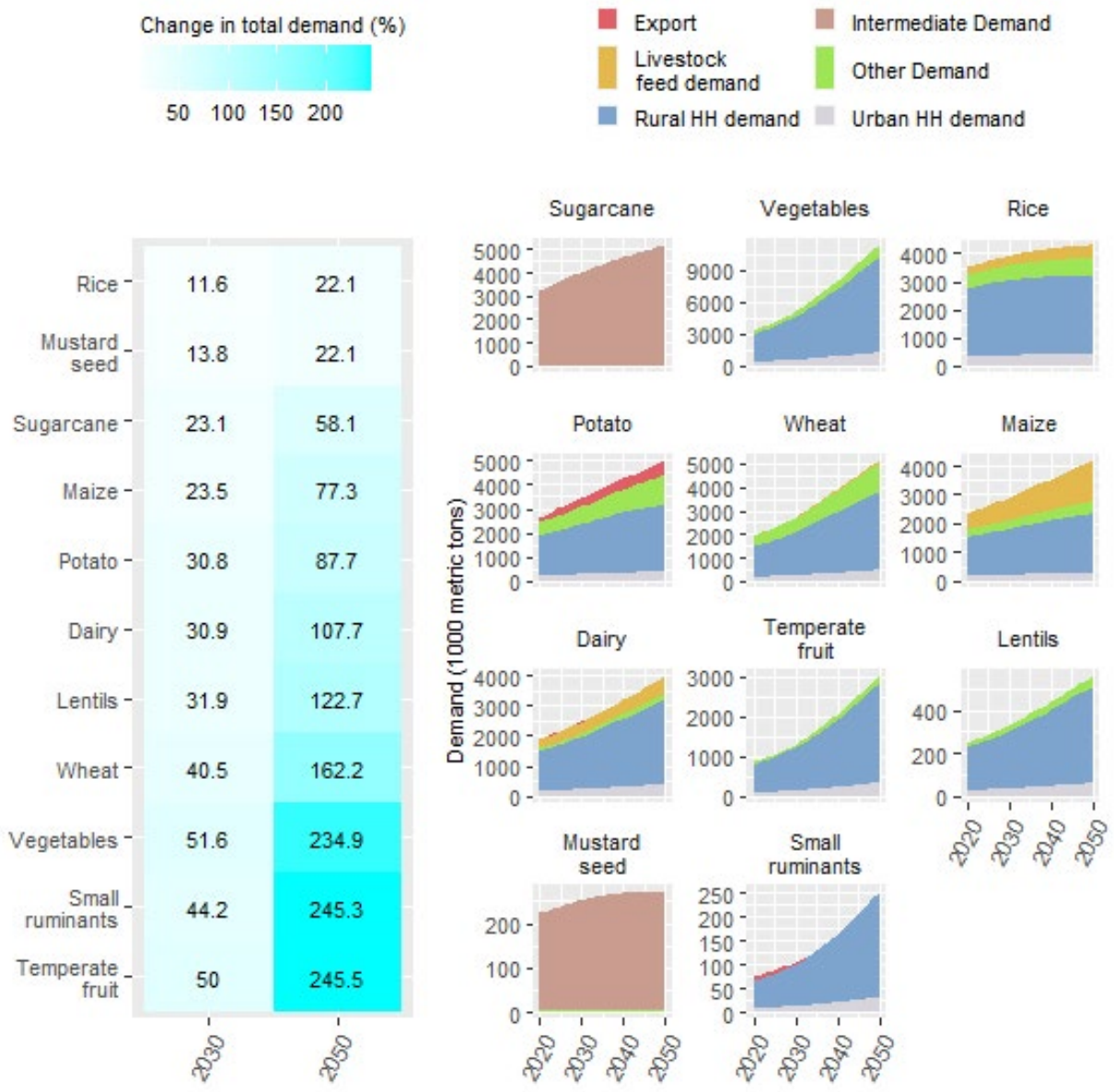

Figure 22: Projection of demand profiles for key crops according to the IMPACT 2020-2050 analysis.

4 "Intermediate demand" refers to processing factory demand and is based on the demand for final processed goods (for example, peanut butter). The "Other Demand" category "summarizes all other demands for agricultural products from sectors outside of the focus of IMPACT (for example, seeds, industrial use)" (Robinson et al. 2015).

DIET TRAJECTORY

Per capita diet composition out to 2050 is presented in Figure 23. This accounts for food available from both domestic production and international trade.[5] The residual categories "other cereals", "other pulses", and "other animal products" are included for context. Per capita consumption of all key food commodities is projected to increase considerably in the coming decades. Rice, wheat, and maize are projected to constitute the primary calorie source out to 2050, followed by potato, fruits and vegetables, pulses (primarily lentils), and animal products.

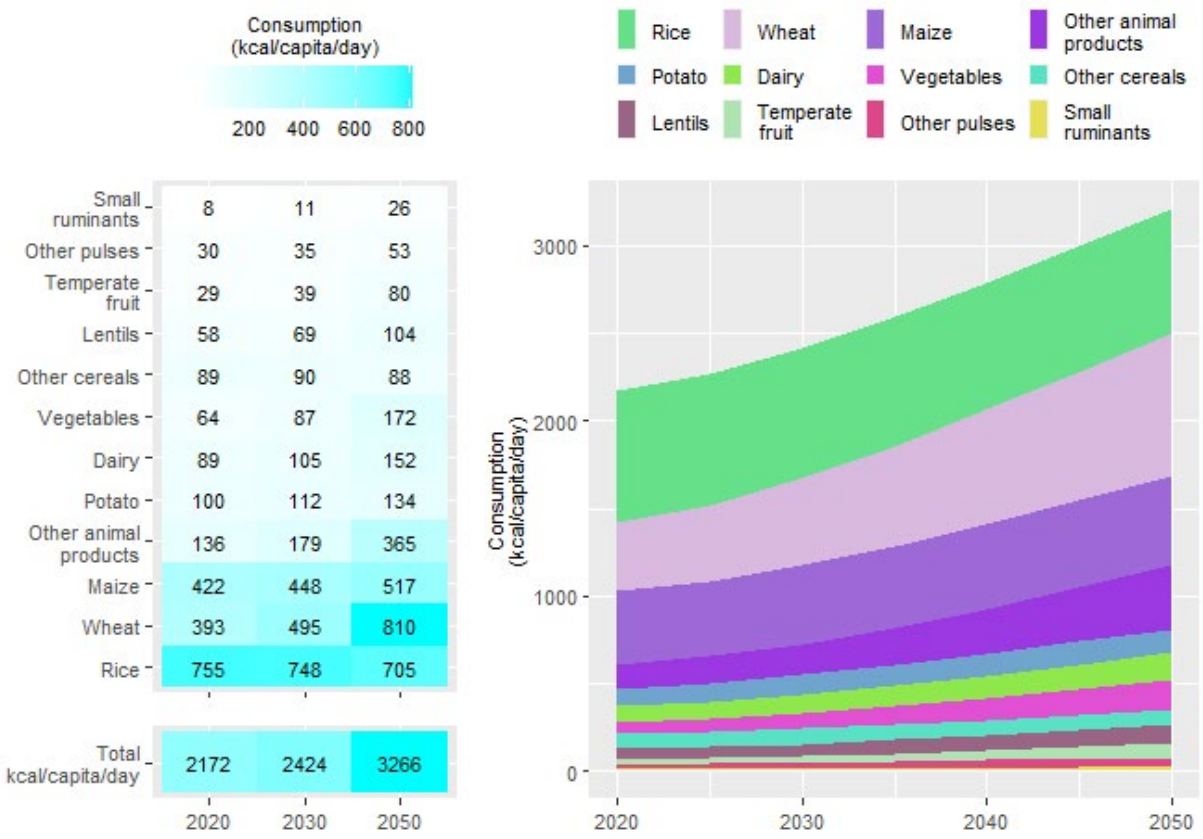

Figure 23: IMPACT 2020-2050 projection of energy value in kcal/capita/day for key products.

In more aggregate terms, consumption of starchy staples (cereals, roots & tubers) is projected to rise from about 1770 kcal/capita/day to 1902 kcal/capita/day in 2030, and then to 2262 kcal/capita/day in 2050. However, as a share of total diet, starchy staple consumption is projected to decline from about 82% to 78% in 2030, and then 69% in 2050. This is consistent with Bennett's law, an empirical trend often seen in developing nations [77]. The receding starchy share of diet is replaced largely by consumption of animal products, which is projected to rise from about 17% to 29% of the diet in 2050. Consumption of fruits and vegetables, while remaining a small part of the diet, is projected to increase both in magnitude and percentage terms, from 5% of the diet to 10% in 2050.

5 Calorie availability is widely accepted as a reasonable proxy for calorie consumption (see for example Kearney (2010)), although the former may be higher than the latter by 10%-14%, the difference being lost as waste at the retail and household levels (Popkin 1993).

The projected increase in total calorie intake per capita would clearly be a welcome development vis-a-vis food security. However, careful attention must be paid to composition. A developing nation's "nutrition transition" from starchy staples to animal calories and other carbohydrate sources is often a transition from starchy carbohydrates to sugary foods and fat calories, with the protein calorie share of diet remaining constant [78]–[80]. Care must therefore be taken to promote replacement of the declining starchy staple share of diet with consumption of proteins (whether of animal or vegetable origin), complex carbohydrates, and fibers; while keeping consumption of fats (especially saturated and trans fats) and free sugars below the World Health Organization's recommended levels of 30% and 10% of the diet, respectively.

PREVALENCE OF HUNGER AND MALNOURISHMENT

The percentage of population at risk of hunger and numbers of undernourished children are projected to decline in the coming decades (Figure 24, left panel). Because the number of undernourished children is partly a function of education, the projected improvement in this variable is due in part to the chosen socioeconomic pathway, SSP5, which assumes improved education levels around the world (see Appendix for details). The improving nutritional security outlook is also in line with recent historical trends.[6] However, import dependence for key commodities is projected to increase substantially out to 2050 (right panel). Increasing import dependence is especially pronounced for wheat, maize, lentils, and fruits & vegetables, which are all projected to rise to between 20%-30% by 2030 and upwards of 50% by 2050. Rice import dependence, on the other hand, is projected to decline to below 10% by 2027, and to steadily approach self-sufficiency thereafter.

Figure 24: Projection of the proportions of the population at risk of hunger, import dependency, and the number of undernourished children between 2020-2050 (presented clockwise from top left). Import dependency indicates the percentage of domestic demand for a given product that is imported.

6 https://data.worldbank.org/indicator/SH.STA.MALN.ZS?locations=NP

Annex 2: Methods for spatial analysis to generate maps for hotspot analysis

For both primary and additional vulnerability indicators, we created raster map layers to show a) the total number of indices classified as 'high' (i.e. hotspots) and b) the breakdown of which indicators showed geographical hotspots. Steps in our analysis were as follows:

VARIABLE SELECTION BASED ON SPATIAL VARIABILITY

All primary vulnerability variables were tested for sufficient spatial variation across the livelihood zones. However, only variables with sufficient spatial variation (CV>=10%) were included in the analysis. Additional vulnerability variables were selected based on available data for indicators of interest identified by the WFP Country Office. They were then tested for sufficient spatial variation and either included or excluded from the analysis in the same way as the primary vulnerability variables. An exception was made for food security data, which was always included regardless of spatial variation; this was due to the limited number of food security datasets available and the necessity to represent food security in some respect to accurately capture overall vulnerability. All primary and additional variables considered for Nepal, including whether they were included or excluded from the analysis, are shown in table 1.

BINARIZATION OF VARIABLES

For the included continuous data variables, a binary score of 1 was allocated if any one metric exceeded the 80th percentile of values within the livelihood zones (indicating a negative outcome); the map shows the sum of these binary layers. Any dataset inputs which were already binary (only applicable for additional variables) were always included where data was present and relevant to WFPs programmes. Exceptions were made in limited circumstances; e.g. if all Hunger Map food consumption scores (a continuous dataset) were extremely high, all values would be categorised as 'high' (i.e. 1), as opposed to only those above the 80th percentile.

AGGREGATION INTO MAP FIGURES

The hotspots maps seen in figures 1-2 were created using sets of these binary raster layers. Figure 1a shows the number of included primary variables allocated 'high' vulnerability in any given cell. Figure 2a shows the same for the included additional variables. Figure 1b is based on the sum of three further binary layers, each of which was calculated as the maximum value of all included binary layers in a given grouping of primary variables (food security & nutrition; inequality; and health). Figure 2b shows the combination of additional variables directly, without the use of any further intermediate layers. If part of a map displays 'no areas of high vulnerability', this means that none of the indicators we included were binarized as 1 (high vulnerability) due to the values in the given cell/s being below a predetermined threshold for 'high' vulnerability. As previously mentioned, this threshold is the 80th percentile of the values for a particular indicator for all cells within the livelihood zones, with the higher percentiles corresponding to greater vulnerability. All of the variables which have been included in the spatial analysis are presented as 'included' in table 1.

AVERAGE VALUES FOR ALL VARIABLES FOR EACH LIVELIHOOD ZONE, VARIABLE INCLUSION/EXCLUSION FROM FIGURES 1-2 MAPS WITH REASONS, AND DATA SOURCES. ALL VARIABLES LABELLED 'INCLUDED' WERE USED IN THE SPATIAL ANALYSIS IN FIGS 1-2.

Variable grouping	Variable	Province 2	Karnali	Sudurpaschim Province	Included / excluded from maps for Nepal	Data Source
Primary variables						
Food insecurity & nutrition	FEWSNET food insecurity (current situation, 1=minimal to 5=famine), 2020	NA	NA	NA	Excluded (data not available)	FewsNet https://fews.net/fews-data/333
	WFP Hunger Map food consumption score (mean), Sep'19-Jun'21	18.8	20.8	23.8	Included	Hunger Map https://hungermap.wfp.org
	Wasting prevalence in under 5s (%), 2000-2019	9.12	5.63	7.14	Included	Local burden of disease https://vizhub.healthdata.org/lbd/dbm
	Stunting prevalence in under 5s (%), 2000-2019	31.3	34.7	30.3	Excluded (insufficient variation)	Local burden of disease https://vizhub.healthdata.org/lbd/dbm
	Underweight prevalence under 5s (%), 2000-2019	20.6	16.5	16.8	Included	Local burden of disease https://vizhub.healthdata.org/lbd/dbm
Gender and educational inequality	Education, female (mean years in 15-49 year olds), 2000-2017	1.42	1.22	1.19	Included	Local burden of disease https://vizhub.healthdata.org/lbd/dbm
	Education, male (mean years in 15-49 year olds), 2000-2017	3.74	4.03	4.10	Included	Local burden of disease https://vizhub.healthdata.org/lbd/dbm
	Education gender gap (mean years in 15-49 year olds), 2000-2017	2.32	2.81	2.90	Included	Calculated from the Local burden of disease https://vizhub.healthdata.org/lbd/dbm
Health	Diarrhea prevalence (%), 2000-2017	15.9	17.0	16.8	Excluded (insufficient variation)	Local burden of disease https://vizhub.healthdata.org/lbd/dbm
	Falciparum incidence (incidence rate), 2019	5.71E-04	8.41E-07	1.02E-04	Included	MAP https://malariaatlas.org/explorer/#/
	Vivax incidence (incidence rate), 2019	0.00922	0.00079	0.00871	Included	MAP https://malariaatlas.org/explorer/#/
	Under 5 mortality (per 1000 live births), 2000-2017	20.67	4.44	7.61	Included	MAP https://malariaatlas.org/explorer/#/

Variable grouping	Variable	Province 2	Karnali	Sudurpaschim Province	Included / excluded from maps for Nepal	Data Source
Additional variables						
N/A	Net out-migration (number of people), 2010	29,655	14,336	31,445	Included	WorldPop https://www.worldpop.org/geodata/listing?id=26
	Mean soil pH at 30cm depth (pH * 10), 2019	65.2	63.8	61.5	Excluded) (not specific to country)	Soil Grids https://soilgrids.org
	Mean soil organic carbon at 30cm depth (dg/kg), 2019	158	389	389	Excluded) (not specific to country)	Soil Grids https://soilgrids.org
	Total area of irrigated land (ha), 2005	4,874,912	755,341	1,844,956	Excluded) (not specific to country)	FAO irrigated area map http://www.fao.org/aquastat/en/geospatial-information/global-maps-irrigated-areas/latest-version/
	Conflict events (number of events), 2018-2021 n.b. Table shows fatal and non-fatal events; map shows fatal events only	457	249	319	Excluded) (not specific to country)	ACLED Dashboard https://acleddata.com/dashboard/#/dashboard
	Active fires (count), 2019	338	661	974	Excluded (insufficient variation)	https://modis-fire.umd.edu/pubs.html, https://firms.modaps.eosdis.nasa.gov/active_fire/#firms-shapefile
	Ethnic group diversity (number of dominant groups coexisting), 2010	2	8	9	Excluded) (not specific to country)	Georeferencing of ethnic groups (GREG) database - http://worldmap.harvard.edu/maps/1894
	Ethnic group type (dominant group category), 2010	Biharis, , Biharis, Nepalese	Tibetans, Bhotias, Tharu, Magars, Bhotias, Tharu, Magars, Newars, Nepalese, Gurungs, Bhotias,	Kanauri, Lahuli, Kumaonis, Garhwalis, Hindi-speaking peoples of Northern India, Newars, Kumaonis, Garhwalis, Bhotias, Hindi-speaking peoples of Northern India, Tharu, Newars, Magars, Nepalese, Bhotias,	Excluded (insufficient variation)	Georeferencing of ethnic groups (GREG) database - http://worldmap.harvard.edu/maps/1894
	Time to nearest city (minutes), 2015	42.9	681.7	402.5	Included	https://malariaatlas.org/research-project/accessibility-to-cities/
	Human appropriation of net primary productivity (% reduction), 2000	52.2	33.3	35.5	Excluded) (not specific to country)	Erb et al, 2007 https://boku.ac.at/wiso/sec/data-download ; https://www.tandfonline.com/doi/abs/10.1080/17474230701622981
	Access to improved water source (% of population), 2000-2017	97.9	90.8	87.8	Excluded) (not specific to country)	IHME ata.org/record/ihme-data/lmic-wash-access-geospatial-estimates-2000-2017