

Crop productivity and suitability analysis for land-use planning in Himalayan ecosystem of Uttarakhand, India

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Crop productivity and suitability evaluation form a prerequisite for land use planning. Soil properties and agro-climatic conditions further influence crop performance. This communication examines crop productivity and suitability in view of agro-ecological conditions and soil properties. Time series data of major crops were gathered from secondary sources and their mean value was obtained. Further, district-wise crop productivity of major crops was analysed and suitability criteria evaluated. We observed that crop productivity is low in the mountainous mainland compared to plain districts. However productivity also varies from crop to crop. Our study further revealed that the highlands are suitable for growing potato, small millets, pulses and temperate fruits whereas the valley regions are suitable for growing citrus fruits, paddy, wheat and spices. Tarai and Doon plains are suitable for growing sugarcane, paddy and wheat.

Keywords: Arable land, productivity, suitability analysis, Uttarakhand Himalaya.

THE Uttarakhand Himalaya characterizes an agrarian economy where mainly traditional cereals grow and their production nature is subsistence. People's livelihood and socio-economic development, on the other hand, largely depends on crop production and productivity. Although crop productivity is low, it has largely declined during the recent past¹. Similarly, productivity of grains under agri-horticulture system has also reduced significantly². Productivity varies from one crop to other. Sekhar³ and Semwal *et al.*⁴ observed that wheat and potato crops have high productivity. Further, crop productivity is higher in the plain region compared to the mountainous mainland.

Agriculture is the basis of the livelihood of over 80% of the working population in Uttarakhand⁵. However, more than 90% of the farmers are marginal and land holdings are less than one ha (ref. 6). Agricultural land is also marginal in terms of potential crop productivity. As a result, many mountain families face food insecurity⁷. Increase in crop productivity using innovative measures is therefore necessary⁸.

In Uttarakhand, crop diversity is very high. It was noticed that a household grows 17–30 crop races/cultivars in a year and in a cropped land^{9–13}. This study supports the above observation as we have noticed that 23 crop races/cultivars of food grains, pulses and oilseed and above 20 cultivars of fruits and vegetables grow in Uttarakhand. Meanwhile, crops have specificities as some of them grow in very specific areas. Cash crops (onion and ginger), small millets and pulses (barley, gahat, bhatt, soyabean, manduwa, ramdana, rajama, horse gram, tuar and sawa) grow largely in the mountainous mainland. Wheat and paddy are common crops which grow in every district. Sugarcane and groundnut grow in the plain districts. Paddy, maize and pulses grow twice in a year, both in *Kharif* and *Jayad* seasons, only in three districts – Nainital (plain areas), Udamsingh Nagar (USN) and Haridwar. Meanwhile, potato grows twice in a year in *Rabi* and *Khairf* seasons in every district.

Climate is favourable for growing a number of crop races/cultivars. As a result, Uttarakhand has high crop diversity which varies from the Shivalik foot hills to the high altitudes. In contrast, production and productivity of crops decrease with increasing altitudes. In terms of occupation, agriculture is the mainstay of the people of the hills, whereas in the plain areas, people are also engaged in tertiary and quaternary sectors. Inadequate production and productivity of crops impede the sustainable livelihood of rural people.

The Uttarakhand Himalaya is ecologically fragile and economically underdeveloped with severe limitations on resource productivity¹⁴. Subsistence agriculture is the main source of livelihood as a large number of working population is involved in its practices¹⁵. Arable land represents only 18.5% of the total geographical area and further, most of the area is under hilly terrain where possibility of expansion of arable land is just negligible. Less proportion of arable land and hilly terrain cause low production of crops and thus results in low productivity, food insecurity, malnutrition and unemployment driven out-migration.

The main purpose of this study was to analyse productivity and suitability of major crops at the district level according to the altitudinal gradients in Uttarakhand. The study further dealt with how crop productivity can be enhanced using suitability criteria and what policy measures need to be taken for suitable land-use planning.

The study area stretches between 28°53'24"–31°27'50"N and 77°34'27"–81°02'22"E with an area of 53,483 km². It has 13 districts in total and characterizes two distinct landscapes, i.e. the mountainous mainland (about 92.6% area) and plain areas that comprise Doon valley and Tarai plains (7.4%). Further, out of its total mountainous area, about 16% is snow clad. USN, Haridwar and parts of Nainital and Dehradun districts possess fertile alluvial plains. Altitude ranges from 300 m to above 7000 m and the climate varies accordingly. Arable

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land is only 18.5% and a large part of it is mountainous where crop production and productivity is low although, the climate supports high diversity and productivity of crops.

This study was conducted employing qualitative approach. We gathered data on district-wise total area and arable land and its share in the district and state. Further, time series data (2010–2015) on area, production and productivity of the major crops were gathered from secondary sources – Department of Agriculture and Horticulture (Dehradun, Uttarakhand) and the mean values were noted. Based on mean value of the area, production and productivity; we indexed all three variables into high, medium and low levels. In addition, we analysed productivity of major crops at the district level and indexed crop productivity into high, medium and low levels to determine crop suitability in different districts. We also gathered climate data – temperature (minimum and maximum) and rainfall at district level from the District Statistical Handbooks to establish the relationship between climate and crop suitability. Based on climate, we divided Uttarakhand vertically into agro-ecological zones and suggested crop suitability along the altitudinal gradients. Crop suitability at the altitudinal gradients was also observed through soil characterization. Finally we suggested the suitability of crops at the district level. A rural participatory approach through a rapid field visit of the study area was employed for further interpretation of data.

Area wise, Chamoli district shares 15% area (highest) followed by Uttarkashi (14.3%), Pauri (11.8%), Tehri (8.6%), Almora (8.2%), Pithoragarh (7.3%) and Nainital (7.2%) districts. Bageshwar shares 3.7% area (lowest) followed by Champawat and Rudraprayag (4.1% each). Haridwar shares 4.3%, USN 5% and Dehradun 6.4% geographical area of the state. In terms of district share of arable land, Haridwar shares the highest (61%) followed by USN (58.9%) and Almora districts (28%). Dehradun shares 23% arable land whereas Nainital shares 20.3%. The lowest share of arable land is obtained by both Chamoli and Uttarkashi districts, i.e. 6.7% each. Other districts share between 10% and 18%. State share of arable land varies from 15% in USN (highest) to 2.6% in Rudraprayag (lowest). Haridwar district has 14% state share, Almora 12.3% and Pauri 10.1%. Other districts occupy between 3% and 9% state shares (Table 1).

Table 2 describes mean value (five years) of area, production and yield of the major crops (12). In terms of area, wheat obtains the highest area (355.7 ‘000 ha) followed by paddy (264.4), ragi (118.7) and sugarcane (106) whereas spices (three varieties) obtain the lowest area (3.7) followed by potato (18.6), maize (26.5) and oilseeds (31.2; four varieties). Pulses (four varieties) and small millets obtain 61.7 and 68.6 ‘000 ha area respectively. In terms of production, the highest is from sugarcane crop (6275.1 ‘000 MT) followed by wheat (860.2) and paddy (582.1). Potato largely grows in the highlands and its

production is substantial (213.7). Production of ragi crop is 167.1. Other crops such as pulses, oilseeds, maize, barley, spices and small millets have <100 ‘000 MT productions. Sugarcane has the highest yield (59.2 MT/ha) followed by potato (11.9) and spices (11.7). Wheat and paddy obtain 2.4 and 2.2 MT/ha yield. Other crops have <2 MT/ha yield.

We indexed crop-wise data of area, production and productivity of the major crops into three levels – high, medium and low (Table 3). Wheat, paddy, fruits and vegetables have high area (>200 ‘000 ha); ragi and sugarcane (100–200) have medium area and small millets, pulses, oilseeds, maize, barley, potato and spices have low area (<100). In terms of production of crops (‘000 MT), sugarcane, fruits and vegetables have high production (>1000); wheat and paddy (500–1000) have medium production and a number of crops – potato, ragi, small millets, pulses, spices, maize, oilseeds and barley have low production (<500). Sugarcane has high productivity

Table 1. Arable land in Uttarakhand

District	Total land (ha)	Arable land (%)	State share of arable land (%)
Almora	464,942 (8.2)	28	12.3
Bageshwar	207,902 (3.7)	17.3	3.4
Chamoli	851,764 (15)	7.6	6.2
Champawat	233,225 (4.1)	15.2	3.3
Dehradun	364,830 (6.4)	23	7
Haridwar	243,162 (4.3)	61	14
Nainital	406,118 (7.2)	20.3	7.8
Pauri	669,055 (11.8)	16	10.1
Pithoragarh	411,883 (7.3)	11.3	4.4
Rudraprayag	234,796 (4.1)	11.7	2.6
Tehri	485,517 (8.6)	17.8	8.2
USN	286,495 (5)	58.9	15
Uttarkashi	812,689 (14.3)	7.6	5.7
Total	5,672,378 (100)	18.5	100

Source: Department of Agriculture and Horticulture, Dehradun, Uttarakhand (2015). Figures in parenthesis are the percentage of total area.

Table 2. Area, production and yield (mean value 2010–2015)

Crops	Area*	Production**	Yield***
Wheat	355.7	860.2	2.4
Paddy	264.4	582.1	2.2
Fruits and vegetables	208.5	1136.6	5.4
Ragi	118.7	167.1	1.4
Sugarcane	106	6275.1	59.2
Small millets	68.6	84.4	1.2
Pulses (4)	61.7	50.7	0.8
Oilseeds (4)	31.2	33.6	1.1
Maize	26.5	39.4	1.5
Barley	22.3	29.2	1.3
Potato	18.6	213.7	12
Spices (3)	3.7	43.4	11.7

Department of Agriculture and Horticulture, Dehradun.
*‘000 ha; **‘000 MT; ***MT/ha.

Table 3. Levels of area, production and productivity of crops (mean value)

Indices	Levels	Crops
Area ('000 ha)		
>200	High	Wheat, paddy, fruits and vegetables
100–200	Medium	Ragi and sugarcane
<100	Low	Small millets, pulses, oilseeds, maize, barley, potato and spices
Production ('000 MT)		
>1000	High	Sugarcane, fruits and vegetables
500–1000	Medium	Wheat and paddy
<500	Low	Potato, ragi, small millets, pulses, spices, maize, oilseeds and barley
Productivity (MT/ha)		
>20	High	Sugarcane
10–20	Medium	Potato and spices
<10	Low	Fruits and vegetables, wheat, paddy, maize, ragi, barley, small millets, oilseeds and pulses

Source: By authors.

Table 4. District-wise productivity (MT/ha) of crops (high productivity)

District	Sugarcane	Potato	Spices (four varieties)	Fruits and vegetables (above 20 varieties)
Almora	–	7.5	8	7.74
Bageshwar	–	6.8	8.6	5.39
Chamoli	–	10.3	7.6	6.99
Champawat	–	14.2	7.9	2.40
Dehradun	58.7	22.13	10.3	5.11
Haridwar	60.3	15.9	–	8.59
Nainital	62.6	9.5	10.2	5.49
Pauri	–	8.9	6.5	2.24
Pithoragarh	–	9.7	6.5	5.64
Rudraprayag	–	8.9	–	2.85
Tehri	–	9.2	9.9	3.34
USN	62.6	21.3	–	8.17
Uttarkashi	–	10.7	9.7	6.43
Uttarakhand	61	12	8.5	5.4

Source: Department of Agriculture and Horticulture, Dehradun (2015); analysed by authors.

(>20 MT/ha); potato and spices (10–20) have medium productivity and fruits, vegetables, wheat, paddy, maize, ragi, barley, small millets oilseeds and pulses have low productivity (<10).

We analysed district-wise (13 districts) productivity of 11 major crops grown in Uttarakhand. Of these, four are cash crops and their productivity is the highest (Table 4). Sugarcane grows only in four districts of the state that lie in the plain areas. USN and Nainital districts have 62.6 MT/ha productivity of sugarcane. Two other districts Haridwar and Dehradun have 60.3 and 58.7 MT/ha productivity respectively. Potato is the second important cash crop in terms of productivity which grows in every district. Dehradun district has the highest productivity (22.13) of potato, followed by Haridwar (15.6), Champawat (14.2), Uttarkashi (10.3) and Chamoli (10.3). Other districts have 7–10 MT/ha productivity. Spices, mainly ginger, are the third important crop in terms of productivity (average 8.5). The productivity varies from 6.5 MT/ha in Pauri district to 10.3 MT/ha in Dehradun district. We noticed that three districts – Haridwar, Rudraprayag and

USN do not grow ginger. Fruits and vegetables grow in all districts while their types and productivity varies. Haridwar and USN have the highest productivity, i.e. 8.59 and 8.17 MT/ha respectively. These districts grow mango, litchi, guava and papaya. Almora, Chamoli and Uttarkashi districts grow temperate fruits mainly apple, pear, peach, apricot, walnut, plum, almond, etc. and their productivity is high.

Productivity of foodgrains is medium and varies from district to district (Table 5). Among foodgrains, wheat obtains the highest productivity (1.9 MT/ha) followed by paddy (1.6), barley and maize (1.4 each) and small millets (1.2). USN obtains the highest productivity followed by Haridwar and Dehradun. Productivity of paddy is the highest in USN (2.5) followed by Nainital (2.3) and Dehradun (2). Uttarkashi (1.7), Haridwar (1.6), Rudraprayag (1.6) and Tehri (1.5) districts have moderate productivity of paddy. Other districts have less than 1.5 MT/ha productivities. Barley and maize are grown in all districts and their productivity is comparatively high in plain areas. Small millets are largely grown in the mainland of

Table 5. District-wise productivity (MT/ha) of crops

District	Medium					Low	
	Wheat	Paddy	Barley	Maize	Small millets	Pulses*	Oilseed**
Almora	1.3	1.0	1.0	1.7	1.2	0.6	0.3
Bageshwar	1.3	1.2	1.3	1.3	1.25	0.5	0.2
Chamoli	1.5	1.4	1.5	1	1.5	0.5	0.2
Champawat	1.3	1.0	1.2	0.9	1.35	0.6	0.3
Dehradun	2.4	2	2	1.8	1.45	0.7	0.6
Haridwar	2.5	1.6	1.3	1.9	0	0.3	0.7
Nainital	2.8	2.3	1.6	1.7	1.35	0.7	0.8
Pauri	1.1	1.1	1.1	0.9	1.15	0.6	0.2
Pithoragarh	1.4	1.3	1.4	1.2	1.45	0.7	0.2
Rudraprayag	1.6	1.6	1.5	1.2	1.7	0.5	0.2
Tehri	1.6	1.5	1.2	1.1	1.4	0.6	0.2
USN	4	2.5	1.3	2.2	0	0.4	0.7
Uttarkashi	1.7	1.7	1.4	1.2	1.7	0.6	0.2
Uttarakhand	1.9	1.6	1.4	1.4	1.2	0.6	0.4

Source: Department of Agriculture and Horticulture, Dehradun (2015).

*Ramdana, Urd, Gahat, Tuar, Rajma and Soya bean, Bhatt, Horse gram, Peas and lentil.

**Til, Bhangzeera, Mustard and Groundnut.

Table 6. District-wise temperature and rainfall

District	Temperature (°C)		Rainfall (mm)
	Maximum	Minimum	
Almora	27.1	3.1	1,015
Bageshwar	30.2	-3.1	1,114
Chamoli	31.7	-1.6	1,225
Champawat	28.8	-3.7	1,452
Dehradun	41.2	3.1	1,353
Haridwar	40	3.1	1,271
Nainital	32.5	-1.6	1,513
Pauri	31.7	-1.6	1,225
Pithoragarh	32.5	-4.6	1,114
Rudraprayag	37.5	-4.6	1,375
Tehri	33.3	-2.2	1,526
USN	43.5	3.3	1,256
Uttarkashi	31.7	-1.6	1,225
Uttarakhand (average)	33.7	-0.9	1,281

Source: District statistical diaries of all 13 districts of Uttarakhand (2015).

Uttarakhand with low productivity. Although pulses and oilseeds grow in all districts, their productivity is low.

Table 6 shows that the maximum temperature varies from 43.5°C in USN (highest) to 27.1°C in Almora district (lowest). Minimum temperature ranges between -4.6°C (lowest in both Pithoragarh and Rudraprayag districts) and 3.3°C (highest in USN). In the mountainous mainland, the snow falls during winter and severe cold waves reduce temperature. The average maximum temperature is 33.7°C and the average minimum temperature is -0.9°C in the state. The average rainfall in the state is 1281 mm and in every district, rainfall is above 1000 mm. Rainfall varies from 1015 mm (lowest) in Almora to 1526 mm (highest) in both USN and Tehri districts.

We analysed crop suitability based on their area, production and productivity (Table 7). Sugarcane is an important crop which has high productivity, and grows only in the plain districts. Fruits and vegetables grow in all districts with high diversity. Yet, based on their productivity and types, Chamoli, Dehradun, Haridwar, Uttarkashi, Almora, Bageshwar, Nainital, Pithoragarh and USN districts are suited for their cultivation. Ginger is an emerging cash crop and its productivity is high; it can grow mainly in Chamoli, Dehradun, Pauri, Tehri, Uttarkashi, Almora, Bageshwar, Champawat, Nainital and Pithoragarh districts. Spices, mainly ginger and garlic are suited to grow in Almora, Bageshwar, Chamoli, Champawat, Dehradun, Nainital, Tehri and Uttarkashi districts. Productivity of potato is substantial and it is suited to grow in Chamoli, Dehradun, Haridwar, Uttarkashi, Champawat and USN districts. Wheat and paddy crops are suited to grow in the all the plain districts and few river valleys area of hill districts. Productivity of maize, small millets, pulses and oilseeds is low although they are the main cereal crops and their agro-diversity is high.

Uttarakhand state has rich agro-climate for growing diverse crop races/cultivars. Crop suitability depends on the agro-ecological zones which vary from tropical (300–1100 m) to sub-tropical (1100–1800 m), temperate (1800–2800 m) and cold (2800–3400 m) (Figure 1). Paddy, wheat, sugarcane, mango, guava and papaya are the major crops grown in the topical zone mainly in Tarai and Doon valley. In the valley regions, paddy, wheat, tomato, citrus and plum are grown. Further, paddy, wheat, millets, pulses, oilseeds, onion and citrus are the suitable crops in the sub-tropical agro-ecological zone. In the highlands (1800–2800 m), which fall under temperate agro-climate zone, multi-grain (Barahnaza), millets, pulses, oilseeds, potato, vegetables, apple, almond, pear

Table 7. District-wise crop suitability areas

Crops	Districts
Sugarcane	Udhamsingh Nagar, Haridwar and plain areas of Nainital and Dehradun
Potato	Chamoli, Champawat, Dehradun, Haridwar, USN and Uttarkashi
Spices	Almora, Bageshwar, Chamoli, Champawat, Dehradun, Nainital, Tehri and Uttarkashi
Fruits and vegetables	Almora, Bageshwar, Chamoli, Dehradun, Haridwar, Nainital, Pithoragarh, USN and Uttarkashi
Wheat	Chamoli, Dehradun, Haridwar, Nainital, Rudraprayag, Tehri and Uttarkashi
Paddy	Dehradun, Haridwar, Nainital, Rudraprayag, Tehri, USN and Uttarkashi
Barley	Chamoli, Dehradun, Nainital, Pithoragarh, Rudraprayag and Uttarkashi
Maize	Almora, Dehradun, Haridwar, Nainital and USN
Small millets	Almora, Bageshwar, Chamoli, Champawat, Dehradun, Nainital, Pithoragarh, Rudraprayag, Tehri and Uttarkashi
Pulses	All districts except USN and Haridwar
Oilseeds	Dehradun, Haridwar, Nainital and USN

Source: By authors.

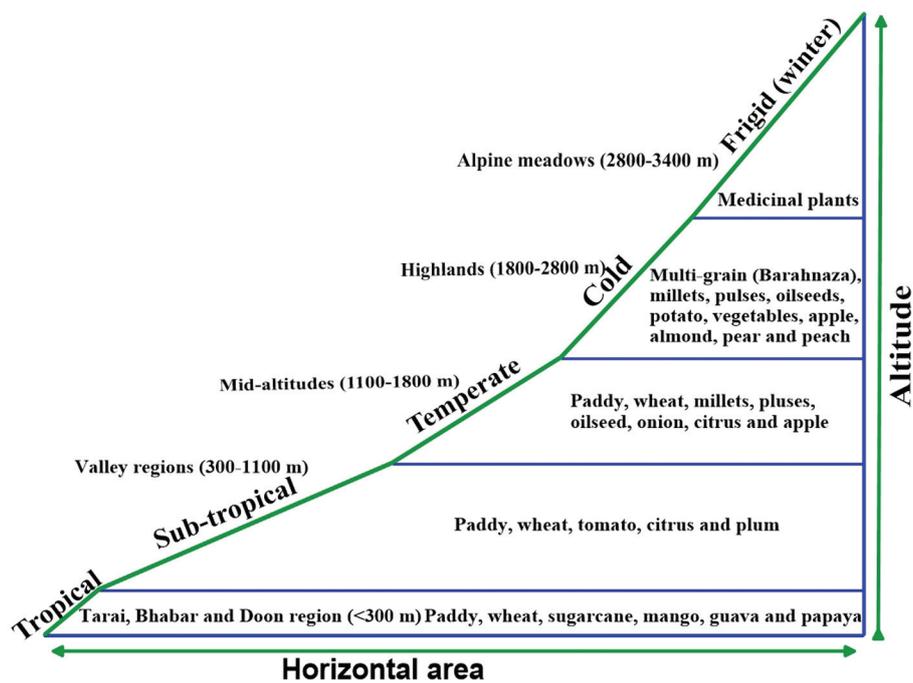


Figure 1. Agro-ecological zones and crop suitability. Source: by authors.

and peach are grown largely. Cold alpine meadows are suitable for growing medicinal plants. Spices mainly ginger, garlic, chilli and turmeric grow from tropical to temperate zones.

Soils of Uttarakhand are rich in organic content suitable for the growth of number of crops. Mainly four soil types are found in Uttarakhand, i.e. debris eroded from glaciers in the northern part – highlands and alpine pasture lands, alluvial soil in the river valleys and Tarai and Doon plains, unfertile soil in Bhabar region and mountain soil in the mid-altitudes and the highlands. Mountain soil and glacier formed debris is susceptible to soil erosion. This area is suitable for growing temperate fruits such as apple, peach, pear, plum, apricot and nut fruits. Medicinal plants can also be grown in this part of the state.

Alluvial soil is suitable largely for the production of sugarcane, paddy and wheat.

Crop productivity and suitability is dependent on three important components, i.e. arable area, agro-climatic conditions and soil fertility. Our study revealed that crop suitability in Uttarakhand varies along with altitudinal gradients and according to agro-ecological zones. Varied topography and agro-climate provide a base for diversity in crops and thus, agro-biodiversity is the highest in Uttarakhand Himalaya. We noticed that crop productivity also changes according to soil types. The valleys and Tarai and Doon plains stand for high productivity of crops because of alluvial soil brought and deposited by perennial rivers. Meanwhile, the hill arable slopes have low fertility of soil due to the high rate of soil erosion. Agriculture of the

mainland of Uttarakhand is rainfed and thus crops grow mainly during monsoon season. However, substantial rainfall and feasible climate support crop production.

We observed that arable land in Uttarakhand is only 18.5% which results in low production of crops. Further, because about 92.6% area of Uttarakhand is mountainous and its terrain is undulating, the land capability and soil fertility is low. This leads to low crop productivity. On the other hand, mountain areas of Uttarakhand largely produce subsistence cereals as about 80% of the arable land is under its cultivation; however productivity is low, which is <1 MT/ha. Some crops like potato, fruits and vegetables have comparatively high productivity (average 5 MT/ha) whereas area under these crops is only 10% of the arable land. In India, productivity of fruits and vegetables was recorded as 17.6 MT/ha in 2012–13 (ref. 16). The districts that lie in the plain areas and foothills of the Shivalik ranges have only 7.4% geographical area however, average arable land (district share) is above 50%. Production and productivity of crops in these districts are also high. Potential of sugarcane production in plain districts is high as its productivity is the highest. Further, wheat and paddy are other major crops which have high productivity mainly in the plain districts and in the river valleys. Due to high soil fertility and much arable land, the districts that lie in the plain regions have high potential to grow suitable crops.

Uttarakhand state grows many crop races/cultivars as agro-biodiversity is very high; however productivity of a number of crops is significantly low. We observed that although Uttarakhand has varied topography and a range of agro-ecological zones suited for growing various types of crops, due to lack of proper land-use planning and suitability analysis of crops, it has not been able to harness these rich and suitable conditions. Analysis of crop productivity and suitability suggests that selection of suitable crops in different districts and altitudinal gradients (horizontally and vertically) will enhance crop production and productivity and will restore fragile landscape.

Our study revealed that temperate fruits, mainly apple, peach, pear, plum, apricot and walnut can be grown in the highlands where the agro-climate is quite suitable. Land demarcation for creation of fruit belts according to altitude is inevitable, so that fragile landscape can be restored and productivity can be enhanced. Mango, guava and papaya can be grown in the tropical regime of the valleys and Tarai and Doon plains. Citrus fruits have potential to grow in sub-tropical regions. Potato is an important cash crop grown both in mountainous and plain areas of the state and its productivity is substantial. It requires intensive cultivation with more area under its cultivation. Wheat and paddy are the staple foods and area under their cultivation is large. Although their average productivity is low, they can grow in plain districts where productivity is comparatively high. Spices, mainly ginger and garlic, can be grown largely in the valleys and mid-

altitude to enhance livelihoods. Finally, crop cultivation should be intensified and modern innovation in agriculture should be employed in cropped land to enhance productivity.

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