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Soil characteristics and land use in flood prone lower Gandak plain

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Abstract
Soil of any area is the product of the processes through which it is formed. Local parent materials or transported materials from other places/regions have also important bearing on its characteristics. Change in geomorphic bases and processes of soil formation lead to significant changes in its quality. In its qualitative change, climate/precipitation has direct bearing as it provides productivity to the soil. The Lower Gandak Plain has warm and humid climate due to which fertility of this region is very high and it is one of the most fertile pockets/ regions of the world. The Gandak plain and soils of the area is on make with annual flood water spreading. High population density and greater pressure on land for cultivation to feed people has led to excessive use of land surface. Apart from river channels, no natural landscape is visible. Almost entire Lower Gandak Plain has a cultural landscape. The Plain is flood prone due to which crops are also damaged annually. Change in the channel course also causes land/soil to be damaged. Land use has gone through changes over time. The pace of change was slower a few decades/centuries before, while in recent times it is changing with rapid rate. Land use and land cover in the Gandak Plain has mostly been modified by human activities. Therefore, it is attempted to (i) explain soils and land use in the Lower Gandak Plain and (ii) examine the spatial distribution of land use.

Keywords: lower gandak plain, flood prone, soil types, land use, cultivable land. non-cultivable land

Introduction

Geomorphic processes operating in any part of the global surface determine development of soil. One of the best soils developed are associated with fluvial processes with higher temperature. Fluvial processes are found in those areas where precipitation is sufficient. Higher humidity in the area concerned causes greater vegetative growth in association with higher temperature. Thus, humus content found is abundant in the fluvial process dominated regions. The Lower Gandak Plain falls at the outfall of the Himalayan slope and its altitude is less than 130 meter. The Lower Gandak Plain witnesses tropical climate and hence, has high vegetation growth, suitable for cultvation and high humus content and thus very fertile soils are found.

The term "land use" is defined as "the arrangements activities, and inputs people undertake in a certain land cover type to produce, change or maintain it" (FAO/UNEP, 1998) [5]. Therefore, land use has a direct association with human activities at earth surface. When land is used by human beings to fulfill their needs, it is termed as land use. The concept of land use change refers to "a change in the use or management of land by humans, which may lead to a change in the observed physical and biological cover of the earth's land, as vegetation or man-made features" (IPCC 2000) [8]. The intensity of flooding has been continuously increasing and it has increased by four times in comparison to 1980 (EASAC, 2018) [3]. IPCC (2018) [9] observes that there is very high degree of expectation to further increase in flood frequency.

Changes on land surface are quite natural, obvious and are happening since unknown times, but the degree of change is not alike since then. Increasing population is a big driving force for land use change (Vitousek *et al*., 1997) [22]. Natural habitat has been turned into cultural landscape due to use of advancing technologies since a few centuries. When population was less a few thousand years before, environmental/ land use changes were not so drastic but increasing population density, their needs, technological advancement and overall making the life more comfortable has led to more and more resource utilization from our surroundings. That is why more and more land has been put into agriculture, roads, bridges, reservoirs, and many more. Absolute changes have taken place if we compare even for just one century before. In other words, more rapid land use changes are witnessed in the last 100 years, it is still under tremendous pressure. Since last fifty years, agriculture has a great challenge to provide food to global increasing population (UNESCO, 2006) [21]. The change has severely accelerated since 1970s and has reached to an alarming stage (Lambin and Geist, 2006) [11]. It is resulted many cultivated areas turning to non-productive barren and waste land. Many of the areas are turning to fallow land. All is happening at the cost of natural vegetative cover as it is removed for use by human beings.

Modern technology of remote sensing and satellite data has helped a lot in tracing out the actual status of land in shortest possible time with greater possibility of repetitive studies. It is much easier to quantify, map and detect changing pattern on earth surface (Chen *et al*., 2005; Rahman *et al*., 2011) [2, 17]. To find changes in land use and land cover (LULC) with the help of satellite data, it is very convenient and easy. There is direct relationship between land use change and water availability on surface for runoff. When natural vegetation is removed and cultural space is created, runoff increases. It happens because natural vegetative cover used to hold water temporarily, evaporation as well as infiltration is increased and runoff is lowered (Poelmans, 2010) [14]. Due to human activities, about 83 percent of land surface of the world has been affected (Sanderson *et al*., 2002; Liu and Titan, 2010) [18, 12]. It has been studied and found that human footprint has altered about 83 percent of global land surface and it is the cause of about 60 percent degradation of terrestrial ecosystem after mid-20th century (EU, 2012) [4]. Land use and land cover changes are causing changes in climate change and food production at different scales starting from local to regional to global (Jain and Yang, 2005; Tao *et al*., 2013) [10, 20].

Floodplain is basically low lying areas nearby river which expands away from its banks in both directions depending upon physical and physiographic characteristics of the area concerned. When a river is at spate, water spread is the most. For certain level of discharged water how much area is submerged, when it is identified, it is called flood zone map. Flood zone maps are prepared for different return period of flood which is computed statistically by several methods based on peak discharge analysis (Prasad, 2009; Prasad and Rishideo, 2018) [15, 16]. For better understanding and record for flood mitigation, one should have mapping of areas for more than 100-year of return of floods by estimation so that preparation could be made accordingly. For this purpose, area can be surveyed and information can be collected through high resolution satellite data/imageries, air photo, Light Detection and Ranging (LiDAR) images (APEGBC, 2012) [1]. These are used to prepare geological, topographical and geomorphological mapping. WMO (2007) [23] observes, "The development of land has consequences on the flow of water on the one hand, either by accelerating runoff through reducing the infiltrating capacity of soil or obstructing the natural drainage system, as well as sediment on the other". NRSC (2020) [13] in association with National Disaster Management Authority (NDMA) has prepared a very good report about Flood Hazard Atlas of Bihar with detail description of different aspects. The Sustainable land management tries to focus on integrated land, water, biodiversity and environmental management (INTOSAI, 2012) [7] to meet the needs of existing people while sustaining ecosystem services and livelihood for the generations yet to come. Therefore, there has to be a balance between need of the people and ecological system for a better and balanced growth.

Objectives, data and Methods

Objectives

The main objectives of this study are to (i) explain soils and land use in the Lower Gandak Plain and (ii) examine spatial distribution of land use.

Data Source and Methods

The data used in this paper have been, broadly, classified into two types (a) population and district-wise flood plain area distribution, (b) district-wise soils distribution and land use. Population data has been collected from Census of India 2011. Data pertaining to basin-wise area and its population is collected from Ganga Flood Control Commission (GFCC). Major soils found in the study area have been taken from Comprehensive Plan Report of the Gandak River 2004. Land use data is nine-fold, i.e., classified into nine categories. They are forests, land put to non-agricultural uses, barren and wastelands, area under permanent pastures and grazing lands, area under miscellaneous trees crops and groves, cultivable waste-land, current fallow, fallow other than current fallow and net area sown. The areas under these heads are collected from Directorate of Economics and Statistics, Government Bihar, for the period 2011-12 for eight districts. Two districts are from Utttar Pradesh for which land use data is taken from Sharma and Tiwari (2013) [19].

Nine categories of land use are reorganized into two groups (i) Cultivable land and (ii) Non-cultivable. Cultivable groups are that category of land on which cultivation could be done, but not necessarily that it is right now under cultivation. They include (a) net sown area, (b) current fallow, (c) other than current fallow and (d) land under miscellaneous tree, crop and groves and (e) cultivable waste land. Non-cultivable groups are that category of land on which cultivation is not at all possible "under present condition". They include (a) forest, (b)) permanent pasture and grazing land, (c) land put to non-agricultural uses and (d) barren and un-cultivable land.

River basin area as well as administrative boundaries rarely coincides. Ganga Flood Control Commission (GFCC) has delineated basin area of the Gandak River in the plain and, it has been shown by district-wise bar diagram. Basin-wise area and population for 2001 is given by the GFCC (2004) [6]. Since the exact earmarking of basin area is not known to the authors, the population for 2011 was extrapolated based on the information provided by the GFCC (2004) [6]. It is a comparative expression of total area of the districts as well as its portion of area falling into the Lower Gandak Basin. Pie diagrams shown for districts area and area under the basin represent a relative contribution in their totals. As mentioned above, land use categorized in two, both are represented by district-wise bar diagrams. They vividly exemplify the relative area under different land uses. How much area is under cultivable and non-cultivable categories in districts in terms of percentages is also shown by percentage bar diagram.

Study Area

The Lower Gandak Plain occupies an area of 7620 km^2 below Triveni where river debouches into plain. Triveni is the tri-junction of Pachnad and Sonha with the Gandak. It forms the boundary between India and Nepal. Upstream to it, huge Himalayan catchment is there from where, river collects rain and snowmelt water during summer and beings flood havoc in the plain. The upper catchment covers the area of Tibet and Nepal where it occupies 38980 km^2. The total catchment, upper and lower, is 46600 km^2. In this way, lower catchment is very narrow and small from where huge collected water along with its sediment has to pass through during high flood/discharge. Only 16.35 percent area is in the plain while 83.65 percent is in the Himalayan zone. A map of upper Himalayan catchment as well as the lower can be seen from Figure 1.

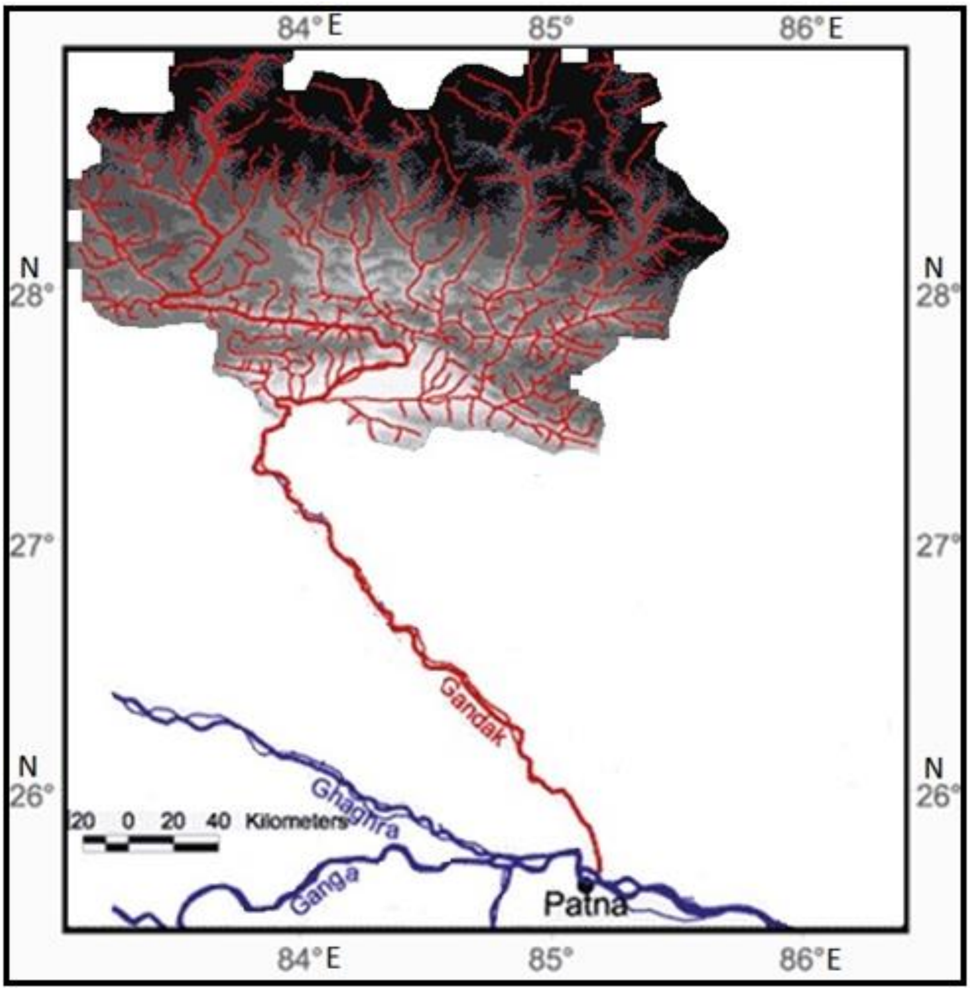
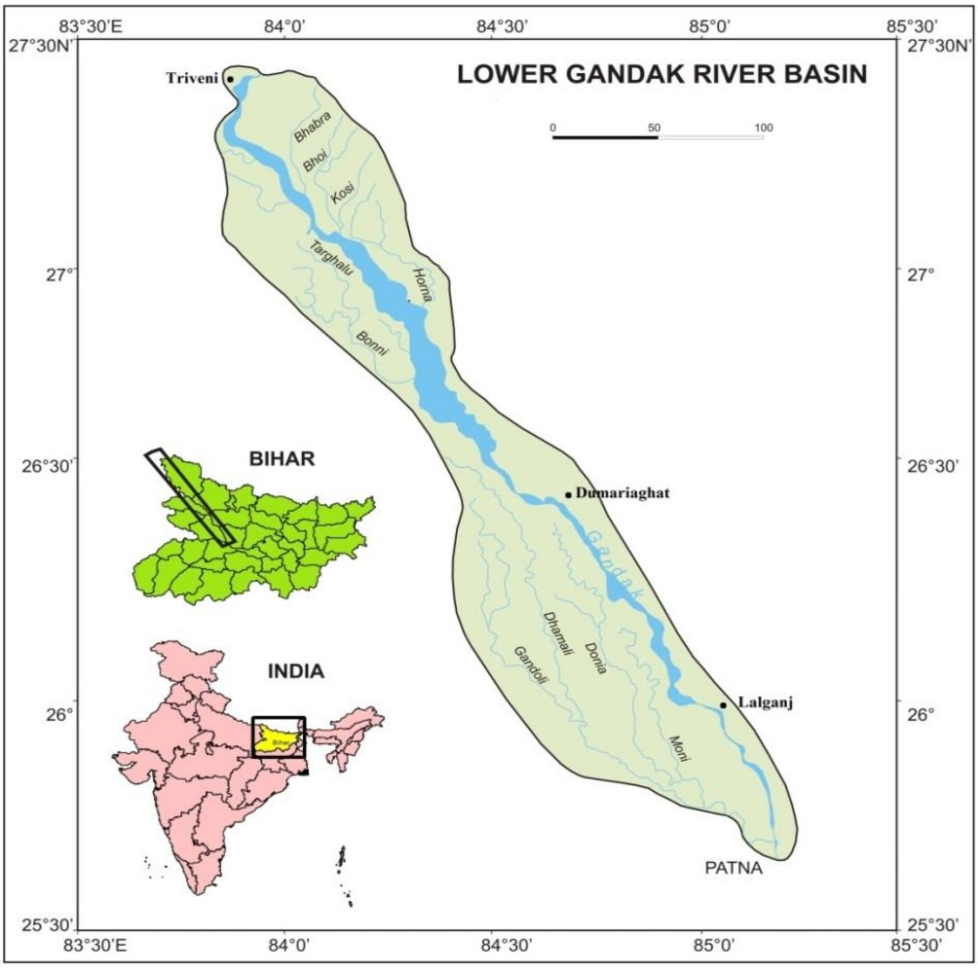


Fig 1: Gandak River: Huge Himalayan Catchment and Narrow Lowe Basin

The Lower Gandak Plain is located between $25^0 21' 23''$ north to $27^0 26' 54''$ north latitudes and $83^0 49' 00''$ east to $85^0 15' 52''$ east longitudes with a 7620 km^2 in Indian (Figure 2). Its general direction of alignment is from northwest to southeast characterized with relatively flat surface. Entire area falls in the plain except little portion of Maharajganj district of Uttar Pradesh and West Champaran district of Bihar. The northern fringe of these two districts is a narrow strip along the foothills represents low hilly tract. Rest of the area is alluvium deposited plain. The plan is flat except little difference in slope. Slope is also according to its direction of flow. In the northwestern part, slope is relative is higher as it happens with all rivers of the world when they descend in the plain. With advancing distances towards southeast, slopes keeps on declining. At the lower end slope is very less. The gradient of the river is in upper part is 0.57 meter/km while in the lower part it is less than 0.17 meter/km, near its confluence with the Ganga at Hajipur opposite Patna. The length of the Gandak River in the plain is 260 km. The plain area of the river is spread over ten districts out of which two falls in Uttar Pradesh – Maharajganj and Kushinagar. Eight districts are in Bihar. They are West Champaran, East Champaran, Gopalganj, Saran, Muzaffarpur, Vaishali, Samastipur, and Begusarai. Altogether 968 km^2 area is lying in Uttar Pradesh and rest 6652 km^2 is in Bihar. In Uttar Pradesh, area is 12.70 percent while it is 87.30 percent in Bihar with respect to total area in the plain.



Source: Based on Plate 11 & 12: Soil and Land Use Survey of India (SLUSI) Atlas (1988)

Fig 2: Location of Study Area

Results and Discussions

District-wise Lower Gandak Plain Areas

District-wise areas falling in the Gandak Plain covering ten districts are given in Table 1. It is obvious that two districts of Uttar Pradesh contribute more than 16 percent of its total area while it is 29.40 percent for Bihar. Since southern districts are lying in Bihar, their contribution towards basin area is a little higher. It is over one-fourth (26.78 percent) of area of ten districts constitutes the Gandak Basin. The entire basin is populated by around one million people according to 2011 census. Its density is 1290 persons/km^2 for the basin but for UP area it is 1104 persons/km^2 and for Bihar, it is 1317 persons/km^2. District-wise area falling in the basin varies considerably. It is a low of 11.63 percent for Samastipur to the highest 60.15 percent for Vaishali. It is shown in 5th column of the Table 1. Two southernmost districts Samastipur and Begusarai have lower percentage of area under the basin because of their location. They are lying below the confluence point but their tail-end area extends in its basin. A comparative picture is vividly visible from Figure 3.

Table 1: Area Distribution and Population Density in the Lower Gandak Plain

State	Districts	Total District Area (km²)	Area under lower basin (km²)	% area in the basin	% of basin falling in the district	Population in the basin (2011)	Basin Density persons/ km²
U.P.	Maharajgunj	2951	400	13.55	5.25	363904	910
	Kushinagar	2874	568	19.76	7.45	704475	1240
	Total	5825	968	16.62	12.70	1068379	1104
Bihar	W. Champaran	4250	2100	49.41	27.56	1944374	926
	E. Champaran	4155	1150	27.68	15.09	1411378	1227
	Gopalganj	2009	402	20.00	7.87	512657	1275
	Saran	2624	650	24.77	15.75	978929	1506
	Muzaffarpur	3123	600	19.21	3.94	922394	1537
	Vaishali	1995	1200	60.15	3.28	2102268	1752
	Samastipur	2579	300	11.63	8.53	495723	1652
	Begusarai	1889	250	13.23	5.28	393137	1573
	Total	22624	6652	29.40	87.30	8760860	1317
Grand Total		28449	7620	26.78	100	9829239	1290

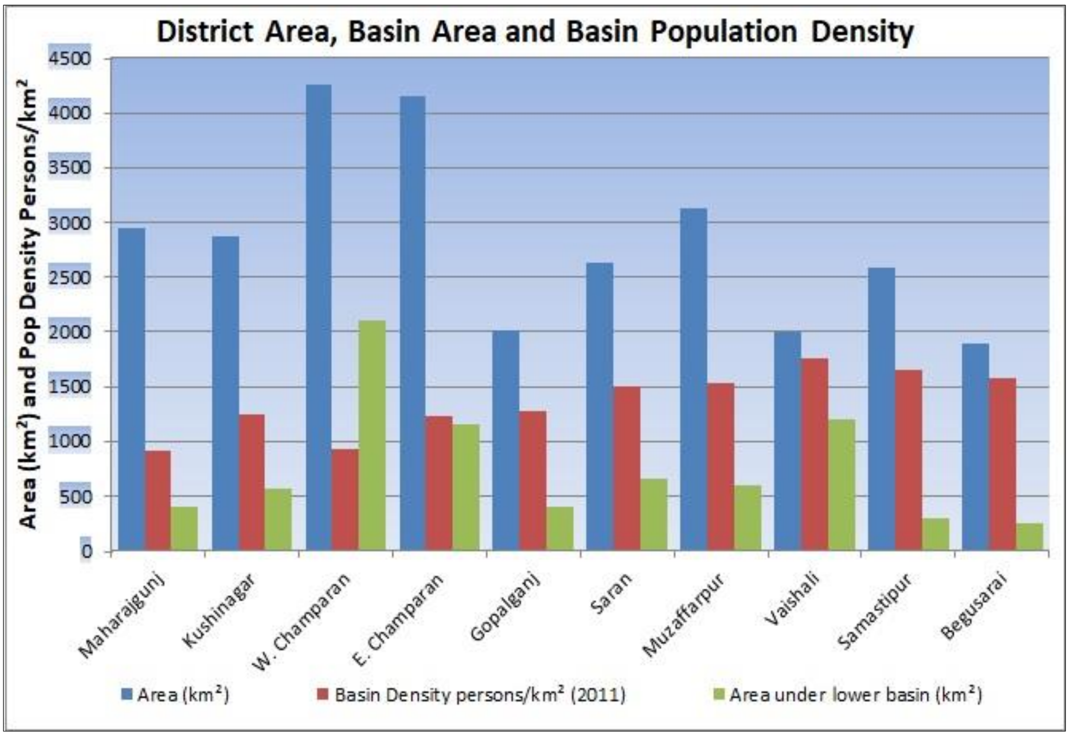


Fig 3: District Area Distribution and population Density in the Gandak Basin

The total area of districts covering Gandak basin is shown in Figure 4(a) by pie diagram. It simply shows relative size of the districts but Figure 4(b) is exact presentation of the area covered by different districts. It is quite apparent that two northwestern districts of Bihar – West Champaran and East Champaran and one southern district – Vaishali occupy almost 60 percent area of entire basin. Rest of the 40 percent area is shared by remaining seven districts.

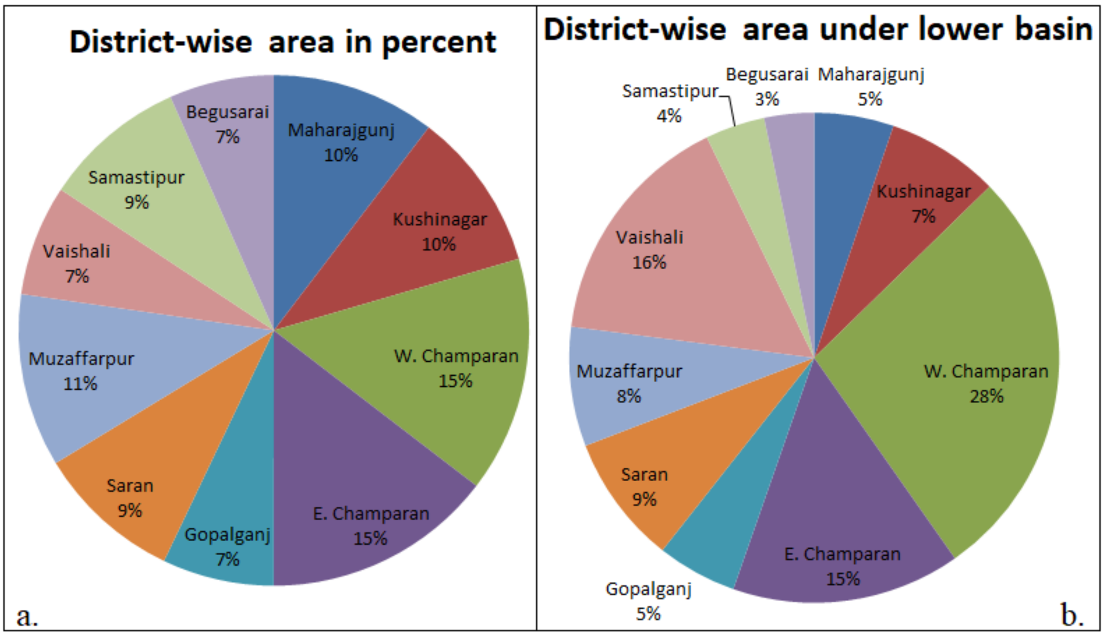


Fig 4: Distribution of District-wise Area and Area Falling in the Gandak Basin

Soil Types and Characteristics

The soil types found in the Lower Gandak Plain has been kept, broadly, into three groups (i) Terai soil, (ii) Calcareous soil and (iii) Alluvial soil.

Tarai Soil: This type of soil is found in foothills of the Gandak Plain. Its location is along the Himalayan border mainly confined to Mahrajganj and West Champaran. It is this area where natural forest cover is found in entire of the Lower Gandak Plain. It is characterized by marshy tract where humidity is very high due to relatively more rain in comparison to plain. Slope in this area is comparatively high and made up of unconsolidated and fragmented rock materials are brought down from the mountainous zone. It is also has risen due to recent most Himalayan orogeny of Siwalik formation. Due to rich floral cover, warm and humid climate, the soil is very reach in humus content and has high fertility. This area is highly suitable for the cultivation of rice, wheat, maize and sugarcane.

Calcareous Soil: This soil is found in some parts of Maharajganj and Kushinagar of Uttar Pradesh and West Champaran, East Champaran, Siwan, Gopalgaj and Samastipur (GFCC 2004) [6] in Bihar. High content of calcium carbonate ($CaCO_3$) is found in this soil. Primarily, $CaCO_3$ is derived from decay of shells and bones of marine lives. Since the rise of the Himalaya is from the bottom materials of Tethys, calcareous soils as found at several places. This soil is lighter in colour and its texture varies from sandy loam to loam. Its pH value ranges from 7.5 to 8.5.

Alluvial Soil: Alluvial soil is formed by alluviums brought by many rivers in the Lower Gandak Plain. This soil is found abundantly in all districts of the basin. It looks pale grey, yellow- brown and dark grey in colour. Its texture is mostly silty loam to silty clay loam. Along the channels, soil is mostly silty as the clay content is washed and transported downstream. Sand and silt is bigger in size and are denser, they remain there. Clayey soil is found a little away from the channel as clay is deposited during flood. Distribution of soils in the Gandak basin is presented in Table 2.

Table 2: Soils in the Gandak River System

Sl. No.	State	Districts	Type of Soil
1	U.P.	Maharajganj	Calcareous Alluvial Soil
2	U.P.	Kushinagar	Calcareous alluvial Soil, Alluvial Soil
3	Bihar	W.Champaran	Terai Soil, Calcareous,Alluvial Soil
4	Bihar	E.Champaran	Terai Soil, Calcareous,Alluvial Soil
5	Bihar	Gopalganj	Alluvial Soil
6	Bihar	Saran	Calcareous Alluvial Soil
7	Muzaffarpur	Muzaffarpur	Calcareous alluvial Soil, Alluvial Soil
8	Bihar	Vaishali	Alluvial Soil
9	Bihar	Samastipur	Calcareous Alluvial Soil
10	Bihar	Begusarai	Alluvial Soil

Source: Comprehensive Plan of Gandak River (2004)

Land Use in the Gandak Lower Plain

Land Revenue Department of Sates keeps records of the use of land under their jurisdiction. It deals with land management, do land survey and updates revenue records. After land survey, thorough examination and data validation, concerned maps are prepared and published by the department. The records of agricultural lands are updated every year and annual reports are prepared and published. The classification and annual update is conducted under nine heads of land use classification. They are (i) forests, (ii) land put to non-agricultural uses, (iii) barren and wastelands, (iv) area under permanent pastures and grazing lands, (v) area under miscellaneous trees crops and groves, (vi) cultivable waste-land, (vii) current fallow, (viii) fallow other than current fallow, and (ix) net area sown.

For practical purpose, these nine categories data has been grouped into two classes – (a) cultivable land and (b) non-cultivable land. Cultivable land is defined as that land on which agriculture is practiced now or in recent past it was done or possible to cultivate the land with precautions and treatment. Non-cultivable land is termed as those lands where it is not possible to cultivate the land. Therefore, first four classes mentioned above are under non-cultivable and last five classes are under cultivable land. These two categories of classes are presented in Table 3(a) and 3(b). The total area of the districts is given in Table 1. The utilization of the same area is again subdivided into nine land use classes but the additions of these subdivisions are not matching with the total geographical area. It is worth mentioning here that it happens because of non-reporting (under-reporting) of some areas by the concerned persons/authority. Therefore, addition of subdivisions is less than the geographical area of the district.

Table 3(a): Cultivable Land Use in Lower Gandak Basin All area figures are in hectares

States	Name of the Districts	Total Area	(A)*	Net Sown Area	Current Fallow	Other than Current Fallow	Land under Misc. Tree crop and Groves	Cultivable Waste Land
Uttar Pradesh	Maharajganj	290548	207746	202307	3514	1243	254	428
	Kushinagar	191470	134324	125184	2355	1189	3839	1757
	Total	482018	342070	327491	5869	2432	4093	2185
Bihar	W. Champaran	484351	293962	279899	3696	2595	6472	1300
	E. Champaran	431715	345805	272125	43340	2962	27121	257
	Muzaffarpur	315351	246528	218931	8466	1401	17420	310
	Vaishali	201449	138973	126007	2774	301	9750	141
	Samastipur	262390	194762	172867	12708	917	8270	0
	Begusarai	187828	128108	116736	6796	836	3695	45
	Saran	264887	212199	166338	33456	3670	8575	160
	Gopalganj	203774	164340	147912	5193	2390	7446	1399
	Total	2351745	1724677	1500815	116429	15072	88749	3612
UP and Bihar	Grand Total	2833763	2066747	1828306	122298	17504	92842	5797
% to total area of district		100	72.93	64.52	4.32	0.62	3.28	0.2

*(A): cultivable land

Source: V.N. Sharma and Anil K Tiwari (2013) [19] (2009-10, two districts of Uttar Pradesh)

Source: Directorate of Economics and Statistics, Government Bihar, (2011-12, eight districts of Bihar)

Cultivable Land
Cultivable land is that part of the surface of the earth where cultivation is practiced. It is also termed as agricultural land or arable land. At present, it is meant to that piece of land where agriculture is practiced or it is possible to cultivate the land. Hence under this category, (i) net sown area, (ii) current fallow, (iii) other than current fallow, (iv) land under miscellaneous trees, crops and groves, and (v) cultivable wasteland are included. These categories of lands are such, where it may not cultivated currently but may be cultivated with due treatment and precautions.

Net Sown Area includes total area over which crops and orchards are grown. Land/area sown many times in a year (multiple cropping) are not included multiple times but counted only once. It constitute about two-third (64.52 percent) of geographical area of the plain. It varies from 57.79 percent in West Champaran to 72.59 percent in Gopalganj.

Current Fallow includes those areas which are not under cropping in the current referred year when the data was collected. It is 4.32 percent to the total area of the lower basin during 2011-12. Its variation can be seen from less than one percent (0.76) in West Champaran to 12.63 percent in Saran district with respect to district area. The next highest is associated with East Champaran (10.04 percent). Rest of the districts witnessed less than five percent of current fallow during 2011-12 with their respective areas.

Other Than Current Fallow land is counted which is lying fallow temporarily for more than one years but not more than five years. Its total contribution in the study area is little more than half a percent (0.62 percent) to its geographical area. It varies with as little 0.15 percent (Vaishali) to maximum of 1.39 percent (Saran) and 1.17 percent (Gopalganj) to their respective areas. Only these two districts have an area of more than one percent under "other than current fallow" during 2011-12 to its basin areas.

Land Under Miscellaneous Trees, Crops and Groves are all cultivable area which is not put into net sown area but utilized into some other agricultural uses like bamboo bushes, thatching grasses, and trees which are not put into orchards. It has a contribution of 3.28 percent of the total geographical area of the Lower Gandak Basin. The percentage of the district area under this category is almost nil (0.09 percent) in Maharajganj (only district with less than one percent area under this category) and maximum is seen in 6.28 percent in East Champaran to the district areas.

Cultivable Waste Land is categorized as land available for cropping but not cropped for more than five years in a row due to any reason. This type of land may be fallow or covered with shrubs and jungles which are not included into other categories of land use. The area under this category is very negligible with only 0.20 percent of the total area. Samastipur district does not have any area under this category. Out of ten districts, no district is having more than a percent area of the district in this class. Hence, variation in this category is from absolute zero in Samastipur to 0.92 percent in Kushinagar.
The addition of five categories of land use in the lower Gandak Plain is about three-fourth (72.93 percent) of its total area. But under cultivation, it was about one-third (64.52 percent) during 2011-12. Other remaining areas can be, theoretically, cultivated but it not so. It is possible to cultivate fallow land, land under trees and cultivable waste, but the cost may not be suitable for cultivation. All theoretically cultivable area cannot be put into agriculture because of its cost-benefit negativity. That is why, it is said to be cultivable land but could not be cultivated. All categories under cultivable land and their share of contribution in the districts is shown by a stacked bar in Figure 5(a).

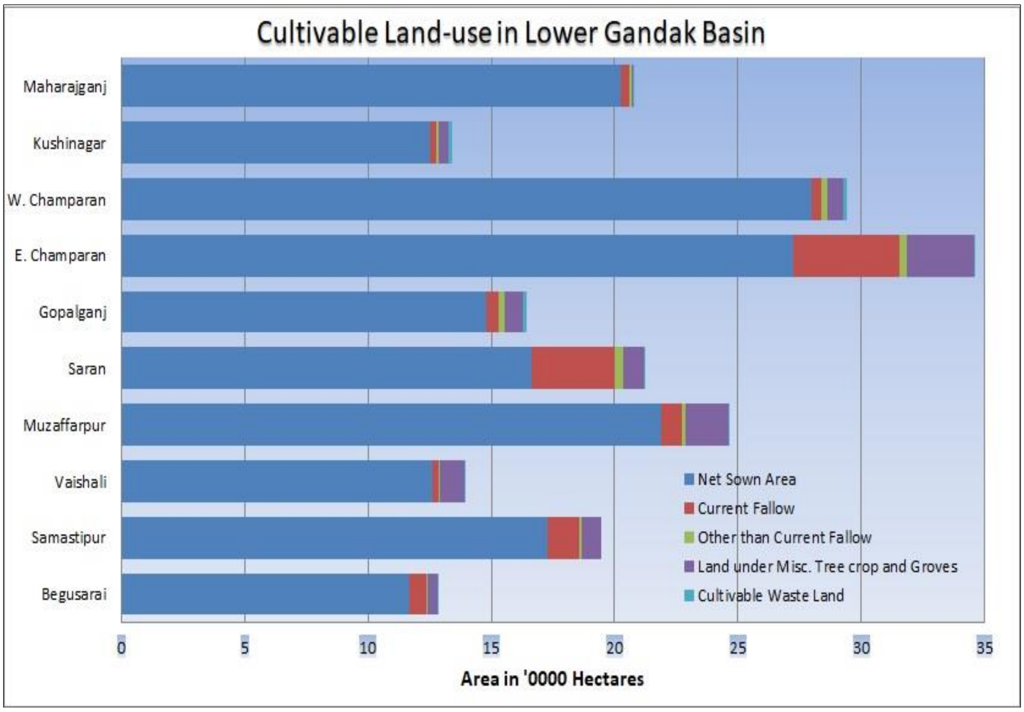


Fig 5(a): District-wise Cultivable Land-use in Lower Gandak Basin

Non-cultivable Land

As the name suggests, it is that land/surface of the earth where cultivation is not possible in normal circumstance. In other words, non-cultivable land is not suited for forming. For example, there could be any reason like rocky area (no soil development), steep slope, mountainous surface, harmful level of saline soil/ devoid of fertility of the soil etc. under this category. Four types of land uses are included into it. They are (i) forest, (ii) permanent pasture and grazing land, (iii) land put to non-agricultural uses, and (iv) barren and uncultivable land. The details of the non-cultivable land are presented in Table 3(b).

Forest is dominated by trees and tree itself vary in their type, density, height. Large forest area is owned by governments – national or state or district level jurisdictions. Some forest is also under private ownership. Therefore, any areas dominated by trees are put into this category. But mostly, it is owned by governments at different levels. Forest cover in the area is limited to only 5.04 percent. It is found significantly in only two districts – West Champaran (3.24 percent) and Maharajganj (1.77 percent) to their own areas. In both Kushinagar and East Champaran districts, area under forest is only 0.033 percent of the total geographical area of the basin. Rest six districts are completely devoid of forest.

Permanent Pasture and Grazing Land includes common grazing land for domesticated animals. Under this category, all grazing or pasture lands are counted, whether it is permanent or not, but should not have been counted in any other categories of land use. The area under this category is the least among all the classes of land use. It is just 0.10 percent of the geographical area of the basin. The maximum area is in West Champaran district and it is 1148 hectares. The minimum is seen in Begusarai district where the area is confined to only 15 hectares.

Land Put to Non-agricultural Uses includes all areas over which any kind of construction has been done or any type of infrastructure has been developed. All area over which buildings are constructed, roads or railways have been built, wherever small water bodies are there like river or pond or canal etc. power stations or airport or water ways are developed, all are incorporated into this category. Under this category of land use, significant amount of area is covered. In Gandak basin, it is 18.70 percent area of the basin. With respect to total district area, the lowest is observed with Maharajganj (10.70 percent) while the maximum is observed with Kushinagar (26.95 percent).

Barren and Uncultivable Land includes all areas which cannot be cultivated or not at all suitable for cultivation. Due to this reason, these areas are barren. It could be because of the fertility of the soil where river deposited sand/ desert is spread or the mountain bare lands are there but those lands are not included in any other class of the land use. Only 3.22 percent of geographical area of the basin is coming in this category. The minimum area is only 0.43 percent of Maharajganj district whereas the maximum is associated with Vaishali district (11.96 percent). The details of the distribution of areas in different categories of land use are very clearly put in Figure 3(b).

Table 3(b): Non-cultivable Land Use in Lower Gandak Basin All area figures are in hectares

States	Name of the Districts	(B)**	Forest	Permanent Pasture and Grazing Land	Land put to Non-Agricultural uses	Barren and Uncultivable Land	% of (A) to Total	% of (B) to Total
Uttar Pradesh	Maharajganj	82802	50265	177	31101	1259	71.5	28.5
	Kushinagar	57146	817	342	51607	4380	70.15	29.85
	Total	139948	51082	519	82708	5639	70.97	29.03
Bihar	W. Champaran	190389	91745	1148	94579	2917	60.69	39.31
	E. Champaran	85910	118	436	77277	8079	80.1	19.9
	Muzaffarpur	68823	NA	30	63526	5267	78.18	21.82
	Vaishali	62476	NA	329	38049	24098	68.99	31.01
	Samastipur	67628	NA	62	63755	3811	74.23	25.77
	Begusarai	59720	NA	15	41744	17961	68.2	31.8
	Saran	52688	NA	214	34559	17915	80.11	19.89
	Gopalganj	39434	NA	200	33713	5521	80.65	19.35
	Total	627068	91863	2434	447202	85569	73.34	26.67
UP and Bihar	Grand Total	767016	142945	2953	529910	91208	72.93	27.07
% to total district area		27.07	5.04	0.1	18.7	3.22	100.00%	

N.A. = Not Available, **(B): Non-cultivable land

Source: V.N. Sharma and Anil K Tiwari (2013) [19] (2009-10, two districts of Uttar Pradesh)

Source: Directorate of Economics and Statistics, Government Bihar, (2011-12, eight districts of Bihar)

The addition of the four classes under non-cultivable is equivalent to 27.07 percent out of which major contribution is from land put to non-agricultural uses (18.70 percent) followed by forest (5.04 percent). A visual presentation of the same van be had from Figure 5(b).

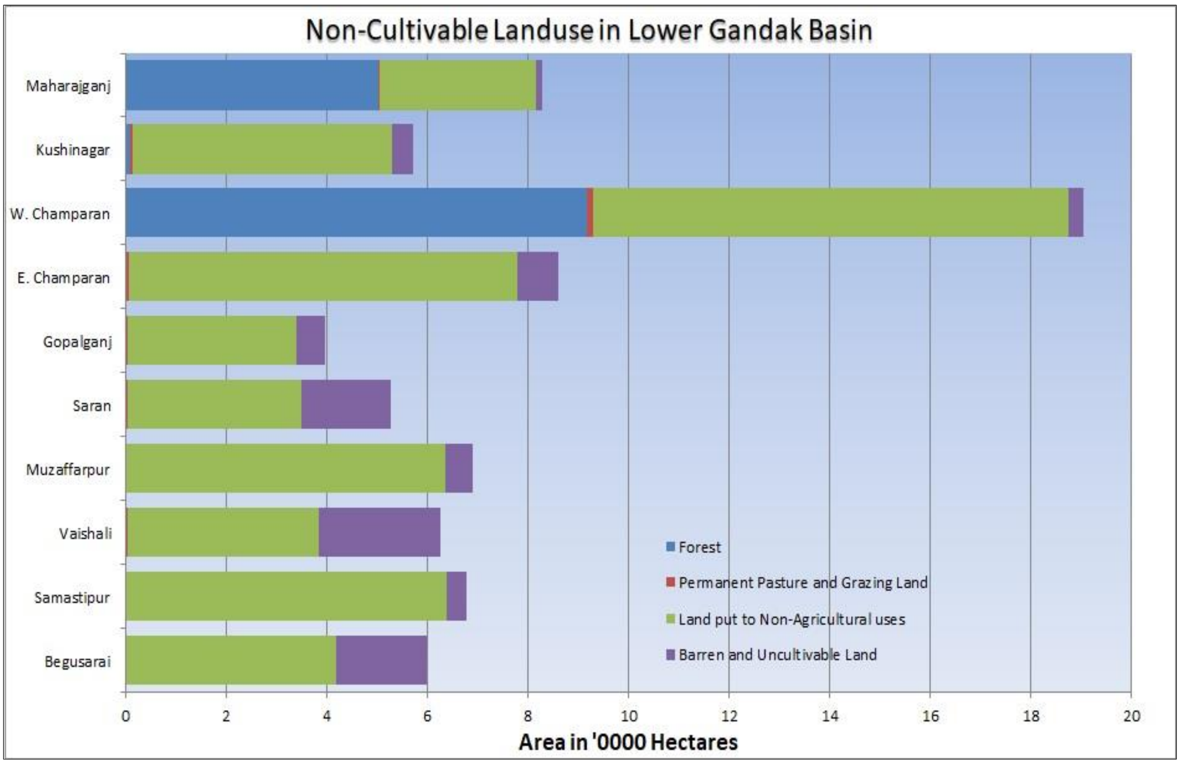


Fig 5(b): District-wise Non-cultivable Land-use in Lower Gandak Basin

District-wise Cultivable and Non-Cultivable Land

From Tables 3(a) and 3(b), Table 4 is derived to express its conclusive remarks. From this table, it is quite obvious that district-wise total area as well as area under cultivable and non-cultivable is given in columns 3, 4 and 5. The percentages of cultivable and non-cultivable to their respective district area has been computed and presented in columns 6 and 7. From this table, it is undoubtedly clear that there are substantial variations in the land use pattern among the districts. West Champaran is at the foothills of the Himalaya and it has higher forest cover and on this account the cultivable land percentage is substantially low (60.69 percent) while non-cultivable share has increased the highest (39.31 percent) among the districts. The highest cultivable land is with respect to Gopalganj (80.65 percent) and the lowest non-cultivable to 19.35 percent. A clear picture of the same can be had from Figure 6.

Table 4: Cultivable and Non-cultivable Land in Lower Gandak Basin

States	Name of the Districts	Total Area	(A)*	(B)**	% of (A) to Total	% of (B) to Total
Uttar Pradesh	Maharajganj	290548	207746	82802	71.50	28.50
	Kushinagar	191470	134324	57146	70.15	29.85
	Total	482018	342070	139948	70.97	29.03
Bihar	W. Champaran	484351	293962	190389	60.69	39.31
	E. Champaran	431715	345805	85910	80.10	19.90
	Muzaffarpur	315351	246528	68823	78.18	21.82
	Vaishali	201449	138973	62476	68.99	31.01
	Samastipur	262390	194762	67628	74.23	25.77
	Begusarai	187828	128108	59720	68.20	31.80
	Saran	264887	212199	52688	80.11	19.89
	Gopalganj	203774	164340	39434	80.65	19.35
	Total	2351745	1724677	627068	73.34	26.67
UP and Bihar	Grand Total	2833763	2066747	767016	72.93	27.07
% to total area of district		100	72.93	27.07	100.00%	

*A= Cultivable Land, **B= Non-cultivable Land

Source: V.N. Sharma and Anil K Tiwari (2013) [19] (2009-10, two districts of Uttar Pradesh)

Source: Directorate of Economics and Statistics, Government Bihar, (2011-12, eight districts of Bihar)

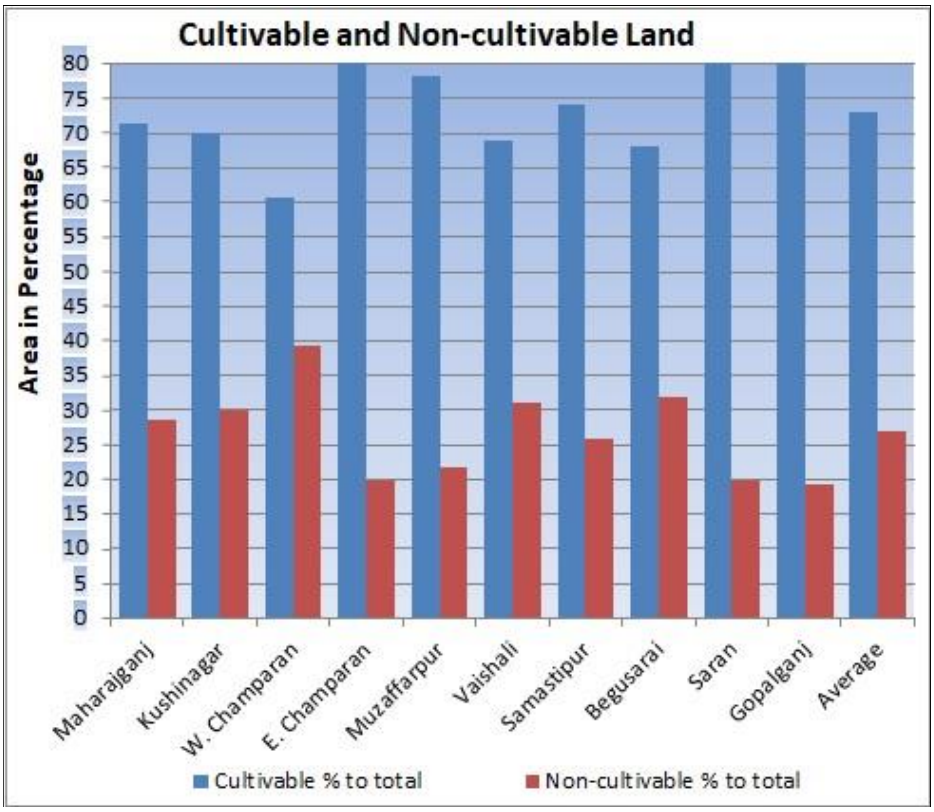


Fig 6: Comparative Distribution of Cultivable and Non-cultivable Areas

Conclusions

The Lower Gandak plain is located at the outfall of the Himalayan slope where there is torrential rain in association with huge snowmelt leading to substantial increase in discharge. Precipitous slope, weak and fold forming compressed sedimentary rocks, high rate of weathering, seismically active belt and human encroachment in fragile ecosystem lead to large amount of sediment yield. The large quantity of sediment is brought to the plain especially in Bihar where the oscillatory tendency of the Gandak determines the fate of land and people of the area. The Lower Gandak Plain is one of the finest pocket/region/plain in the world in terms of fertility of the soil. Area/plain is made up of alluviums deposit brought by the river and its tributaries. Hence, the study of land use in the Gandan Plain has striking relevance. For the purpose of data collection for land use classification, some of the area is not reported by the concerned persons/ authority. Hence, total geographical area of the district is not represented. It happens due to non-reporting/ under reporting. It is quite obvious that nine categories of land use are regrouped into cultivable and non-cultivable. From this study, it is very clear that cultivable land accounts for about three-fourth of the area whereas non-cultivable is only one-fourth. Areas lying in the upper part of the plain near foothills have relatively higher non-cultivable proportion. Relatively less flood affected districts like East Champaran and Muzaffarpur have higher percentage of cultivable in comparison flood affected areas of southern part of the basin.

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