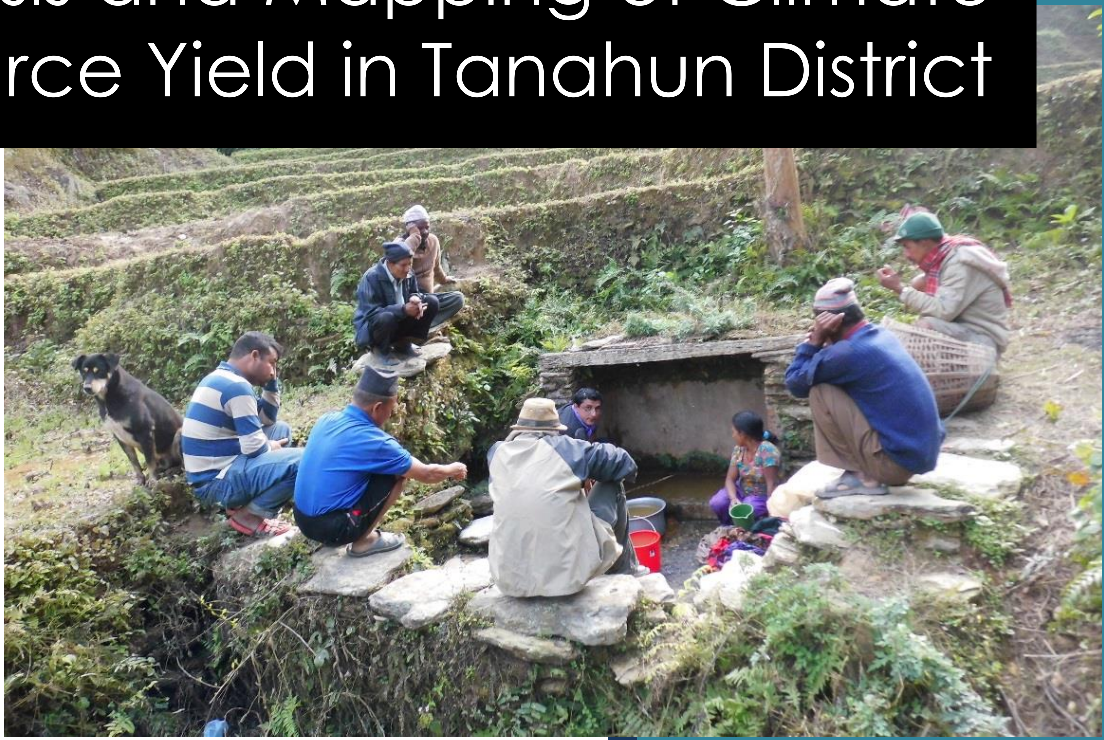
Rural Water Supply and Sanitation Project in Western Nepal Phase II

2015

Analysis and Mapping of Climate and Source Yield in Tanahun District



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RWSSP-WN Phase II
Pokhara, Kaski, Nepal

Abbreviations

CBS	Central Bureau of Statistics
DHM	Department of Hydrology and Meteorology
GPS	Global Positioning System
IPCC	Intergovernmental Panel on Climate Change
AR4	IPCC Assessment Report 4
Q-GIS	Quantum Geographic Information System
RWSSP–WN II	Rural Water Supply and Sanitation Project in Western Nepal, Phase II
VDC	Village Development Committee
mm	Millimetre
l/s	Litres per second
T	Annual Average Temperature
R	Runoff
P	Precipitation

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1 Background

The recent climate change study in Nepal and IPCC 4th and 5th assessment report indicates increase in rainfall intensity, decrease in number of rainy days and increase in temperature in future. In such situation, there is a highly possibility of overland flow and decrease in rain infiltration inside ground. Such scenario will certainly impact on mountain spring and stream flows, which ultimately impact the livelihood of people living in mountain and hill settlements of Nepal.

Springs are important component of hydrosphere where ground water flows into the surface by gravity for the use. The gravity flow systems for domestic and irrigation provision is the most appropriate and common option in the context of rural hill settlements in Nepal. Therefore, springs are most important source of water supply which could be diverted through pipes to lower settlements hills by gravity flow. In recent days, several spring sources have been dried out or slowly decreasing its yield across the country due to changing character of rainfall and increasing evaporative losses.

Many hilly areas of Nepal, currently face water supply issues. The amount of spring water available in these areas is declining, and demand will continue to rise as population grows. Water quality could suffer in areas experiencing increases in rainfall intensity. Heavy downpours can increase the amount of runoff into stream, washing sediment, nutrients, pollutants, trash, animal waste, and other materials into water supplies, making them unusable, unsafe, or in need of water treatment.

To manage the water sources, the The Rural Water Supply and Sanitation Support Project Phase III (RWSSSP III) supported the districts in Central region of Nepal to prepare District Profile of Water Supply and Sanitation in 2003/2004. In one district, Tanahun, all water sources were measured and sources were located with the GPS, in addition to other information that was collected for the district profile. This was done in all Tanahun district VDCs except Ghiring Sundhara VDC that was supported for Water Use Master Plan by Helvetas at the time and Byas municipality.

RWSSP-WN Phase II continues to work in Tanahun district. Given that climate change is of high importance and given that the project has water sources data available from 2004 covering the Tanahun district, total 3320 sources, it was proposed to repeat the exercise to see changes in the district. The findings contribute to the debate on whether there truly are changes in water sources or are these rather localized human induced changes, i.e. related to land use changes and increased water use rather than source depletion as such.

1.1 Purpose of study

The project RWSSP-WN II has collected large number of spring source data (year 2004 and 2014). Water source yield was measured in March/April 2004. Again during data collection phase, project has collected data in March/April 2014 to identify changes in water sources across all VDCs of Tanahun district.

The purpose of this work is to compare and analyse the water source yield (previous and current) and its mapping, annual climate trend study between both measurements and check the variation in yields with respect to climate trend. Both climate and water sources will be studied together to provide further insights into how to take disaster risk, land use changes and climate change into account when preparing District Strategic WASH Plans, VDC WASH Plans and Water Use Master Plans.

2 Methodology

2.1 Study area

Tanahun District is located at an elevation of around 869 meters above sea level. Its coordinates are 27°55'0" N and 84°15'0" E in DMS (Degrees Minutes Seconds) or 27.91 and 84.25 (in decimal degrees). This district lies in the middlemost of country Nepal (Figure 1). The district, with Damauli as its district headquarters, covers an area of 1,546 km² and has a population of 323,288 (CBS, 2011). The general geography and climate is presented in Table 1.

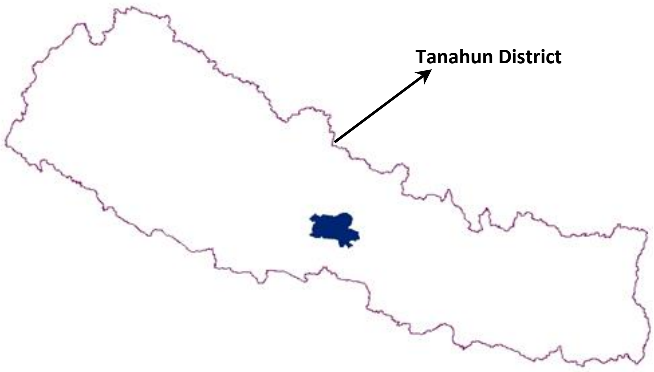

Figure 1: Location of Tanahun district in Nepal

Table 1: Geography and climate – Tanahun District

Climate Zone	Elevation Range	% of Area
Lower Tropical	below 300 meters (1,000 ft)	2.3%
Upper Tropical	300 to 1,000 meters 1,000 to 3,300 ft.	88.0%
Subtropical	1,000 to 2,000 meters 3,300 to 6,600 ft.	8.8%

Source: Forest & Landscape Development and Environment Series 2-2005 and CFC-TIS Document Series No.110., 2005, ISBN 87-7803-210-9, retrieved Nov 22, 2013

2.2 Data collection

Climate data: The station's rainfall and temperature data were collected by Department of Hydrology and Meteorology (DHM). The meteorological stations considered for the analysis is presented in Table 2. Out of 15 stations (Table 2), only few stations have both temperature and rainfall data. The stations used for temperature analysis is shown in Table 4. The rainfall stations inside Tanahun district are not enough for rainfall interpolation. Therefore, stations from adjoining area are also considered for the rainfall analysis. The position of rain gauges is shown in Figure 2. Since previous year monsoon rain impacts the post monsoon of the same year and winter of next year, rainfall data of 2013 rain cycle is consider as most effective inputs for April/May yield of 2014. Further, 2014 is not published till now and winter Jan/Feb rain of 2014 is negligible to April/May yield of 2014.

Table 2: Meteorological stations

Station No.	Meteorological Station	District	Data period
827	Rumjakot	Tanahun	2002-2013
818	Lamachaur	Kaski	2002-2013
817	Damauli	Tanahun	2002-2013
807	Kuncha	Lamjung	2002-2013
805	Syangja	Syangja	2002-2013
802	Khudibazar	Lamjung	2002-2013
801	Jagat (setibas)	Gorkha	2002-2013
726	Garakot	Palpa	2002-2013
710	Dumkibas	Nawalparasi	2002-2013
702	Tansen	Palpa	2002-2013
809	Gorkha	Gorkha	2002-2013
808	Bandipur	Tanahun	2002-2013
815	Khairanitar	Tanahun	2002-2013
902	Rampur	Chitwan	2002-2013
903	Jhawani	Chitwan	2002-2013

Source: DHM

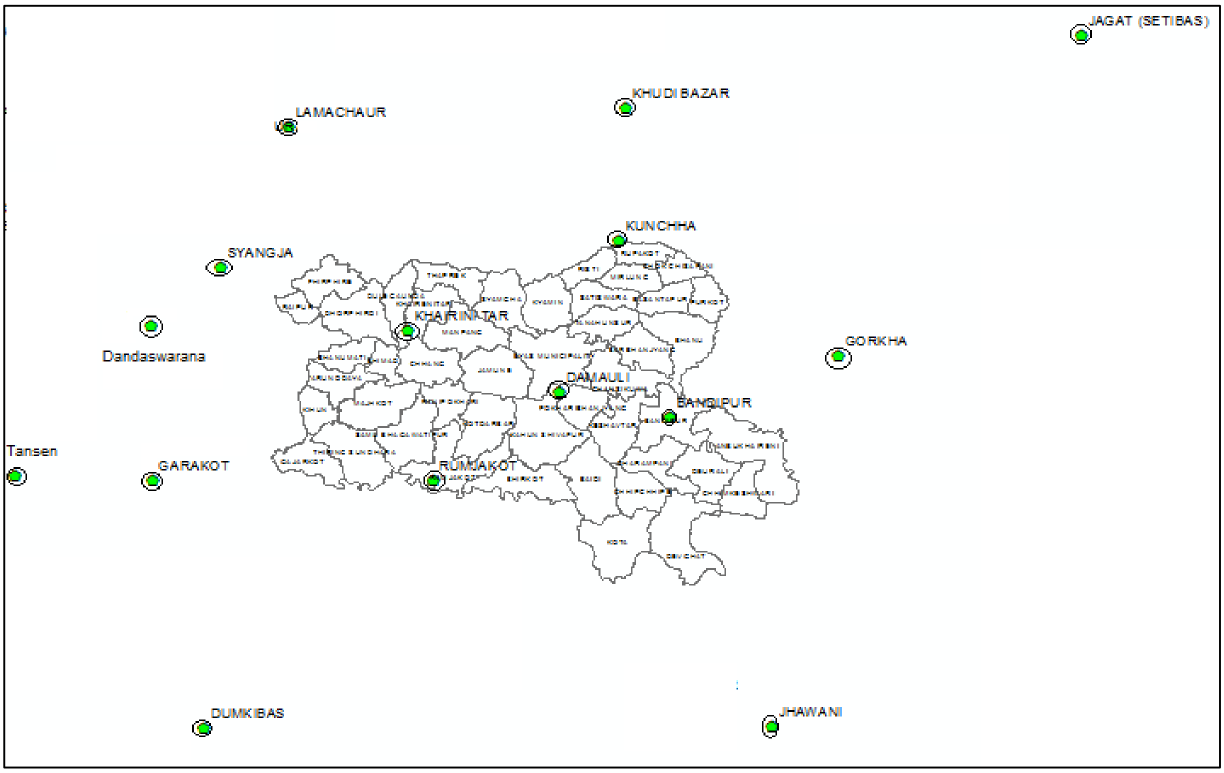

Figure 2: Location of rain gauge stations used for rainfall analysis
Source: DHM

Spring data: Water source data was collected in March-April 2004 and again during March-April 2014 to identify changes in water sources across all VDCs of Tanahun district. The locations were verified from GPS and the source names were cross-checked to ensure the location and name of source. The yield measurement was carried out with the bucket method in both times so that yield collection is harmonized.

The collected data includes source type and name, place (ward/VDC), ownership, GPS location, previous measured yield, present measured yield, safe yield, date measured, use of source, scheme name, scheme type, environment around the source (10 years ago), and environment around the source area at present. The 3320 water sources as identified in 2004 and altogether 4223 including new water sources were identified and measured in 2014. The data of 2004 does not include the source information of Ghiring Sundhara VDC and Byas municipality. However, in 2014 data collection those areas were covered.

Software: The Q-GIS is used for rainfall and water source flow mapping. The Microsoft @ excel is used for data analysis.

Base map: The district boundary and 20m topographical map from Nepal Government, Topographic survey department is used as base map. Beside this, SRTM 30 m is also used for the terrain analysis.

2.3 Rainfall interpolation and mapping

For rainfall interpolation and mapping, Kriging interpolation tool is used. It is an advanced geo-statistical procedure that generates an estimated surface from a scattered set of points with Rainfall (z) values. Kriging assumes that the distance or direction between sample points reflects a spatial correlation that can be used to explain variation in the surface. The Kriging tool fits a mathematical function to a specified number of points, or all points within a specified radius, to determine the output value for each location.

2.4 Trend and lapse rate of temperature

Linear Regression: The linear regression model is used to see the trend and lapse rate of temperature. Linear regression attempts to model the relationship between two variables by fitting a linear equation to observed data. One variable is considered to be an explanatory variable, and the other is considered to be at the mercy of variable.
A linear regression line has an equation of the form $Y = a + bX$, where X is the explanatory variable and Y is the dependent variable. The slope of the line is b, and a is the intercept (the value of y when $x = 0$).

2.5 Estimation of runoff

Uttar Pradesh Irrigation Research Institute, Roorkee, has developed the following relationships between runoff and precipitation in 1960:
For Himalayan rivers Ganga Basin:

$$R=5.45\ P^{0.6}$$

Where: R is runoff in cm and P is precipitation in cm.

2.6 Limitation of data

The measured data is from springs, point sources and streams. It is very difficult to estimate the source yield if only seepage is seen. Further, all sources will contribute its yield to a stream. If sources were trapped for use at upstream, the stream flow will decrease. Some sources were identified but field team were not able to measure yield due to very low discharges (only seepage is traced). Such yield were written as zero value. Since zero value indicates no source, some traced value should be written. For example rainfall value less than 0.02 mm is recorded as traced by DHM.

The network of rainguage stations in Tanahun district is very poor. Only three meteorological stations are situated inside Tanahun district out of which only one station records both temperature and rainfall. Therefore, stations from neighbouring districts were also considered for climate analysis.

3 Analysis

3.1 Climate

a. Rainfall (2002-2013)

The annual rainfall in Tanahun district ranges 1500 to 3500 mm with annual average rainfall of 2298 mm (average 2002-2013). July is the highest rain getting month and November is lowest. The monsoon rainfall is around 79% of total annual rainfall and only 21% of annual rain falls in rest of other months (Annex 2). The average monthly rainfall distribution (2002-2013) of district is presented in Figure 3 and the monthly average rainfall (2002-2013) of stations is presented in Annex 1. Generally, July is a peak monsoon season and occasionally it shifts few days to month. The rainfall from 2002 to 2013 shows some erratic rainfalls. In 2007, the peak shifted to September. In 2008 and 2009, the peak monsoon shifted to August. The temporal peak monsoon movement is shown in Figure 4 and Table 3. The stations' monthly average rainfall of Tanahun district is depicted in Table 4.

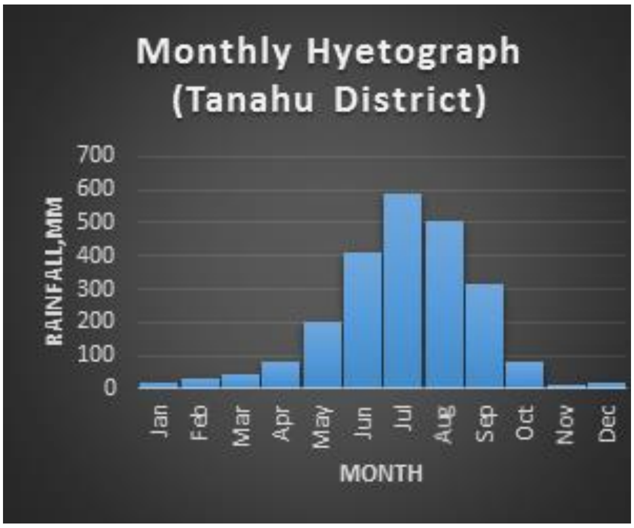

Figure 3: Average monthly rainfall (2002-2013) Tanahun district.

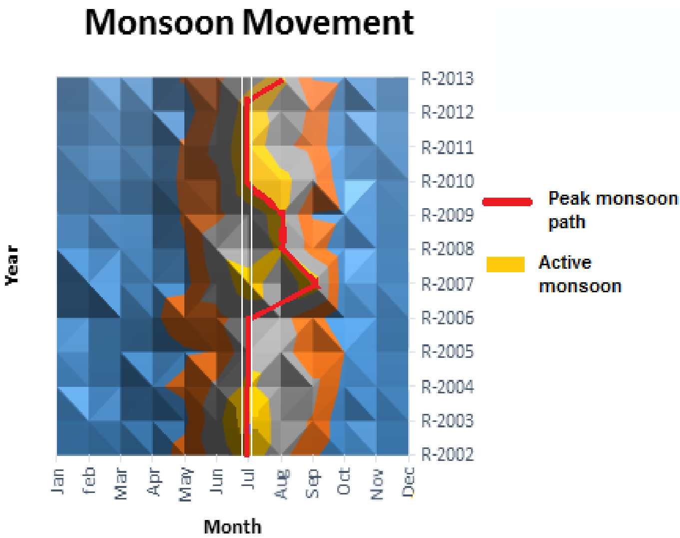

Figure 4: Peak monsoon movement (2002-2013)

b. Temperature lapse rate

In Tanahun district, few meteorological stations are available which record temperature. The stations used in the study and their monthly temperatures with elevation are presented in Table 4. The air temperature (T) is function of elevation (z). In lower atmosphere it decreases with altitudes. The other functions are sunshine and wind. Therefore, it correlates with elevation contours of Tanahun district. The change with altitude (lapse rate, dT/dz) for Tanahun district is calculated using linear regression equation (Figure 5). The lapse rate of temperature is not equal in all months. The lapse rate ranges from -0.0045 ^{o}C/meter (-4.5 ^{o}C/km) to -0.0065 ^{o}C/meter (-6.5 ^{o}C/km). The relation developed between average monthly temperature (2002-2013) and elevation of station is presented in Table 5.

c. Temperature trend

The Syangja Station has quite unbroken temperature record. The station is just outside Tanahun district but the station's elevation is more or less same as Tanahun's average elevation. Therefore, for temperature trend study lapse rate as correction factor is used over Syangja to get average yearly temperature of Tanahun District. The temperature between 2002 and 2013 is in increasing trend. The trend is + 0.041 ^{0}C/year (Figure 6).

Table 3: Average monthly rainfall (2002-2013) - Tanahun District

Month	Rainfall in mm											
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Jan	58	33	35	58	0	0	10	0	2	13	21	21
Feb	38	84	6	17	1	153	4	2	46	33	62	88
Mar	43	73	34	55	67	62	60	18	43	31	42	34
Apr	108	85	185	61	153	105	78	36	104	77	98	36
May	266	156	225	175	338	131	178	222	234	221	102	222
Jun	459	534	441	207	356	466	548	347	349	463	380	347
Jul	733	902	653	548	469	723	450	525	763	767	715	525
Aug	464	468	428	519	456	439	640	658	682	438	514	658
Sep	243	386	463	207	286	725	310	184	447	343	370	184
Oct	43	43	143	199	50	89	58	161	61	18	36	161
Nov	25	1	9	0	3	12	1	0	3	38	0	0
Dec	2	19	1	0	24	4	1	2	0	0	0	2

Source: DHM

Table 4: Monthly average temperature (2002-2013)

Met. Station	Elev.	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Damauli	358	15.3	17.6	22.3	26.9	28.9	29.6	29.1	29.3	28.3	25.6	20.7	16.6
Khudi Bazar	823	12.9	15.0	19.2	22.7	24.1	25.3	25.2	25.3	24.2	21.3	17.6	14.0
Gorkha	1097	13.1	15.4	19.6	23.1	24.2	25.2	25.2	25.0	23.9	21.6	17.6	14.2
Tamghas	1530	9.7	11.7	15.5	19.4	20.9	22.2	22.2	22.2	21.2	18.3	14.3	11.0

Source: DHM

Table 5: Monthly temperature with elevation

Temperature (T) and Elevation (z) relationship		
$T_{Jan} = -0.0045\mathbf{Z} + 17.071$	$T_{Feb} = -0.0047\mathbf{Z} + 19.442$	$T_{Mar} = -0.0054\mathbf{Z} + 24.359$
$T_{Apr} = -0.006\mathbf{Z} + 28.775$	$T_{May} = -0.0065\mathbf{Z} + 30.665$	$T_{June} = -0.006\mathbf{Z} + 31.278$
$T_{Jul} = -0.0056\mathbf{Z} + 30.728$	$T_{Aug} = -0.0058\mathbf{Z} + 30.935$	$T_{Sept} = -0.0058\mathbf{Z} + 29.953$
$T_{Oct} = -0.0059\mathbf{Z} + 27.327$	$T_{Nov} = -0.0052\mathbf{Z} + 22.524$	$T_{Dec} = -0.0045\mathbf{Z} + 18.206$

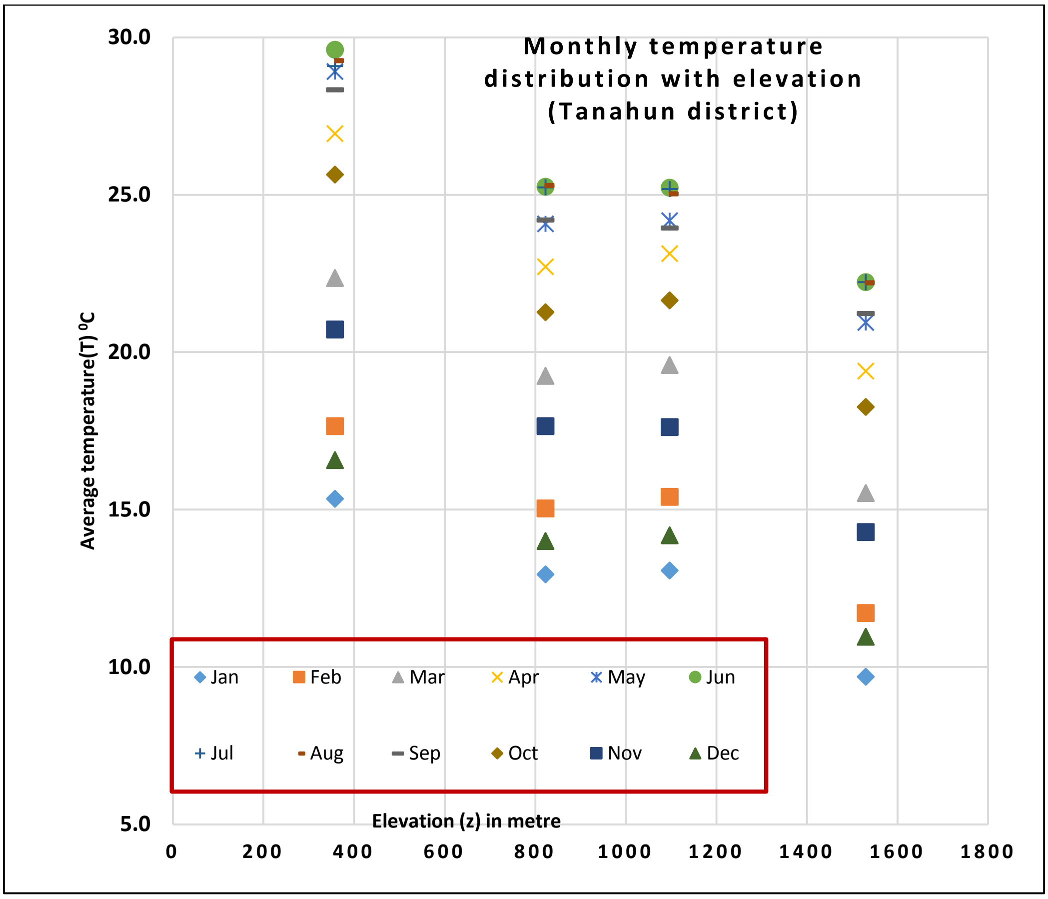

Figure 5: Monthly average temperature (2002-2013) with elevation

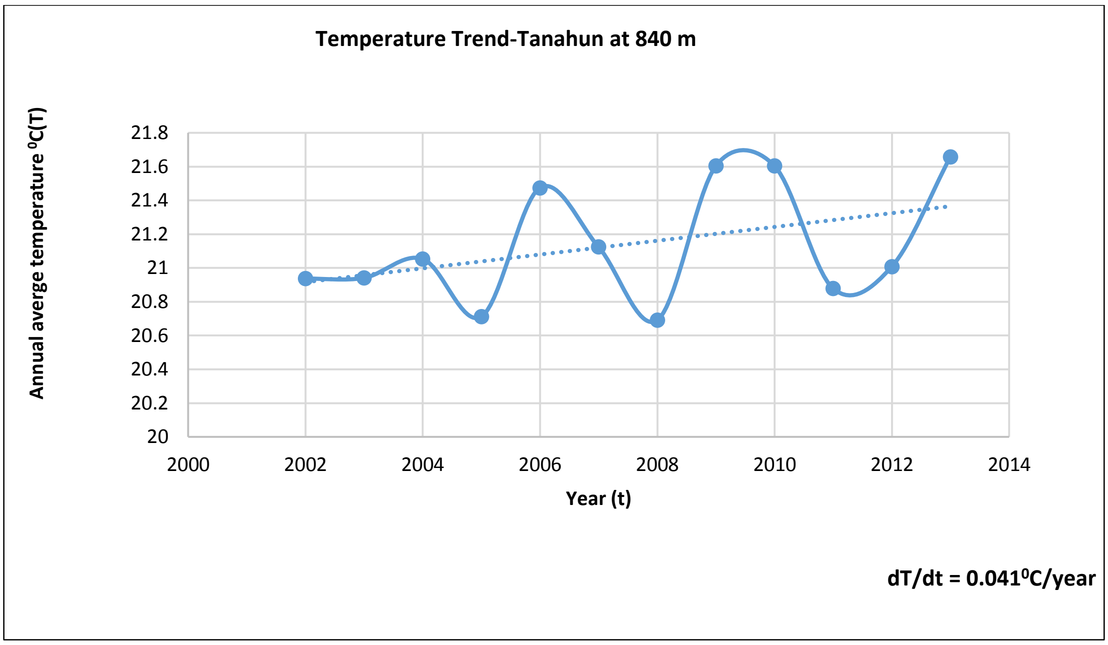

Figure 6: Temperature trend (2002-2013)

3.2 Runoff

The UP Irrigation Research Institute (1960) formulae $R=5.45\ P^{0.6}$ is applied to calculate the runoff of Tanahun District. The runoff (R) and precipitation (P) are in cm. The trend shows decrease of -0.59 cm/year (Figure 7).

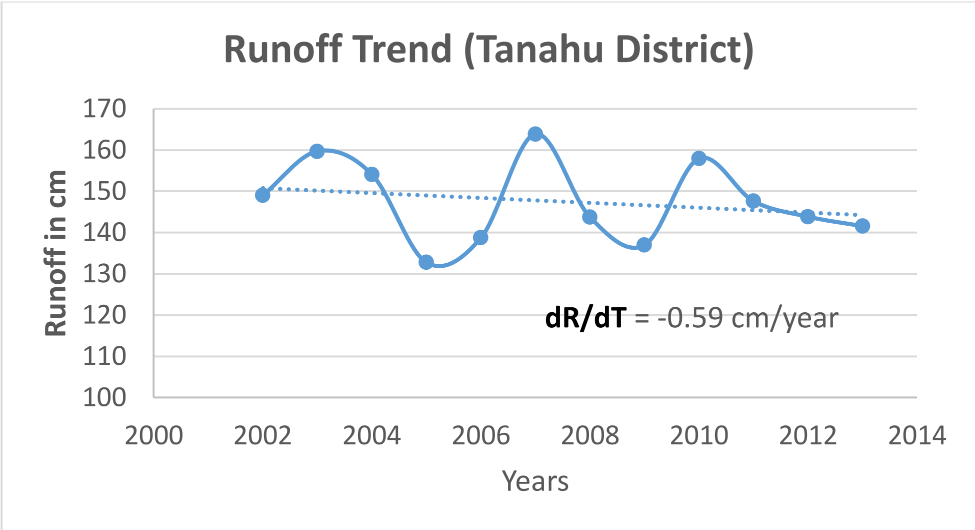

Figure 7: Runoff trend (2002-2013) Tanahun District

3.3 Climate and flow trend

The rainfall record from 2002 to 2013 shows declining of -1.68 cm/year and the temperature trend shows increase of 0.041 °C average annual temperature per year. The Runoff trend shows negative trend of -0.59 cm/year in Tanahun district. The trend 2002-2013 is shown in Figure 8.

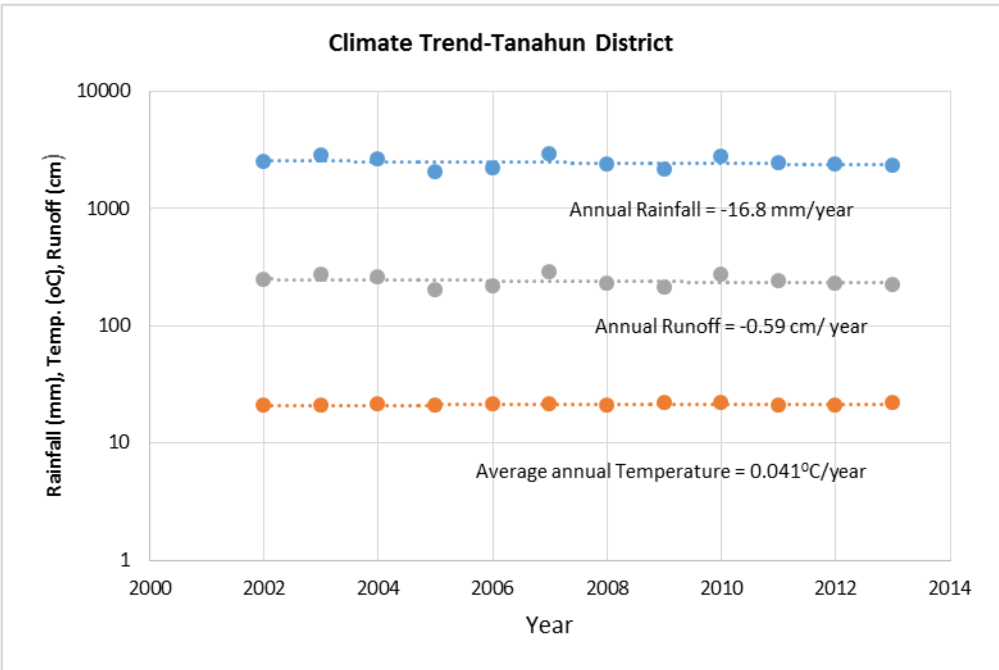

Figure 8: Climate and runoff trend (2002-2013) Tanahun District

3.4 Climate change

a. IPCC AR4-Highlights

The IPCC AR 4 says that continued GHG emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* be larger than those observed during the 20th century. The projected temperature between 2090-2099 relative to 1980-1999 is presented in Table 6. The report also highlighted heavy precipitation events and frequency increases over most areas, increase in drought condition and increase in intense tropical cyclone activity. Some potential impact by future climate change to different sectors is shown in Table 7.

Table 6: Temperature change based on IPCC AR4

Case	**Temperature change (°C at 2090-2099 relative to 1980-1999)**	
	Best estimate	***Likely* range**
B1 scenario	1.8	1.1 – 2.9
A1T scenario	2.4	1.4 – 3.8
B2 scenario	2.4	1.4 – 3.8
A1B scenario	2.8	1.7 – 4.4
A2 scenario	3.4	2.0 – 5.4
A1FI scenario	4.0	2.4 – 6.4

Source: IPCC AR4

Table 7: Major projected impacts by sector

Phenomenon and direction of trend	**Likelihood of future trends based on projections for 21st century using SRES scenarios**	**Examples of major projected impacts by sector**	
		Water resources	**Industry, settlement and society**
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	Virtually certain	Effects on water resources relying on snowmelt	Reduced disruption to transport due to snow, ice.
Heavy precipitation events. Frequency increases over most areas	Very likely	Adverse effects on quality of surface and groundwater	transport and societies due to flooding: pressures on urban and rural infrastructures; loss of property
Intense tropical cyclone activity increases	Likely	Power outages causing disruption of public water supply	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers; potential for population migrations; loss of property

Source: IPCC AR4

b. Climate change - Tanahun District

The average annual rainfall between 2002 and 2013 is **2298 mm**, whereas long term average (1970 to 2010) 12 x 12km gridded rainfall shows **2748 mm** (DHM climate portal). Projected Rainfall (PRECIS-HadCM3Q0-A1B) between 2030 and 2060 (25x25km gridded) is **2153 mm**.

3.5 Point source, spring and stream in Tanahun district

a. Yield in sources

The water source yield was measured in two different years to identify changes in water sources across all VDCs of Tanahun district. First it was measured in March/April 2004 and recently in March/April 2014. The 3320 water sources were measured in 2004 and 4223 including new water sources were measured in 2014. Both yields measured were set for the analysis. But for comparative study, 2387 sources were selected. Due to lack of 2004 data for Byas municipality and Ghiring Sundhara VDCs, they are not included in the analysis. Field team was not able to measure all sources due to very low yield (only seepage is traced). Such yield were written as zero value. Since zero value indicates no source, some traced value should be written. Therefore, '0' values were treated as 0.001 l/s. Few doubtful yields were excluded from the analysis. Further, only single measurement, either 2004 or 2014 is taken out for analysis.

b. Water source yield statistics

The average yield in 685 point sources was around 0.045 l/s in 2014 but it was twice as high in 2004 i.e. 0.09 l/s. The maximum measured yield in 2014 was 1.87 l/s, whereas, the maximum yield was 3 l/s in 2004. Likewise, spring source mean and maximum yield measured in 2014 were 0.16 l/s and 3.33 l/s respectively, whereas, mean and maximum yields in 2004 were 0.204 l/s and 3 l/s respectively. Small streams average yield measured in 2014 was 0.32 l/s with the maximum of around 4.99 l/s. In 2004, mean and maximum yields of streams were 0.485 l/s and 5 l/s respectively. The sample size, ranges, mean, variance, maximum, 75% (q3), 50% (median), 25% (q1) for all three source categories for both measurements are presented in Table 8.

c. Status of water sources

Between 2004 and 2014, around 35% of total water sources included in the analysis seems either improved or constant in flows, whereas, 65% of all sources were in declining condition (Figure 9). The water source categories (point, spring and stream) were also analysed separately. In 37% of the analysed point sources, the yield was in progress or constant, whereas, in 63% of point sources the yield was declining. The same trend was observed in spring sources: in 37% of the spring sources the yield was progressing and in 63% depleting. The measured stream flows show that 72% of the stream sources are declining compared to the flows measured in 2004. The water source flow status is shown in Figures 9 - 12.

Table 8: Descriptive statistics of water source data

Point source (l/s) -2014		**Spring Sources (l/s) -2014**		**Stream source (l/s) -2014**	
Sample Size	685	Sample Size	1115	Sample Size	587
Range	1.86	Range	3.329	Range	4.9
Mean	0.045	Mean	0.16	Mean	0.32
Variance	0.017	Variance	0.09	Variance	0.21
Max	1.87	Max	3.33	Max	4.98
75% (Q3)	0.045	75% (Q3)	0.16	75% (Q3)	0.32
50% (Median)	0.01	50% (Median)	0.06	50% (Median)	0.23
25% (Q1)	0.001	25% (Q1)	0.001	25% (Q1)	0.06675
Point source (l/s)-2004		**Spring Sources (l/s) -2004**		**Stream source (l/s) -2004**	
Sample Size	685	Sample Size	1115	Sample Size	587
Range	2.99	Range	2.999	Range	4.99
Mean	0.09	Mean	0.204	Mean	0.485
Variance	0.048	Variance	0.11	Variance	0.5
Max	3	Max	3	Max	5
75% (Q3)	0. 1	75% (Q3)	0.2	75% (Q3)	0.4
50% (Median)	0.012	50% (Median)	0.11	50% (Median)	0.23
25% (Q1)	0.001	25% (Q1)	0.001	25% (Q1)	0.13

Data source: RWSSP- WN II

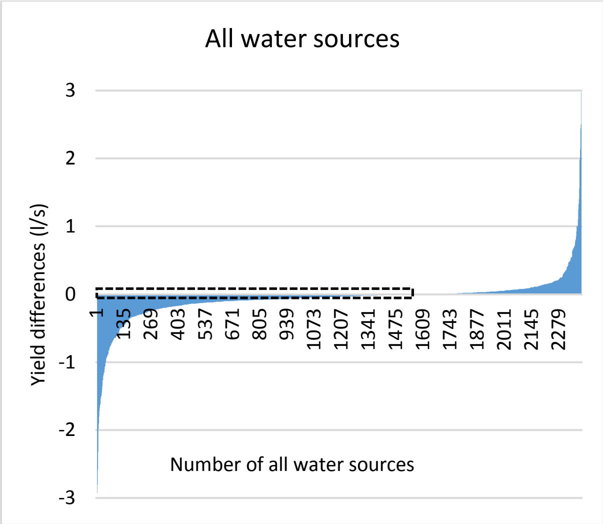

Figure 9: Overall yield changes of all sources (between 2004 & 2014)

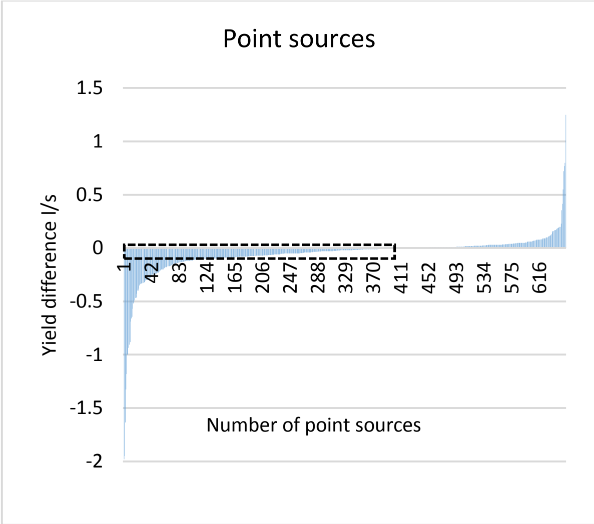

Figure 10: Point source yield changes (between 2004 & 2014)

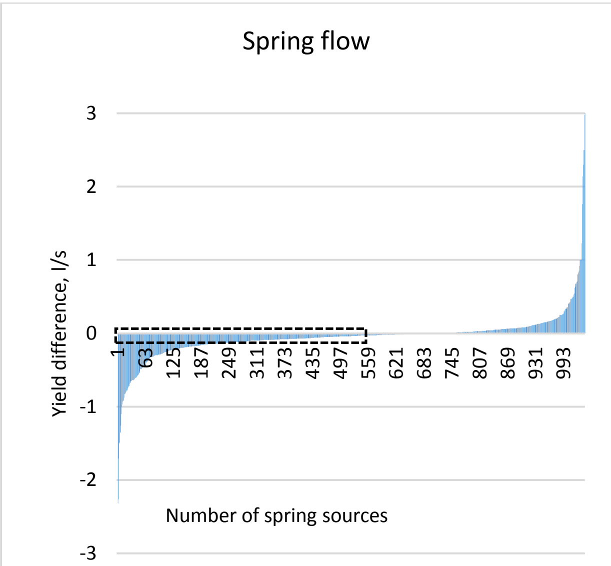

Figure 11: Spring yield changes (between 2004 & 2014)

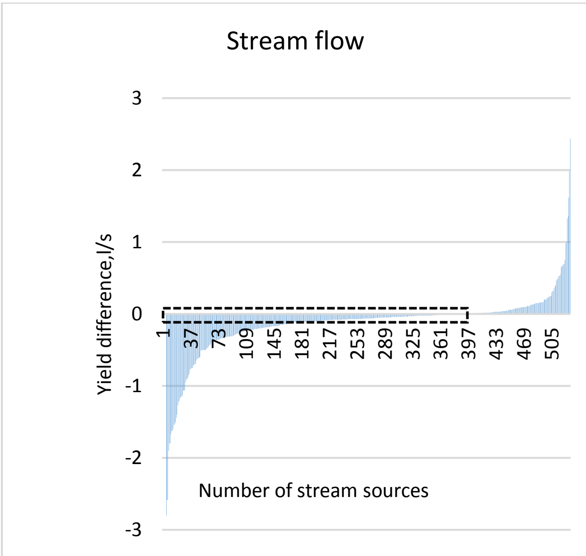

Figure 12: Stream yield changes (between 2004 & 2014)

4 Rainfall and Water Source Mapping

4.1 Rainfall mapping

Since the yield measurements were carried out in dry pre monsoon season (March/April 2004 and March/April 2014), the amount of yield depends on previous year monsoon rainfall i.e. 2003 and 2013 (particularly more effective in depression gravity spring). If the recharge is far away from source and if source/spring is artisan type, the rainfall of one or more previous year's water cycles also impact the yield. Therefore, two previous years rainfall were studied and mapped. The maps constructed are shown in Figures 14 - 17. The annual average rainfall (2002 to 2013) map is also constructed using Kriging interpolation with 5 x 5 km resolution (Figure 13).

4.2 Water source mapping

All type of gravity water source measurements were carried out in dry pre monsoon season (March/April 2004 and March/April 2014). The changes of yield between 2004 and 2014 is mapped with reference to measurement location and Kriging interpolation of 2 x 2 km resolution in GIS. To current strength of yield is also mapped using Kriging interpolation with 2 x 2 km resolution. The constructed maps presented in Figures 18 - 25.

4.3 Mapping analysis

a. Rainfall

In Tanahun District, year 2002 can consider as active rainfall year. The maximum rainfall of the year was 3400-3600 mm at North-East and North-West part of the district and minimum rainfall between 1800-2000 mm was found South-Central part. In 2003 maximum rainfall was between 3000-3200 mm at North West. However, low rainfall between 1000-1200 mm also received by district, this low patch is only concentrated Ramjakot VDC.

The maximum rainfall in 2012 is between 2800-3000 mm. This high pocket was found only at small area i.e. at Firfire VDC only (North-West). The low rainfall between 1400-1600 mm was found at South-Central Area. The year 2013 has received maximum rainfall between 2600-2800 mm but this pocket was located at small area at Gajarrakot VDC (South –West).

b. Water source mapping

As mentioned above water sources are declining in many of the sources. The interpolated maps shows majority of areas are under declining yield stage. The blue monochrome i.e. progressing area is far less than declining areas (purple monochrome (Figures 19, 21, 23 and 25).

5 Conclusion and Recommendation

a. Conclusion

The overall climate between years 2002 to 2013 and measured yield data between 2004 and 2014 shows climate as one of the causes of water source decline. The temperature is rising with pace of 0.041 ^{0}C per year and rainfall is decreased by 16.8 mm/year. The UP Irrigation Research Institute (1960) formula $R=5.45\ P^{0.6}$ shows decrease of 0.59 cm/ year in runoff.

The water source measurements in 2014 and 2004 show 50% deduction of point sources' average yield in 10 years. Similarly 21.6% and 34% deductions of average yield were found in spring and stream water sources respectively (Table 9).

Table 9: Changes in climate and yield status - Tanahun District

Changes between 2004 and 2014		Remarks
Annual Rainfall	-16.8 mm/year	Projected annual average Rainfall (PRECIS-HadCM3Q0-A1B) between 2030 and 2060 (25x25km gridded) is **2153 mm.** The average annual rainfall between 2002 and 2013 is **2298 mm**, whereas long term average (1970 to 2010) 12 x 12km gridded rainfall shows **2748 mm** (DHM climate portal).
Annual Average Temperature	+ 0.041 ^{o}C /year	
Runoff	-0.59 cm/year	
Point source yield	-50%	
Spring source yield	-21.6%	
Stream source yield	-34 %	

Data Source: DHM and RWSSP-WN II

The Projected Rainfall (PRECIS-HadCM3Q0-A1B) between 2030 and 2060 (25x25km gridded) is **2153 mm.** Whereas the long term average (1970 to 2010) 12 x 12km gridded rainfall shows **2748 mm** (DHM climate portal). It shows the overall decrease in rainfall between year 2030 and 2060 is around 21 %. Therefore, further decrease in water source yield is expected in future.

It is highly possible that some area will be effected by drying sources. The most severe will be low rainfall area. The average annual rainfall (2002-2013), shows different rainfall patches. The low pocket is observed at central south part of district whereas, high pocket is seen at upper northern part of the district. The average rainfall (2002-2013) and overlying VDC's are presented in Table 10.

Table 10: Annual average rainfall (2002-2013) and VDCs (see Figure 13)

Annual Rainfall	VDC	Scale
2400-2800 mm	Firfire, Raipur, Dhorphirdi Dulegaunda, Thaprek, Rupakot	**High**
1800-2400 mm	Risti, ChokChisapani, Mirlung, Shymgha Kyamin, Purkot, Satiswara, Basantapur, Khairenitar, Manpang,Tanahunsur, Bhanu, Barbhanjyang, ByasN.P. Chhang Bhanumati Bhimad JamuneBhanjyang, Ghansikuwa, Arunodaya Majhakot, Ranipokhari(Resing) Bandipur, Pokharibhanjyang, Kihun, Keshavtar ShambuBhagawatipur, Anbukhaireni Sundhara(Ghiring), Gajarkot, Dharampani Baidi, Deurali, Chhimkeshwori, Chhipchhipe, Devghat, Kota,	**Medium**
1600-1800 mm	Firfire, Raipur, Dhorphirdi Dulegaunda, Thaprek, Rupakot	**Low**

Note The interpolated annual rainfall is 5x5 km grid. Some VDCs shares two different rain grids. These VDC are scaled by VDC area that fall more area in particular rain group (more than 50% VDC area coverage with particular rainfall categories is kept in same category.*

The source yield in 10 years is in declining stage. The changes in yield is also shown in maps. The purple monochrome shows declining area and blue shows progress area (Figures 19, 21, 23 and 25). In maps VDC boundaries were merged to see the flow status in VDCs.

b. Recommendation

One of the causes of decline of Yield is particularly low rainfalls and high evaporative losses due to warming. Beside this intense rainfall may also reduce the stream flow as there will be more overland flows. The possible hazard in future is drying up sources due to lowering ground water table. The study recommend following measures:

1. Investigation on water source recharge area using advance technology is needed.
2. Construction of Recharge ponds will be helpful in recharging grounds. But overland flow and subsurface flow tracking should be studied before construction of ponds.
3. As total rainfall is declining, construction of multiple percolation ponds is also recommended as recharge.
4. As adaptation to climate change, roof top rainwater harvesting and overflow recharging ground should be promoted in large scale.
5. The water source yield data should be collected at least once in peak season and dry season to estimate the total yearly flow which will be handy during storage tank design.
6. Proper source yield measurement training (chemical and area velocity) is essential for field technical staff.
7. The measured data should be checked by ordering ‘A to Z’ in sheet for consistency or to find out data entry mistakes.
8. The corrected GPS elevation water sources is very sensitive data for GIS environment. It should be checked by converting it into ‘KMZ’ file and importing it into Google earth.
9. Yields should not be left ‘0’ if flow is visible. Possible technology should be applied to estimate low flow or one can record as traced instead of writing zero value.
10. Shifting of rainfall distribution may help in forming new spring but it may dry up existing source. Therefore conservation ponds or pits should be planned if source yield is remarkably decreasing.
11. During any water source measurement, leaks/overflow should be checked to ensure the actual yield.
12. Besides changing climate impact as major, there might be other small multiple causes in declining water sources. Therefore, it is necessary to delineate spring shed boundary of declined sources. The human interventions should be studied pertaining to negative change in source yield
13. The land use digital maps were available with department of Survey (Nepal Government-1996). European Satellite Agency’s 300m x 300m resolution land use digital maps are available in public domain. It is recommended to study both maps to see the human intervention in spring’s watershed.
14. Generally source yield declines sharply when its water table will be cut down by some construction. Therefore, the rural road construction pattern should be studied.
15. It is also possible that deepening of downstream Main River may lower down the water table. Therefore, the research should include such factors in spring yield study.
16. Rise in temperature may evaporates high amount of water to atmosphere. It will greatly effect at agriculture or barren land. Therefore, the result may be more losses and less percolation into ground. In such condition, the numerous recharge pits in barren land or cultivated land is recommended. It is highly recommended to apply this approach at watershed where yield is critically falling.
17. Single measurement is not enough to estimate total annual yield. Monthly measurement of couple of easily accessible sources is recommended. It will help to estimate annual yield of other non-measured sources.

Table 11: Water source yield changes (2004-2014) and VDCs (based on Figures 19, 21, 23 and 25)

		Point Source	Spring Source	Stream source
Yield between 2004 & 2014	**Highly Declined**	Risti (south-west), Deurali(north), Dharampani, Chipchhipe (north), Rupakot (north-west), Keshavtar (south-east), Anbukhaireni (south),	Kotdabar (central), Kota (central & south), Virlung (west and east)	Risti (central), Virlung (west) Satiswara (Central-north)
	Declined	Rupakot, ChokChisapani Firfire, Dorphirdi (north-east) Thaprek, Dulegaunda Virlung, Shymgha, Kyamin Purkot, Dhorfirdi, Satiswara Basantapur, Khairenitar Raipur, Manpang (south), Tanahunsur, Bhanu (south), Barbhanjyang, ByasN.P. Chhang, Bhanumati Bhimad, Ghansikuwa Arunodaya, Majhakot Ranipokhari(Resing), Bandipur (central), Pokharibhanjyang KahuShivapur, Kotdarbar, ShambuBhagawatipur Anbukhaireni, Ramjakot Gajarkot (northwest), Baidi, Deurali Bhirkot, Chhimkeshwori Chhipchhipe, Devghat, Kota, JamuneBhanjyang (north)	Rupakot, Risti, ChokChisapani Firfire, Thaprek, Dulegaunda Virlung, Shymgha, Kyamin Purkot, Dhorfirdi, Satiswara Basantapur, Khairenitar Raipur, Manpang, Tanahunsur, Bhanu, Barbhanjyang, ByasN.P. Chhang, Bhanumati Bhimad, Ghansikuwa Arunodaya, Majhakot Ranipokhari(Resing), Bandipur, Pokharibhanjyang KahuShivapur, Keshavtar Kotdarbar, ShambuBhagawatipur Anbukhaireni, Ramjakot (north) Gajarkot, Dharampani Baidi (north-south), Deurali Bhirkot, Chhimkeshwori Chhipchhipe, Devghat, Kota	Thaprek (north-south-central), Syamgha, Ghansikuwa, ByasN.P (north), JamuneBhanjyang (west-south), Keshavtar, Kyamin, PokhariBhanjyang (south-east), Purkot, Ranipokhari, Syamgha, Tanahunsur, Bhanumati (northeast), Virlung, Satiswara Rupakot, ChokChisapani, Basantapur, Kotdarbar, Chhang(north-south-central), Bandipur, Devghat, Chhimkeshwori, Deurali, Anbukhaireni Dharampani, Baidi north-south east), Bhirkot, Sundhara (south-east)
	Progressed	Jamune Bhayanjang (central –south), Gajarkot (south-west), Bandipur (central-north-west), Bhanumati (west), Bhanu (north), Basantapur (southeast), Phurkot (southwest), Manpang (north), Dorphirdi (west)	Thaprek (north-south-east), Purkot, Kihun, Sundhara, Arunodaya, Ramjakot, JamuneBhanjyang, Baidi, Dorphirdi (southeast), Manpang (central), Pokharibhanjyang (south), Chipchipe (central, south west), Gajarkot (east), Ghansikuwa (south east-southwest), Byas NP(central-west), Khairanitar (south) Bhirkot (east-west)	Kota, Garakot, Majhakot, Raipur, Firfire, Dhorphirdi (north-east-central), Dulegaunda, Khairenitar (north-west-central), Kihun, Manpang (central –south-north), Chipchipe (south), Bhimad, Jamune Bhayanjang, Byas NP (south-west, Sundhara (north-central-west), Bhanumati (south-east-northwest) ShambuBhagawatipur (west), Bandipur (centralwest) Keshavtar (north), Jamune (central-north-east)

Note The interpolated water yield is 2x2 km grid. Many VDCs shares two different unit grids. Therefore, some VDCs name is repeated in two categories in Table 11.*

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Annex 1: Average monthly rainfall (2002-2013) of meteorological stations

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
DANDASWANRA	25	36	53	129	336	586	787	706	441	106	17	3	3225
RUMJAKOT	16	30	37	68	216	320	402	328	181	54	11	17	1679
LAMACHAUR	26	37	67	122	376	794	1062	992	753	175	20	18	4442
DAMAULI	16	26	36	103	237	335	424	320	206	44	6	18	1771
KUNCHHA	22	33	54	101	252	496	614	520	332	98	14	24	2559
SYANGJA	22	32	43	101	286	544	751	619	388	103	11	29	2928
KHUDI BAZAR	27	44	77	101	208	558	861	827	469	104	15	25	3314
JAGAT (SETIBAS)	30	46	75	69	71	185	329	272	166	54	9	20	1325
GARAKOT	21	24	32	67	168	361	514	398	260	54	11	35	1945
DUMKIBAS	17	19	14	36	124	388	683	555	377	79	8	27	2328
TANSEN	23	24	23	35	77	233	460	357	196	51	4	25	1506
GORKHA	22	18	37	76	167	327	435	368	192	51	9	22	1725
BANDIPUR	24	24	36	78	201	335	466	379	202	62	10	24	1841
RAMPUR	18	16	21	55	153	354	540	439	304	80	7	13	1999
JHAWANI	16	19	19	53	121	305	495	473	288	78	9	11	1888
Average	22	28	42	80	200	408	588	504	317	79	11	21	2298

Annex 2: Monsoon and non-monsoon rainfall mm/year (2002-2013)

Station	Yearly	Monsoon	Non-monsoon	%Monsoon	%Non-monsoon
DANDASWANRA	3225	2521	705	78	22
RUMJAKOT	1679	1230	448	73	27
LAMACHAUR	4442	3601	841	81	19
DAMAULI	1771	1285	486	73	27
KUNCHHA	2559	1962	597	77	23
SYANGJA	2928	2302	626	79	21
KHUDI BAZAR	3314	2714	601	82	18
JAGAT (SETIBAS)	1325	952	373	72	28
GARAKOT	1945	1532	412	79	21
DUMKIBAS	2328	2003	325	86	14
TANSEN	1506	1245	261	83	17
GORKHA	1725	1322	403	77	23
BANDIPUR	1841	1382	459	75	25
RAMPUR	1999	1637	363	82	18
JHAWANI	1888	1561	327	83	17
Average	2298	1817	482	79	21

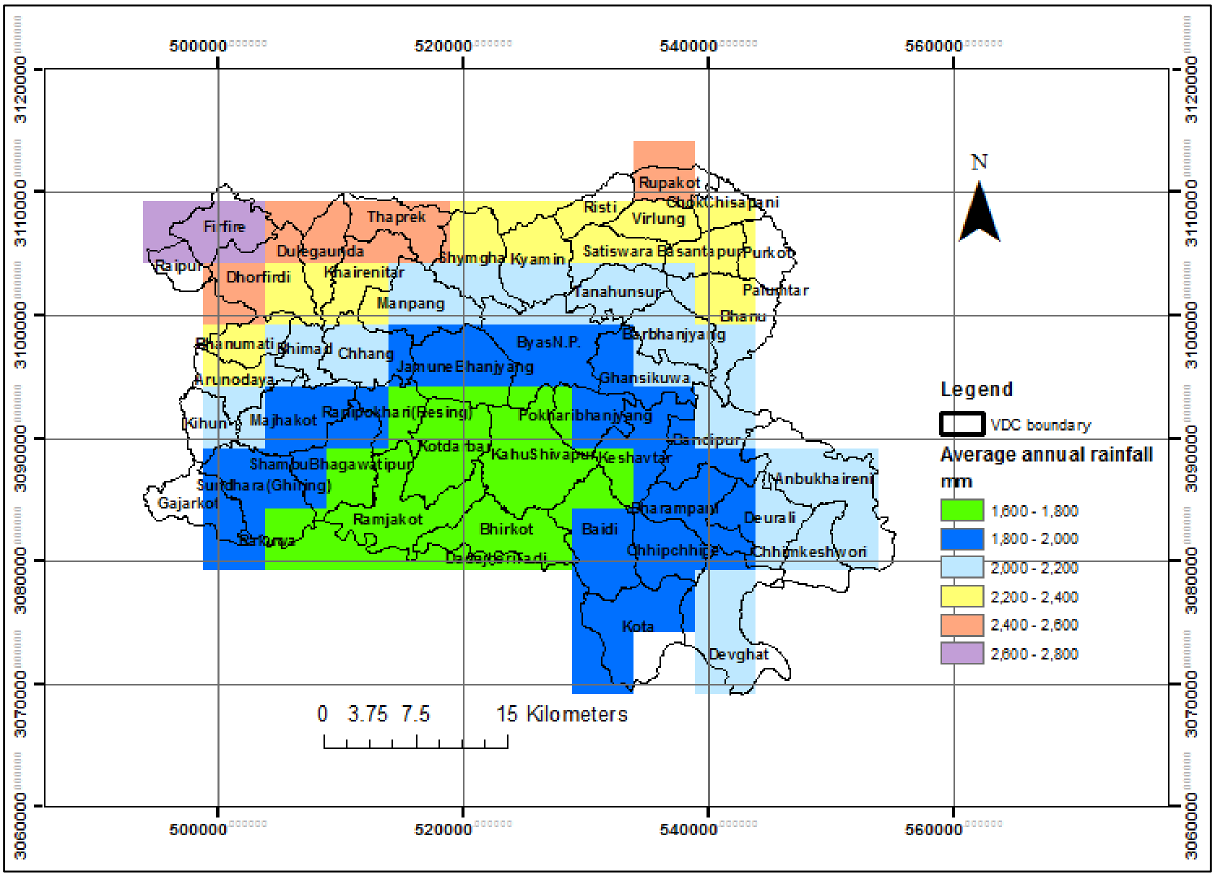

Figure 13: Average annual Rainfall 5 x 5 km (2002-2013), Tanahun

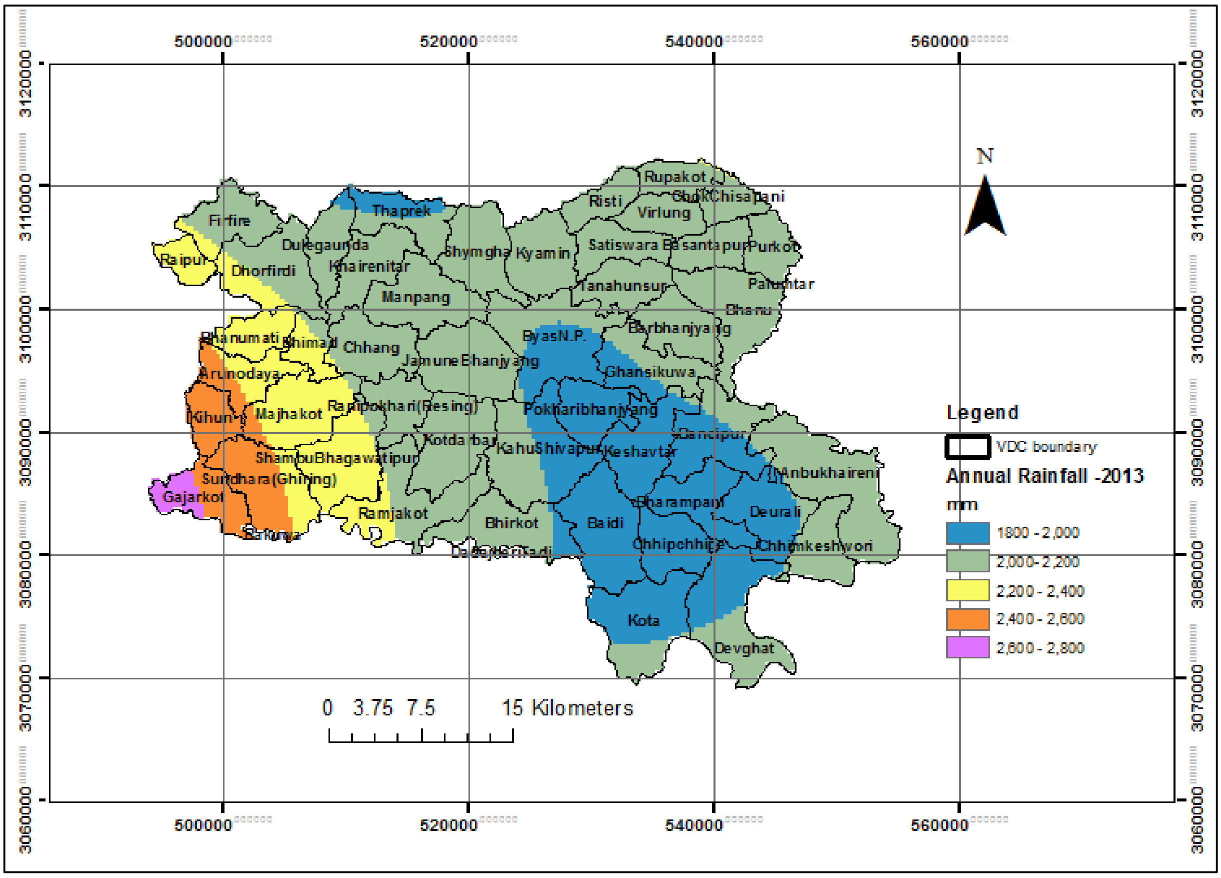

Figure 14: Annual Rainfall – 2013, Tanahun

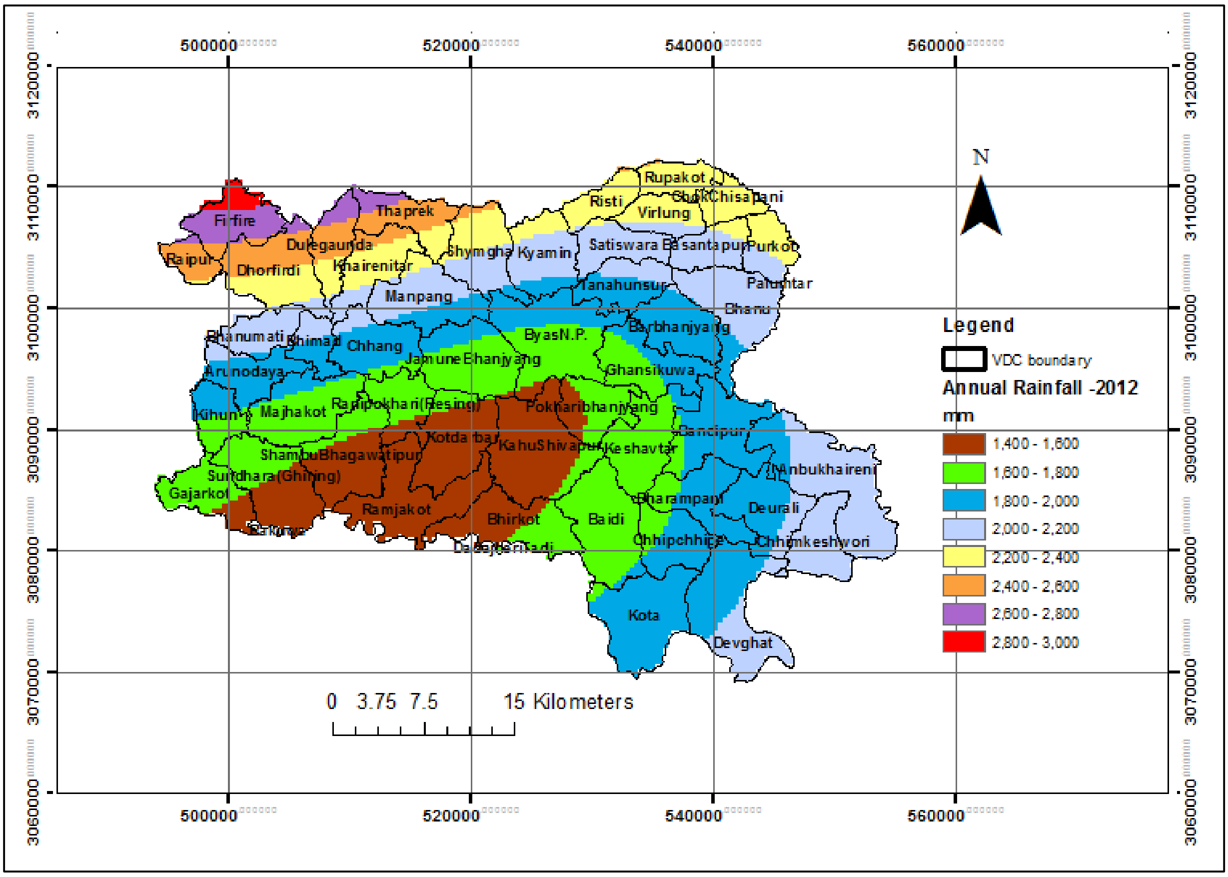

Figure 15: Annual Rainfall – 2012, Tanahun

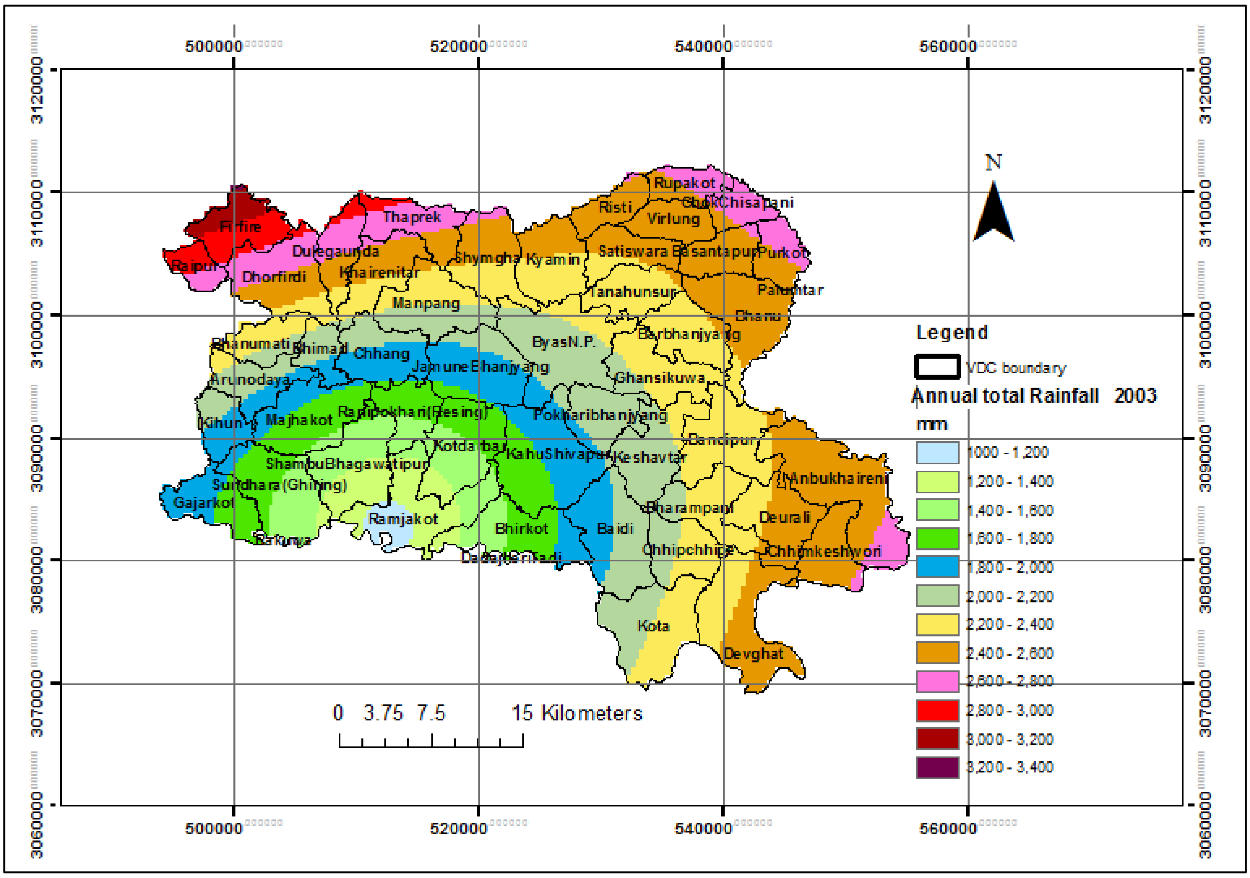

Figure 16: Annual Rainfall – 2003, Tanahun

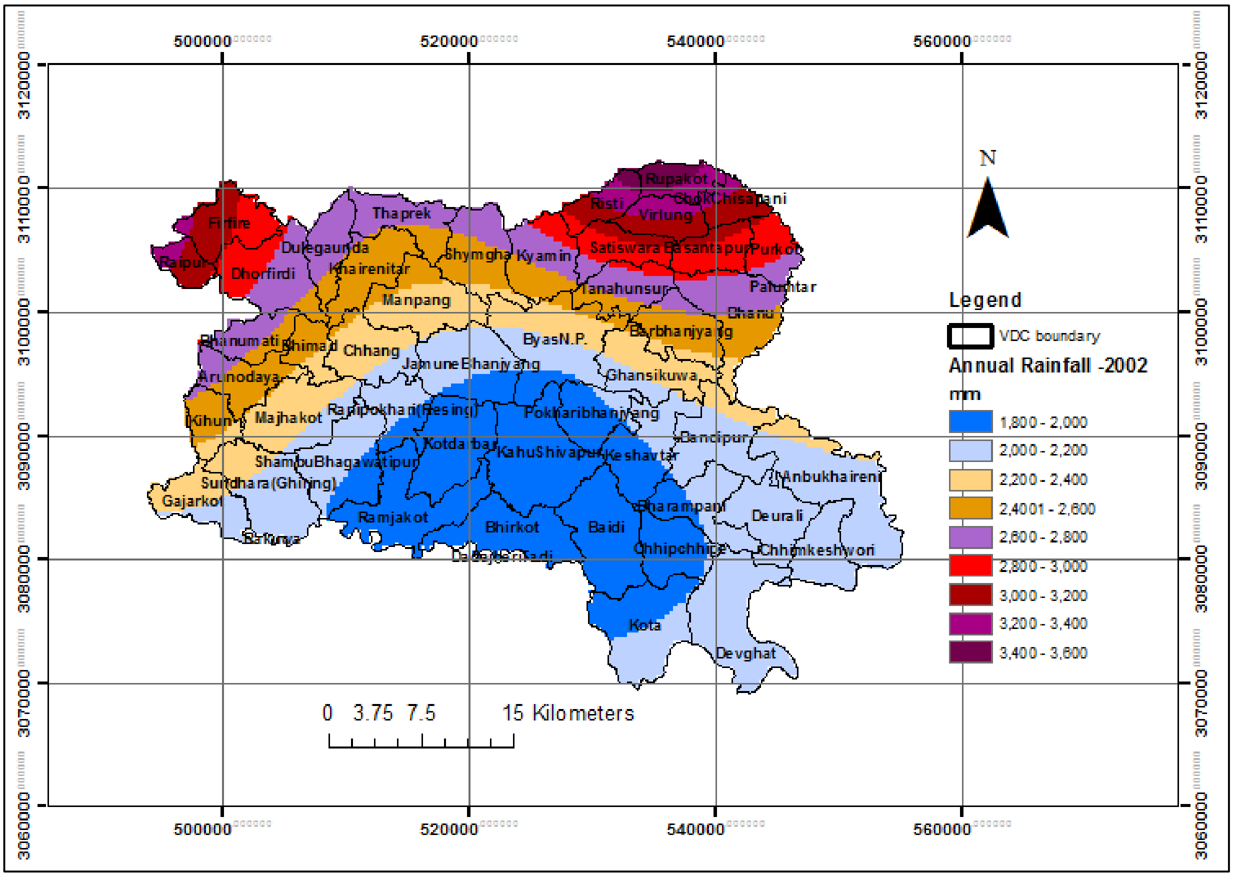

Figure 17: Annual Rainfall – 2002, Tanahun

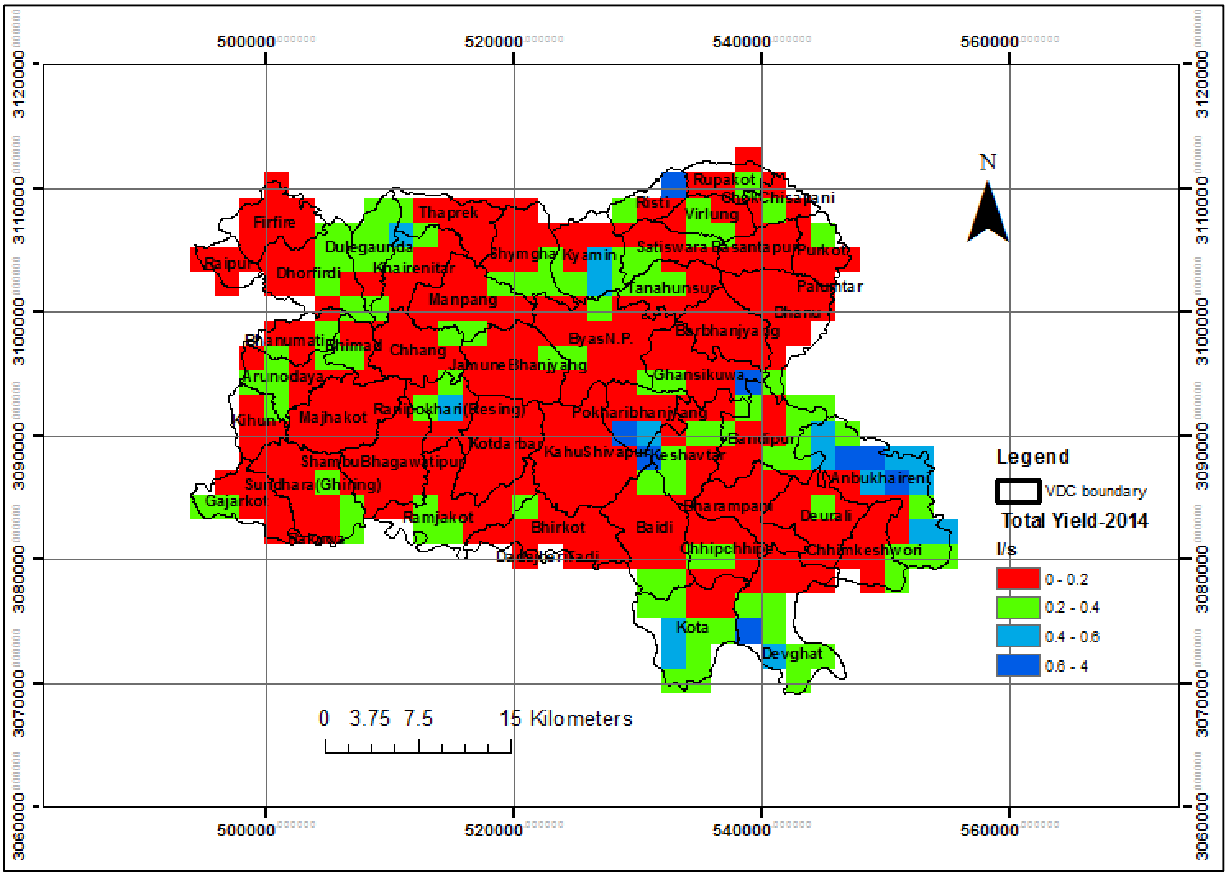

Figure 18: All sources yield -2014, Tanahun

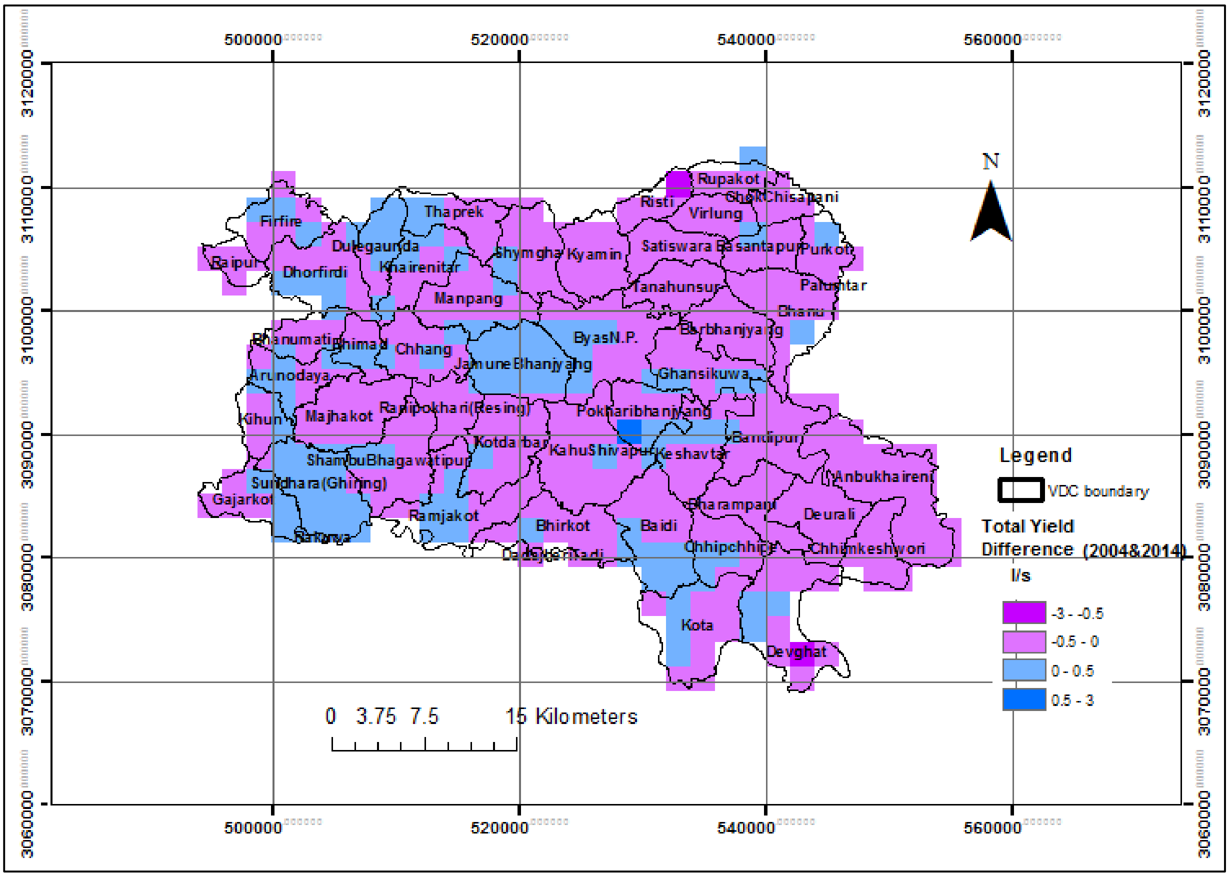

Figure 19: All sources yield changes (between 2004 & 2014), Tanahun

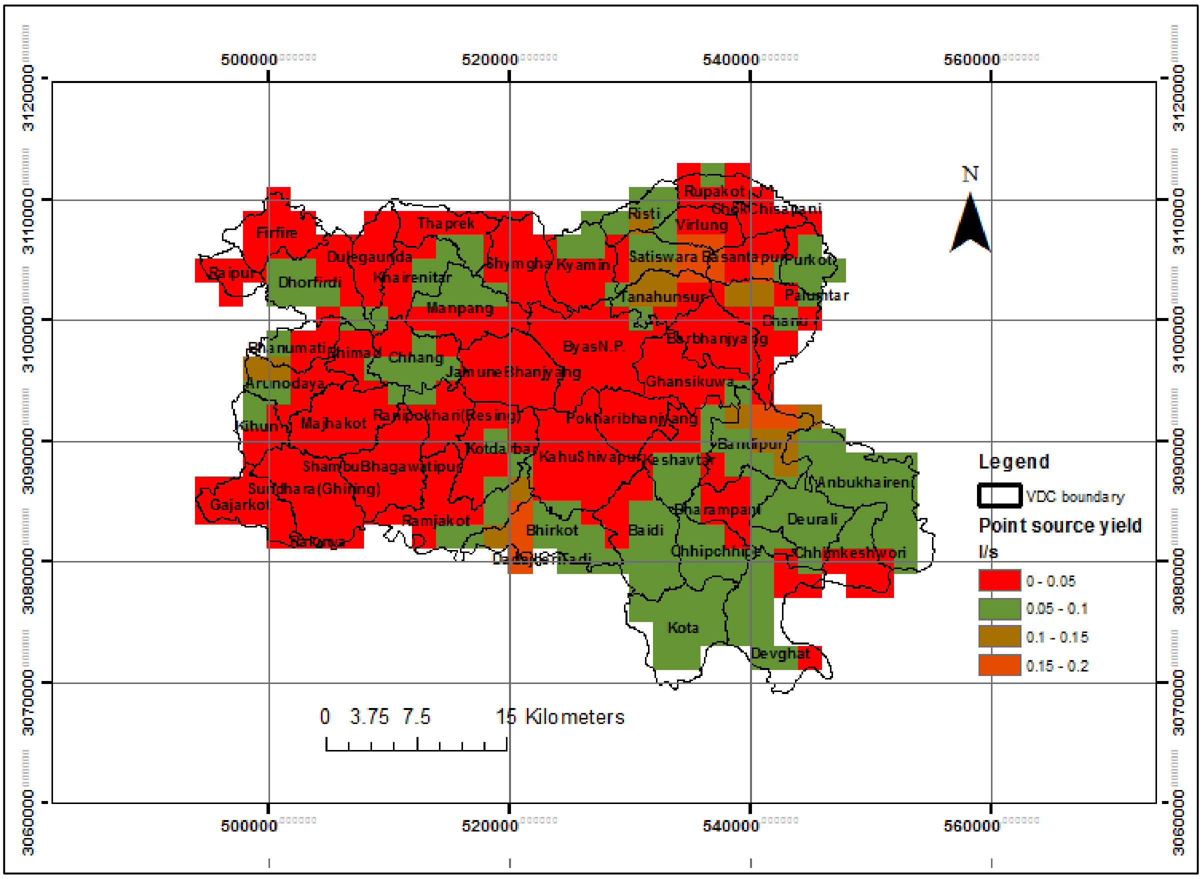

Figure 20: Point sources yield -2014

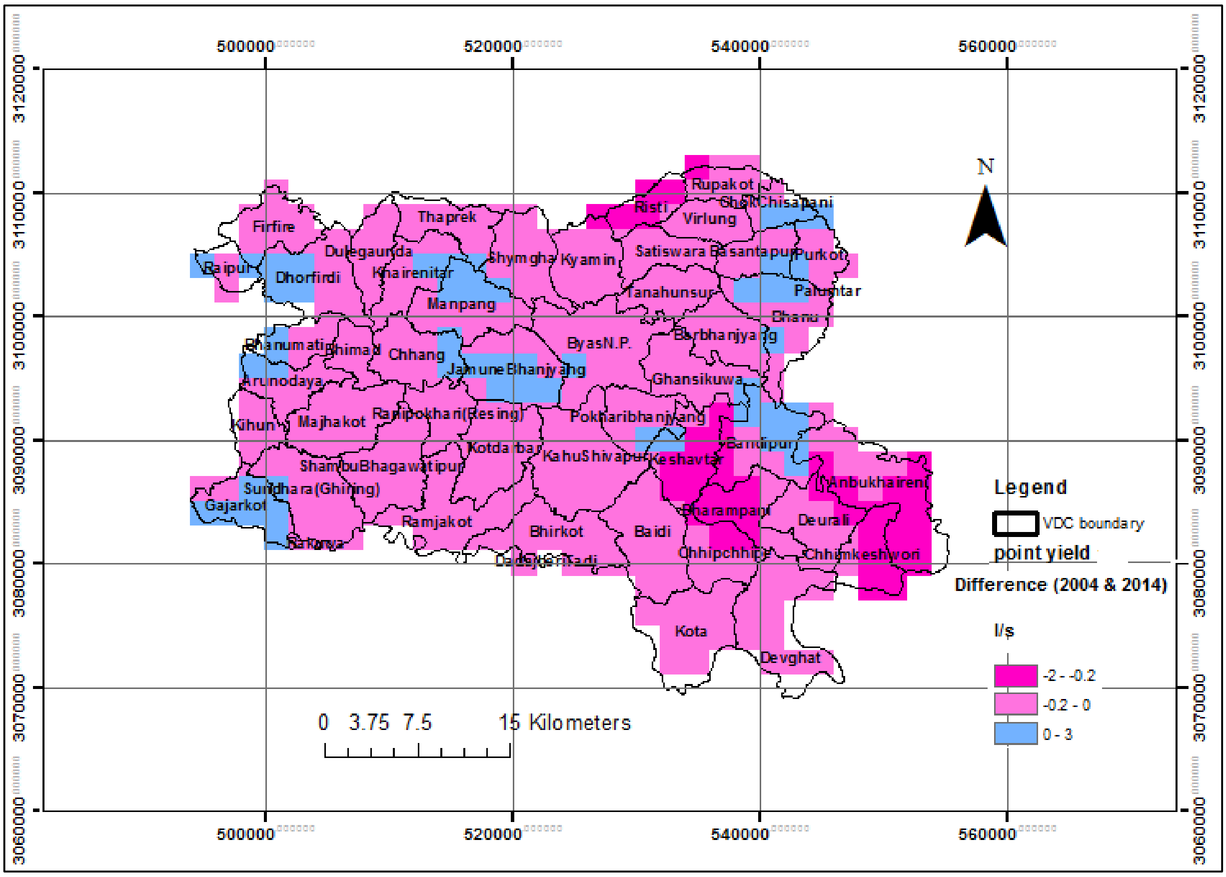

Figure 21: Point sources yield changes (between 2004 & 2014)

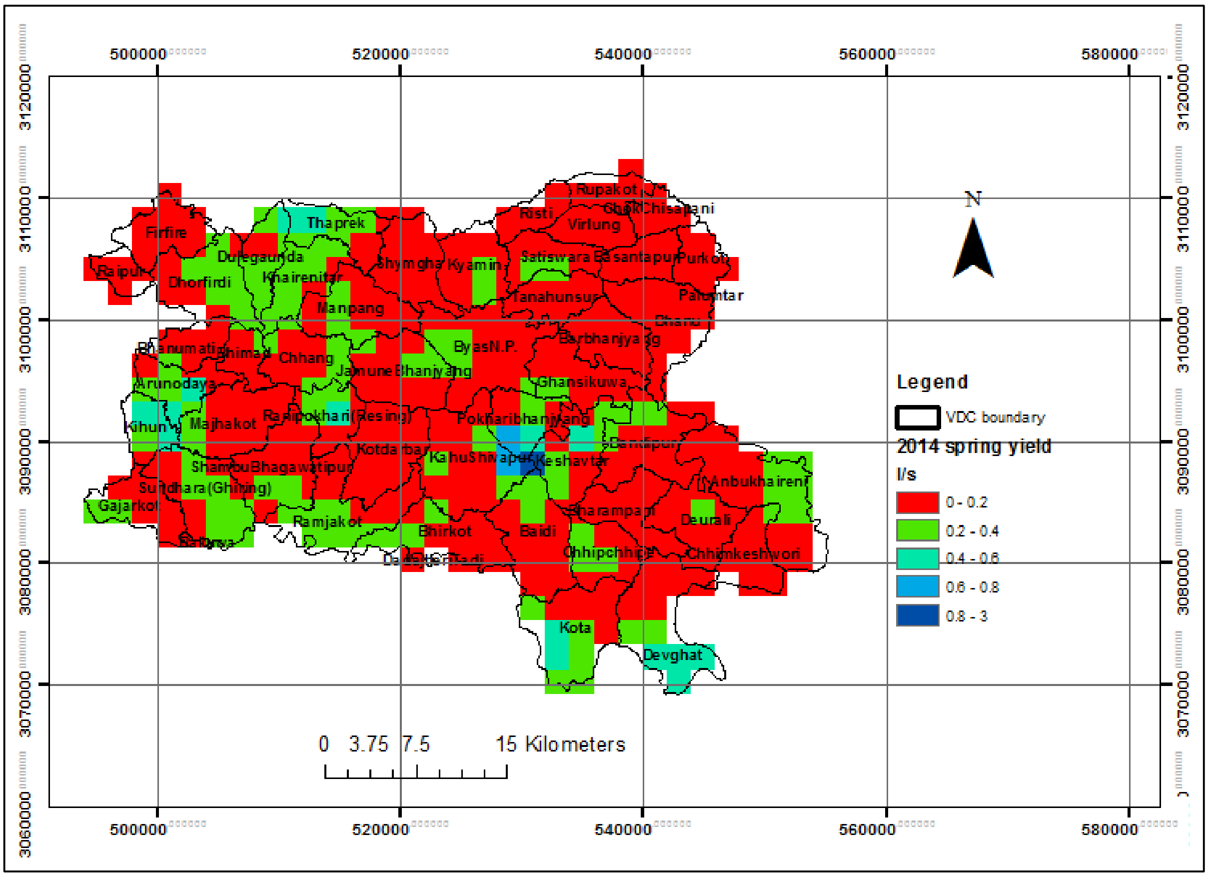

Figure 22: Spring sources yield -2014

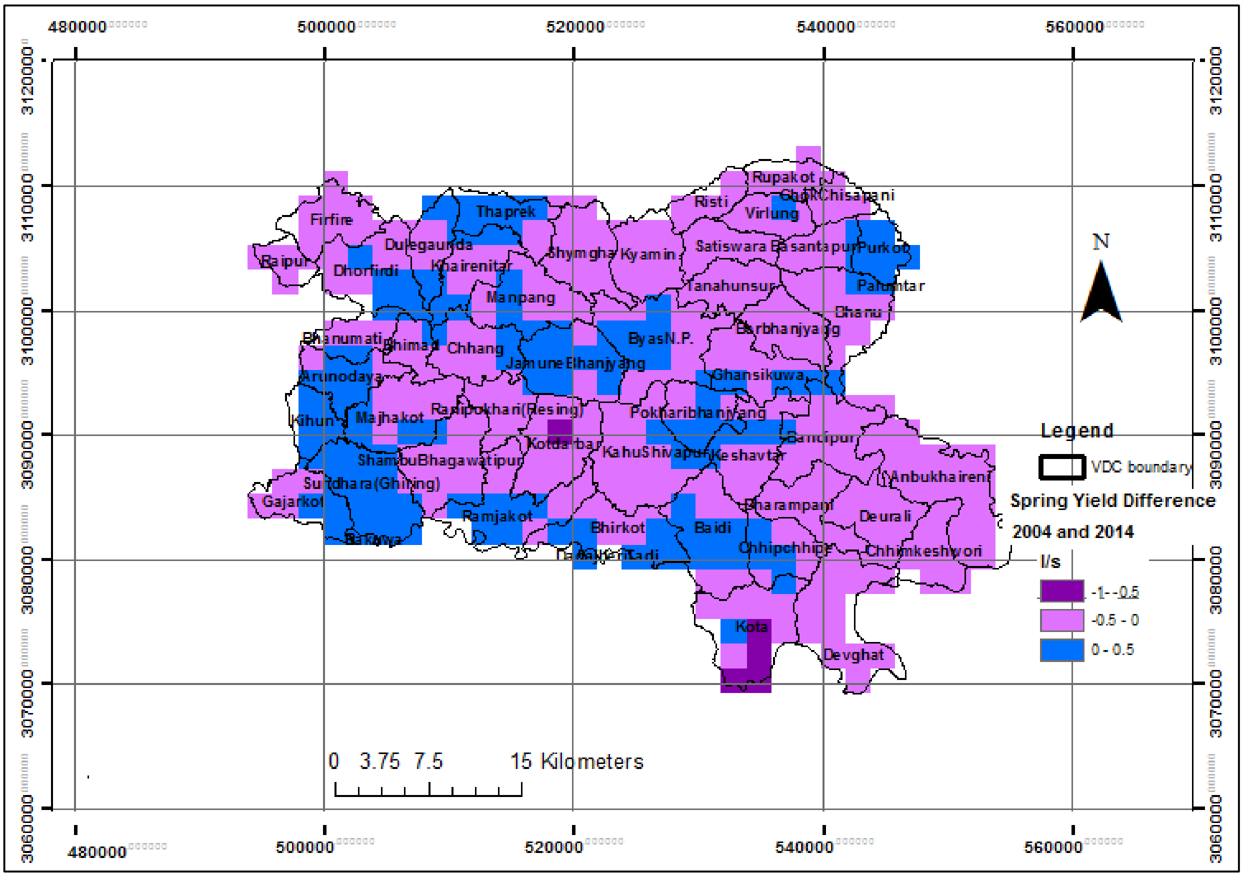

Figure 23: Spring source yield changes (2004 &2014)

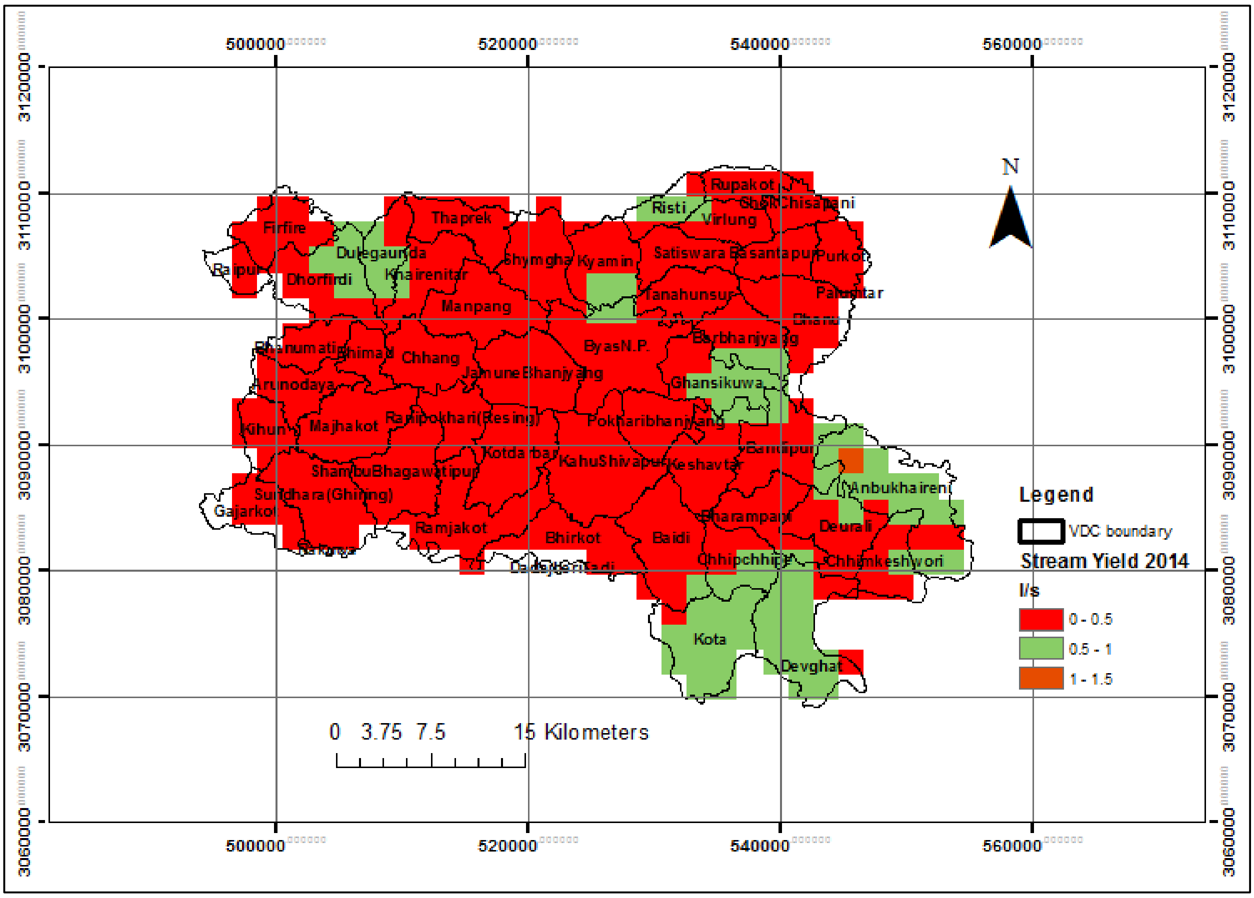

Figure 24: Streams source yield - 2014, Tanahun

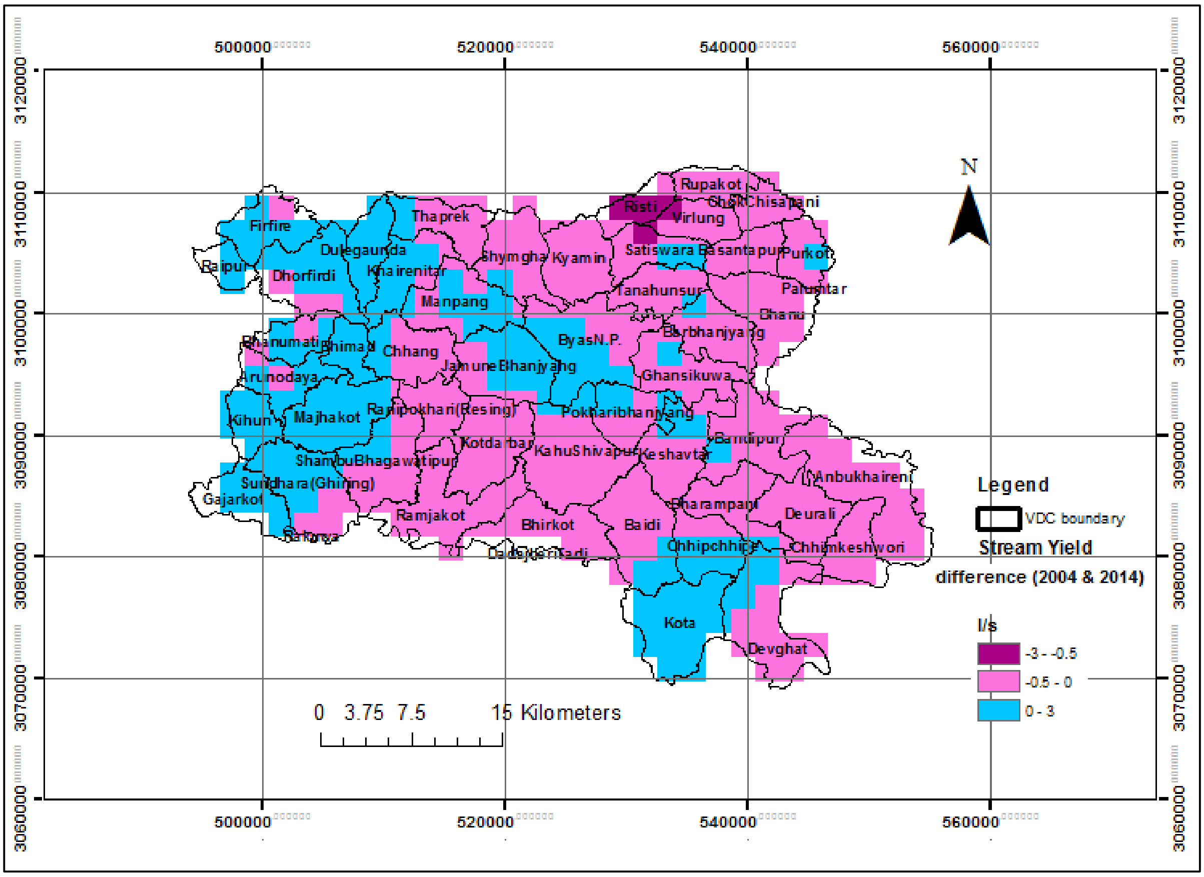

Figure 25: Stream source yield changes (between 2004 & 2014)