Climate and Land-cover Change in Dryland-Catchments, and Their Effect on Spate-hydrology in Semi-arid Lowlands of Raya-valley, Northern Ethiopia

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RESEARCH 2 PRACTICE FORUM 2018

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Outline

- Introduction
- Materials and Methods
- Results and Discussion
- Conclusion and Recommendations

1. Introduction

- One of the challenges Ethiopia is facing in attaining food security and reducing poverty is, its high dependence on rain-feed agriculture, which is characterized by high degree of variability and unreliability of the rainfall pattern (Hiben et al., 2013; Mitiku et al., 2002).

- Crop failure and recurrent droughts are common phenomenon.

- The case becomes worse in arid and semi arid lowlands where its difficult to produce food crops.

- Drought prone communities such as Raya-Valley are applying spate-irrigation as an adaptation to CC and so as to boost food production in rainfall deficit lowlands (Eyasu et al., 2015; Steenbergen et al., 2010; Mehari et al., 2005).

- Spate irrigation is a unique form of irrigation, predominantly found in arid and semi-arid lowlands, where flood water of short duration from the neighboring highlands is diverted in to farm fields (Eyasu et al., 2015; FAO, 2010; Steenbergen, et al. 2010).

Cont..

- In Tigray, particularly in the Raya-Valley, there is a potential of 80,000 ha of irrigable land through flood potential of $170x10^6$ m^3yr^{-1} generated from the surrounding highlands (Eyasu et al, 2012).

- The average annual rainfall in highlands of the Raya-valley is around 800 mm, but that of the lowlands is less than 350 mm (Mehari et al., 2013).

- Thus, use of seasonal runoff in these lowlands is a matchless option of agricultural production, improving livelihood of farmers in the fate of climate change.

- Despite its growing importance, climate and land-cover change in the highland catchments are affecting spate-hydrology to support crop production on spate-based farming community in the lowlands.

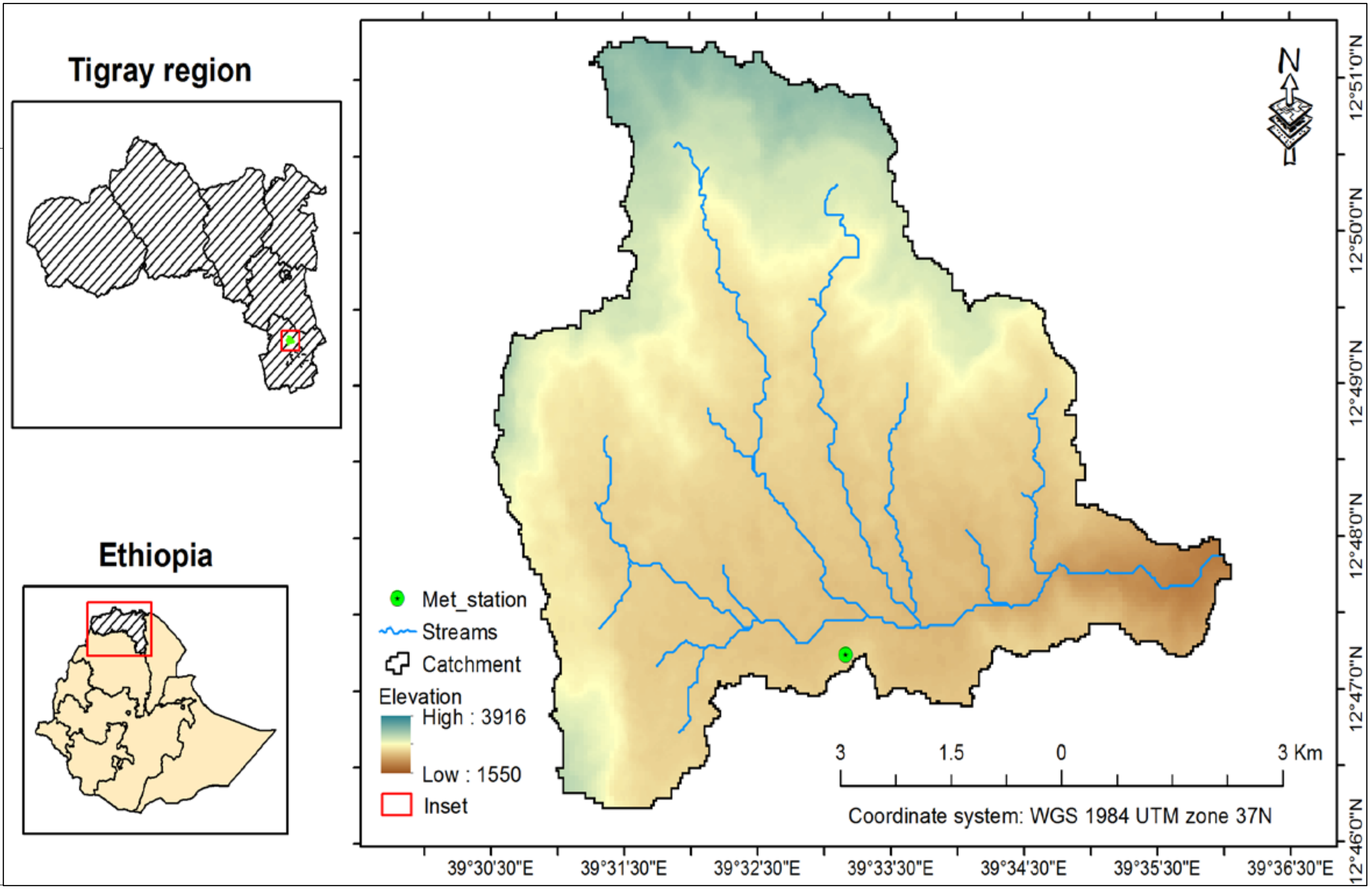
- Even though, climate and land-cover dynamics upstream are big concerns of the community in these semiarid lowlands, there are no sufficient researches conducted in this regard.

- This research was therefore setup to investigate the impacts of climate and land-cover change on spate-hydrology of semi-arid lowlands in the Raya-valley.

2. Materials and Methods

2.1. Area description

- Has a total surface area of 4998 ha
- Found in Endamehoni, and Raya-Azebo districts of Southern Tigray, Northern Ethiopia.
- 12°46'14''-12°51'18''N lat, & 39°30'30''-39°36'4''E long.
- Geologically: Alluvial deposit



2.2. Data sources and analysis

2.2.1. Climate data (1980-2015)

Rainfall	NMA, 2015
Tmax	NMA, 2015
Tmin	NMA, 2015
Evapotranspiration	Hargreaves method

- Data gaps filled using AgMERRA satellite observation data

  www.agmerra.com

2.2.2. Landcover information

Landsat 4-5 TM	1984 and 1994
Landsat 7 ETM+	2002
Landsat 8 OLI	2015

https://earthexplorer.usgs.gov/

Landcover dynamics

Overlay analysis

Image classification

- Pre-processing
- Post-processing

Accuracy assessment

- 115 GCP's

Normalized Difference Vegetation Index

Landsat 4-5 TM, 7 ETM+

$$\mathrm{NDVI} = \frac{\mathrm{NIR(B4)} - \mathrm{Red(B3)}}{\mathrm{NIR(B4)} + \mathrm{Red(B3)}}$$

Landsat 8 OLI

$$\mathrm{NDVI} = \frac{\mathrm{NIR(B5)} - \mathrm{Red(B4)}}{\mathrm{NIR(B5)} + \mathrm{Red(B4)}}$$

Soil data Cascape, 2016

2.2.3. Direct-runoff estimation

- SCS-CN method (Schneider and McCuen, 2005; Descheemaeker et al., 2008).

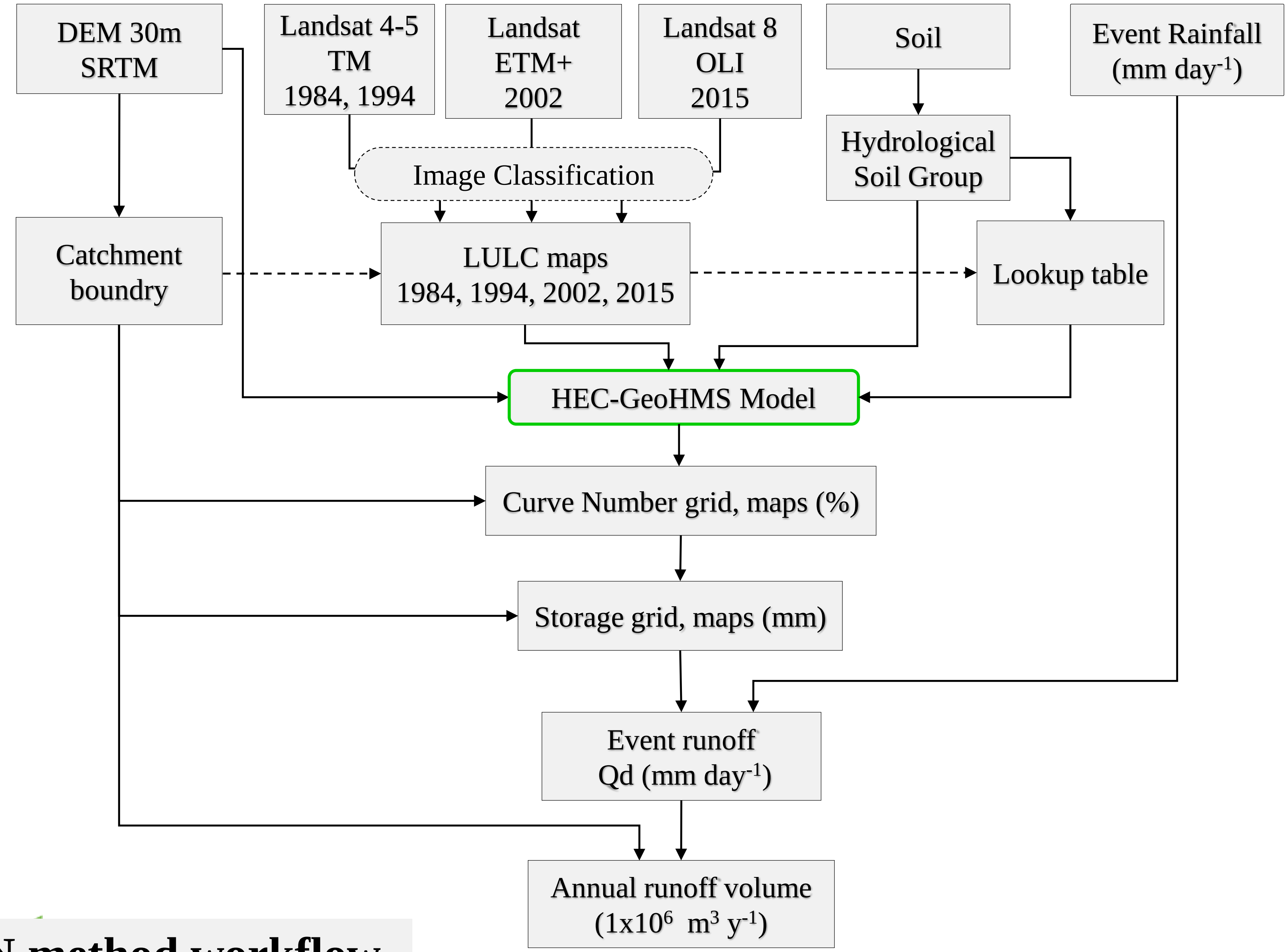
$$Q = \frac{(P - IaS)^2}{(P + (1 - Ia)S)}, \quad when\ P > I_a S,$$

$$Q = 0, \qquad when\ P < I_a S$$

$$S = \frac{25400}{CN} - 254$$

Where Q = event runoff
P = event rainfall
I*a* = Initial abstraction ratio (0.05)
S = Storage capacity of the soil
CN = weighted curve number

- Used as a substitute in the absence of sufficient hydro-meteorological data.
- To quantify the effect of changes in rainfall and landcover on hydrological response of catchments (Gebresamuel et al., 2010; Hawkins, 1993; Teka et al., 2014).



SCS-CN method workflow

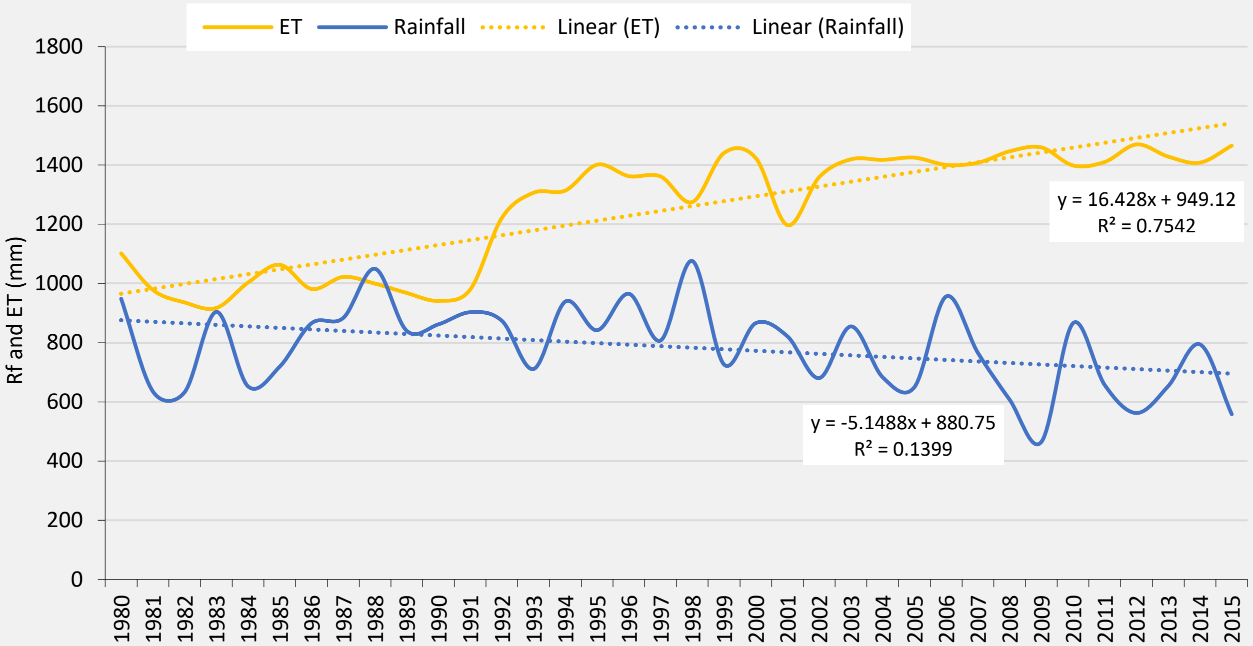
2.2.4. Spate-irrigated agriculture

- Spate-irrigated command area (1980’s versus 2015)
  - ✍ Ground survey using GPS device
  - ✍ Key informants involved
  - ✍ Verified in Google Earth
  - ✍ Analyzed and mapped out in ArcGIS10.2

3. Results and Discussion

3.1. Historical Climate Change

Statistics	n	T_{max}	T_{min}	Rf	ET
Coefficient	36	0.21	0.03	-5.15	16.43
R square	36	0.79	0.31	0.14	0.75
P-value	36	0.01	0.01	0.02	0.01



- Declining Rf coupled with high ET rate aggravates moisture stress, thereby making available moisture insufficient for crop-production (Gebrehiwot et al., 2015; Tilahun, 2006).
- In turn threatens spate-hydrology to support crop-production in the lowlands (FAO, 2010; Pechlivanidis et al. 2011; Alemayehu, 2013; Erkossa et al., 2013).

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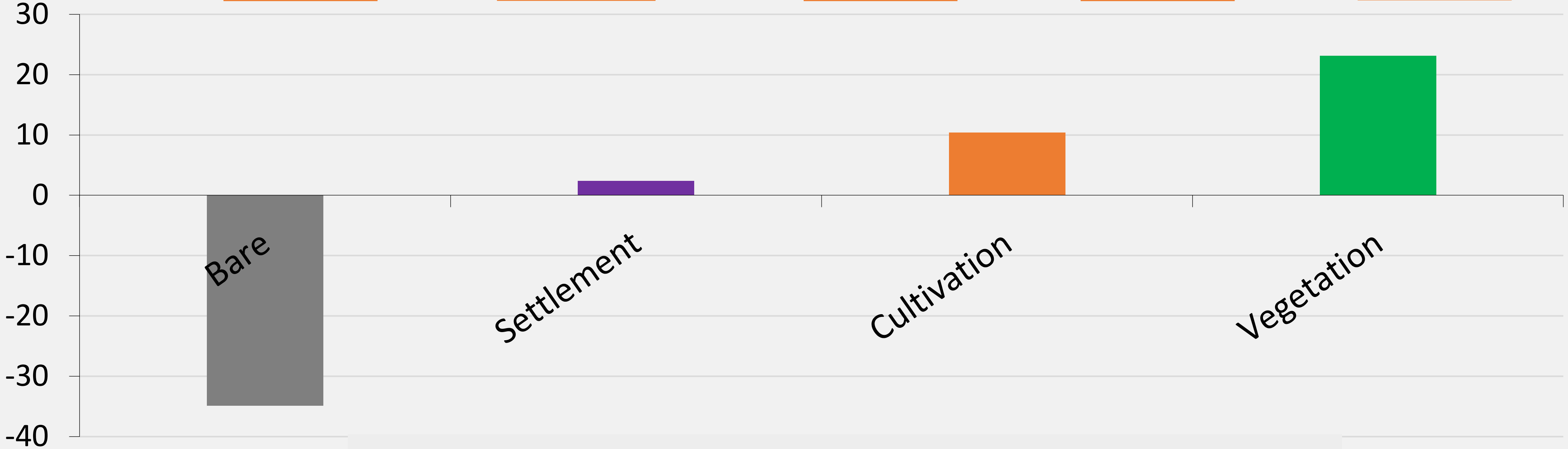
3.2. Land-cover dynamics

Historical land-cover (ha)

Year	Bare	Settlement	Cultivation	Forest	Shrubs
1984	1183.54	33.23	2555.12	131.01	1095.16
1994	849.08	43.29	2607.51	150.3	1347.88
2002	404.53	75.69	2768.09	203.77	1545.98
2015	106.19	102.35	2856.70	459.09	1473.72
	-	+	+	+	IC



Coefficient of change (ha yr^{-1})

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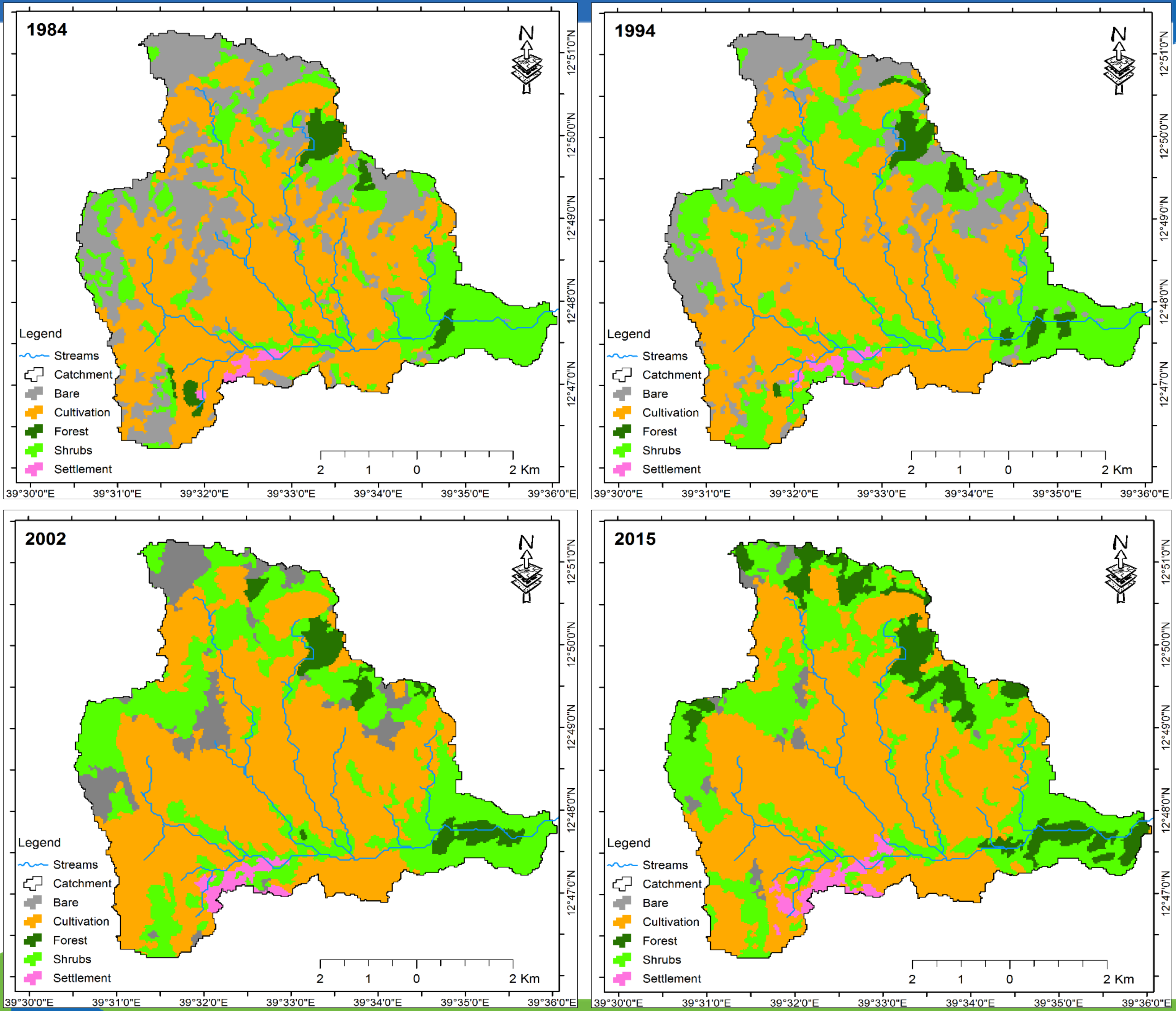

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Land cover dynamics cont..

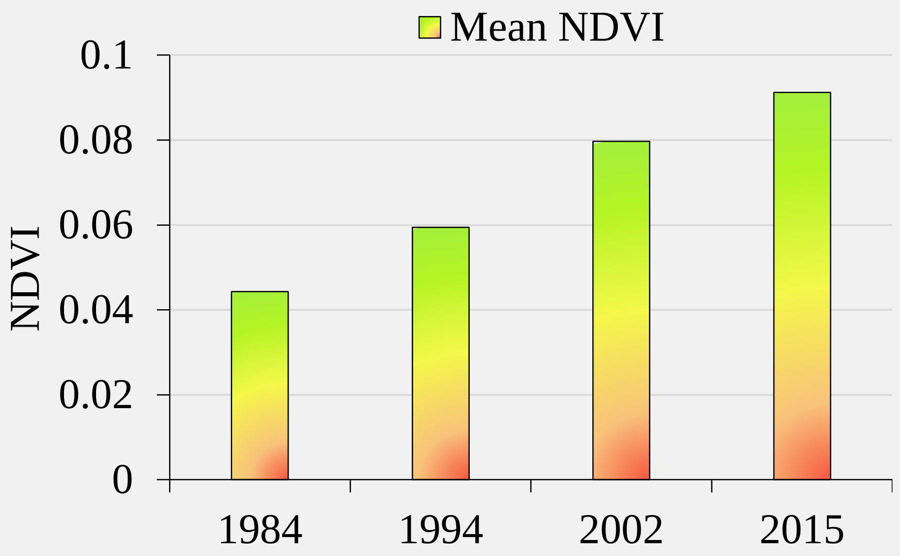
Accuracy Assessment

- Classifications were acceptable to the level recommended by FAO (2005).

Year	Over all accuracy
1984	87.0
1994	82.6
2002	85.2
2015	86.1

- This implies that, classification results were feasible for further analysis.

NDVI analysis



- Showed that, there was significant change in greenness index of the catchment during the last three decades.

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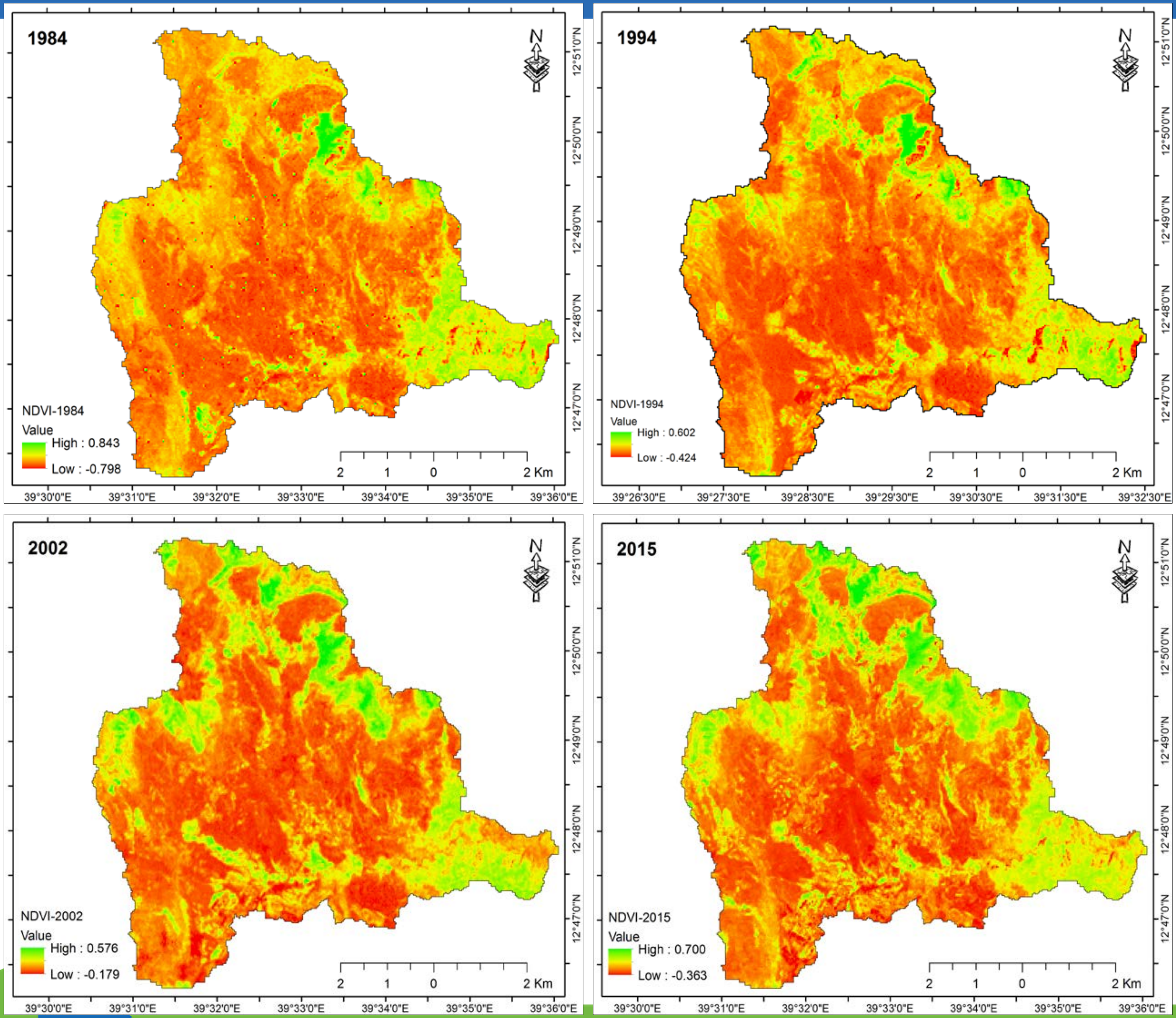
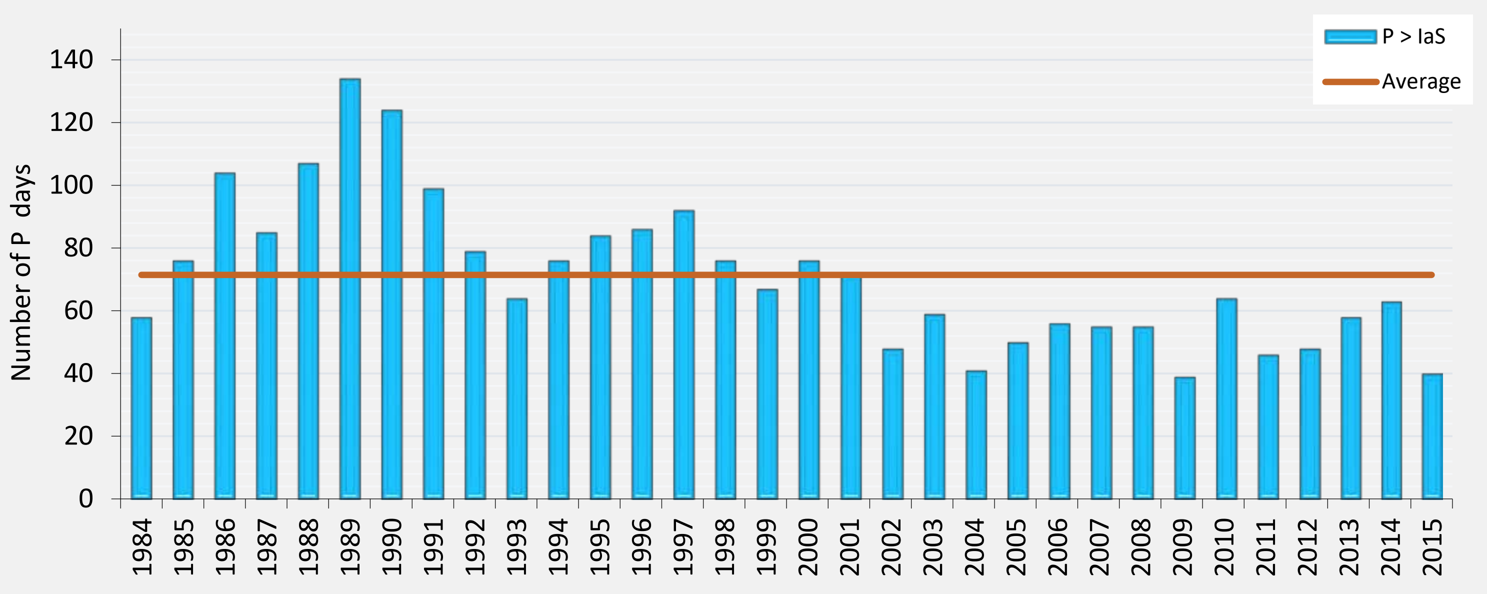

1984
NDVI-1984
Value
High : 0.843
Low : -0.798
2 1 0 2 Km
1994
NDVI-1994
Value
High : 0.602
Low : -0.424
2 1 0 2 Km
2002
NDVI-2002
Value
High : 0.576
Low : -0.179
2 1 0 2 Km
2015
NDVI-2015
Value
High : 0.700
Low : -0.363
2 1 0 2 Km

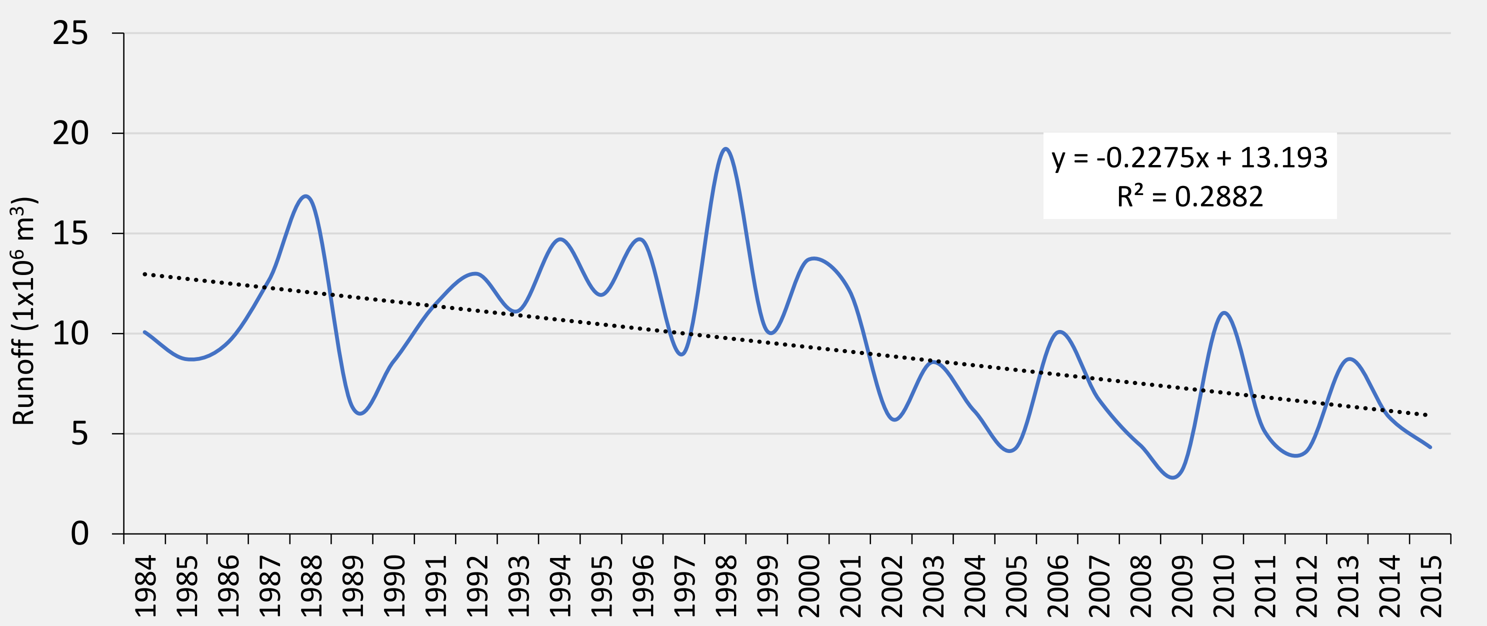
3.3. Direct-runoff estimates

Year	CN	S (mm)
1984	89.28	30.49
1994	89.17	30.86
2002	80.76	60.53
2015	80.11	63.06



Rainfall events capable of generating river flow declined.

Annual runoff estimates declined at a coefficient of $0.23 \times 10^6 m^3 yr^{-1}$.



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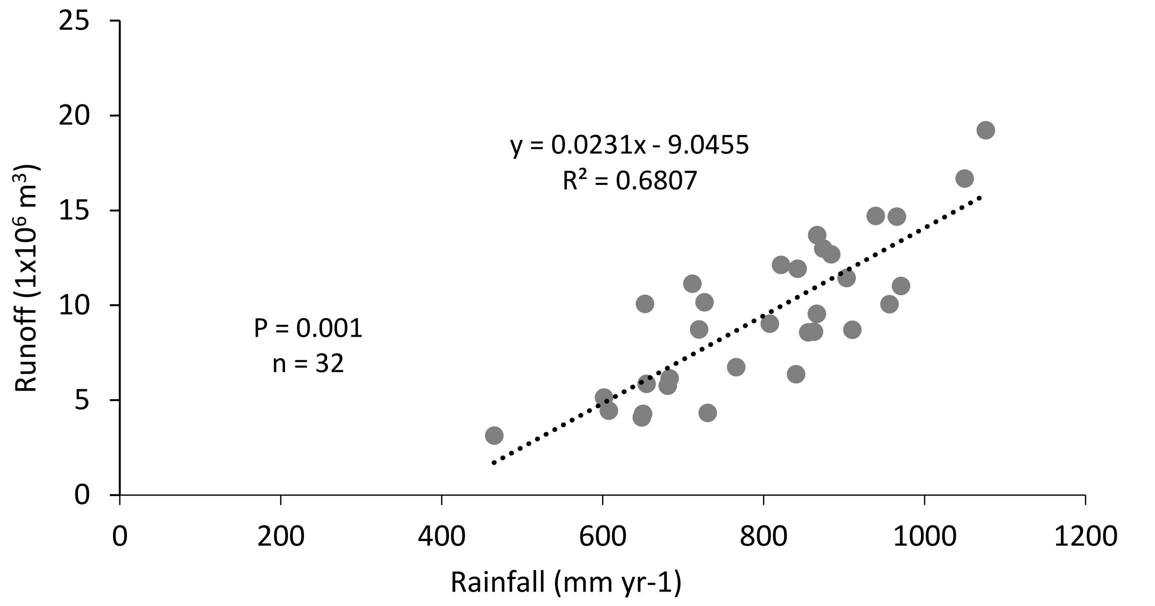
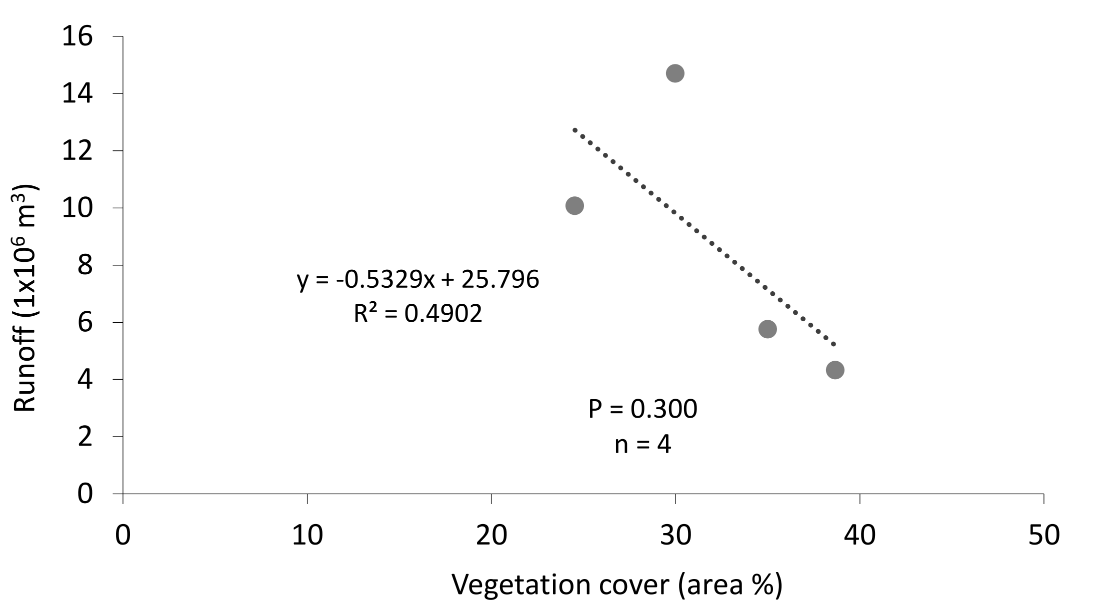
Rainfall runoff relationship



- Since Rf is the primary hydrological input in arid and semi-arid areas, years with high Rf amount are subjected to relatively higher runoff and vice versa (Gebrehiwot et al., 2015; Wheater, 2002).

Landcover runoff relationship



- Unlike rainfall, changes in land cover has negative impact on hydrological response of a catchment (Ashenafi, 2014; Githui, 2009; Mango et al., 2011; Gebresamuel et al., 2010).

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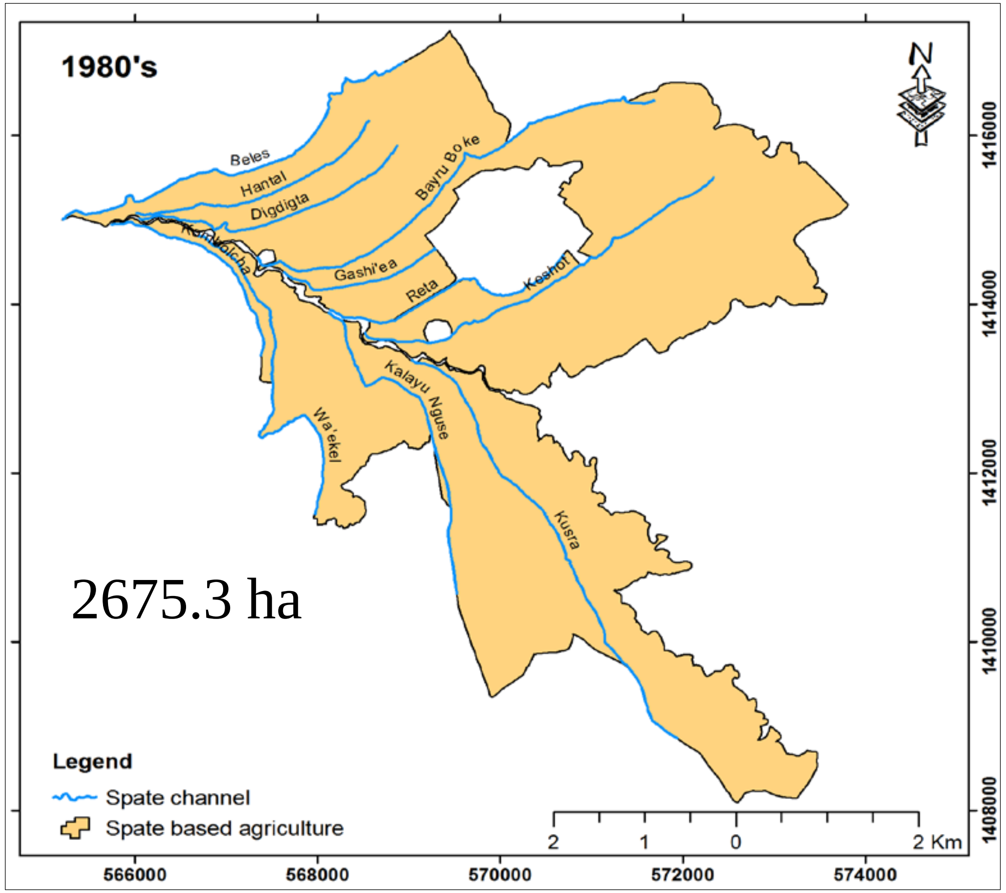
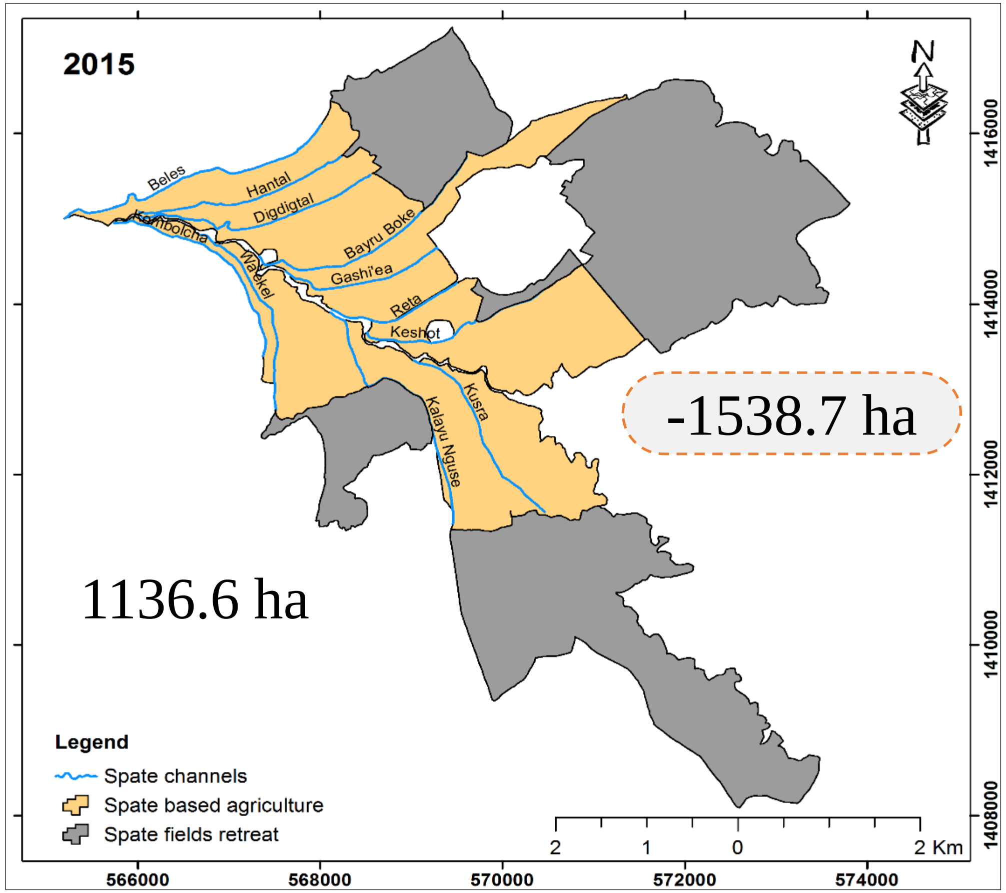
3.4. Spate-based Agriculture





- Implications are usually more pronounced on farm fields located on tail parts of spates, and lesser impact as you go close to the source.
- A 1×10^6 m^3 decline in spate-hydrology caused area of spate-based agriculture to retreat by 268.7 ha.

4. Conclusion

- Climate variables granted that there was considerable difference in Rf, T and ET distribution of the catchment over the last three decades.
- Despite increasing T and ET, annual Rf reduced significantly.
- Declining rainfall amount and number of rainy days beyond threshold rainfall, coupled with rising temperature and evapotranspiration aggravated moisture stress.
- Improvements in Land-cover and NDVI upstream on the other hand contributed to increasing water retention capacity of the soil in the highlands, thereby limiting direct runoff reaching the lowlands.
- i.e., spate-hydrology readily available to support spate based farms in the semiarid lowlands.
- This decline in volume of direct-runoff/spate-hydrology in turn exerted significant influence on area of spate-based agriculture in the semiarid lowlands.

COOPERATION WITH PAUWES

As researchers or practitioners what are the possible interactions/collaboration with practitioners resp. researchers to improve/upscale your activities

Water Security and Climate Change

- Climate and hydrological modelling
- Hydrological linkage of dryland communities
- Enhancing food security in water scarce regions

- PAUWES, a center of Excellence in Energy, Water Security and Climate Change
- Collaborating researchers, practitionars, and initiating further inter-institutional linkage
- Replicating reseach in other hotspots to broaden the scale
- Funding opportunities to collaborating researchers

- I intend to do further research on Climate Change and Water Security epicenter in the tropical and subtropical Africa, a research in line with the PAUWES and other partners theme; which could be a potential collaborative opportunity.

FROM RESEARCH TO PRACTICE

What are the potential aspects of the research that can be transformed into practice?

- Spate irrigation would be a potential coping mechanism to farmers in arid and semiarid tropics and subtropics. *Complementary water source*.
- The system is however being challenged by climate and climate induced factors in the highlands, thereby exerting moisture stress in the lowlands. *CC, a problem for the solution*.
- Collaborative research and policy interventions would be desirable to balance and sustain hydrological linkage between highland and lowland community in the face of climate change. *Research and policy intervention*.
- The lowlanders should also consider using the massive ground water storage of the valley to complement spate-irrigation. *Alternative adaptation.*

Thank you !

April 16-18, 2018 - Tlemcen, Algeria