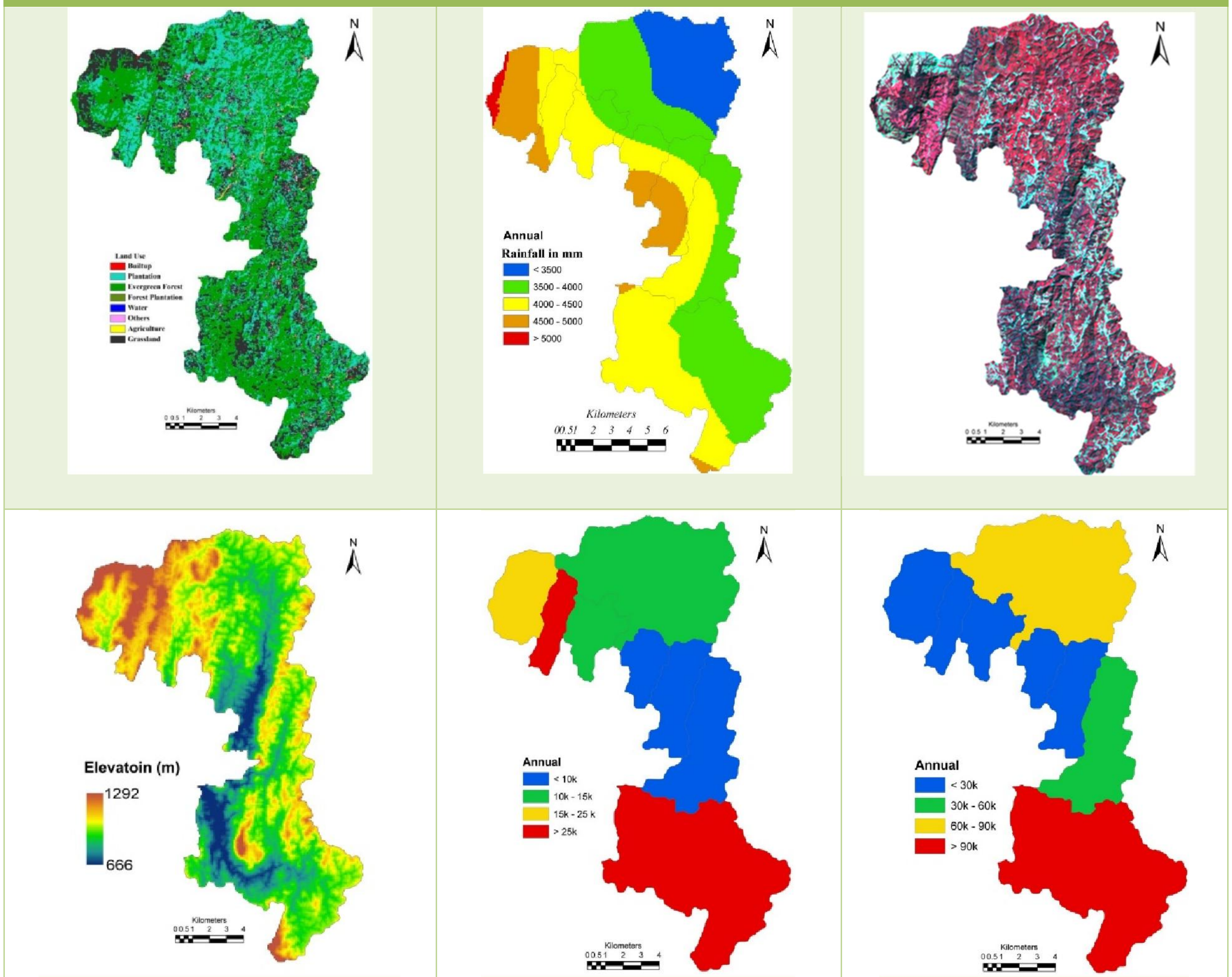
Environmental Flow Assessment in Yettinaholé

Where is 24 TMC to divert?

Ramachandra T.V. Vinay S Bharath H. Aithal



Elevation	Water demand	Water available

The Ministry of Science and Technology, Government of India
The Ministry of Environment and Forests, Government of India

ENVIS Technical Report: 91

April 2015

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Sahyadri Conservation Series 48
ENVIS Technical Report**: 91**
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Ramachandra T.V., Vinay S and Bharath H. Aithal, 2015. Environmental Flow Assessment in Yettinaholé: Where is 24 TMC to divert?, Sahyadri Conservation Series 48, ENVIS Technical Report 91, CES, Indian Institute of Science, Bangalore 560012, India

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ACKNOWLEDGEMENT

We are grateful to (i) the NRDMS division, the Ministry of Science and Technology, (DST) Government of India, (ii) the Ministry of Environment and Forests, Government of India and (iii) Indian Institute of Science for the sustained support to carry out energy research. We thank Mr.Bharath Setturu for compiling the details and providing insights to the Telugu Ganga project.

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1.0 EXECUTIVE SUMMARY:

Western Ghats are the mountain ranges extending from southern tip of India (Tamil nadu – Kanyakumari) to Gujarat. These mountain ranges are rich in biodiversity with diverse and endemic flora and fauna, and is birth place to numerous perennial rivers namely Netravathi, Sita, Sharavathi, Aghanashini, Krishna, Cauvery, etc. The Western Ghats hill ranges forms an important watershed for the entire peninsular India, being the source of 37 west flowing rivers and three major east flowing rivers and their numerous tributaries. The stretch of Central Western Ghats of Karnataka, from 12°N to 14°N, from Kodagu district to the south of Uttara Kannada district, and covering the Western portions of Hassan, Chikmagalur and Shimoga districts, is exceptionally rich in flora and fauna. Whereas the elevation from 400 m to 800 m, is covered with evergreen to semi-evergreen climax forests and their various stages of degradation, especially around human habitations, the higher altitudes, rising up to 1700 m, are covered with evergreen forests especially along stream courses and rich grasslands in between. This portion of Karnataka Western Ghats is extremely important for agriculture and horticultural crops. Whereas the rice fields in valleys are irrigated with numerous perennial streams from forested hill-slopes the undulating landscape is used to great extent for growing precious cash crops, especially coffee and cardamom. Black pepper, ginger, arecanut, coconut, rubber are notable crops here, in addition to various fruit trees and vegetables. Some of the higher altitudes are under cultivation of tea. Conservation and sustainable management of central Western Ghats are extremely important from the point of productivity, revenue generation, employment potential and subsistence.

Forests in the Western Ghats along with the soil characteristics and precipitation plays a major role in storing water during monsoon, and releases to the streams during post monsoon periods catering to the needs of the dependent biota including humans. Some of these undisturbed/unaltered natural flow conditions in rivers and streams have proved their value with presence of very rich and diverse species, which also has helped in sustaining the livelihood of dependent populations. The undisturbed flow conditions meeting the ecological and social needs are referred to as ecological flow / environmental flow.

Environmental/Ecological Flow is defined as "Minimum flow of water maintained in a water body (river, lake, etc.) sustaining ecosystem functions". Understanding environmental flow is important in order to evaluate and understand the role of the water body in catering to the ecological and social (people, agriculture and horticulture, etc.) needs in a sustained and balanced way. The maximum capacity up to which water as a resource catering all demands of the dependent biota is referred as carrying capacity of water resource. The carrying capacity refers to the maximum number of activities (biological, developmental, agricultural, and industrial, population) that is supported over a period of time in the habitat without damaging the:

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1. Existing quality of life,
2. Balance of resources, ecology and productivity of the ecosystem.

Ecological Carrying Capacity provides physical limits as the maximum rate of resource usage and discharge of waste that can be sustained for economic development in the region. This provides theoretical basis with practical relevance for the sustainable development of a region. Carrying capacity of a river basin refers to the maximum amount of water available naturally as stream flow, soil moisture etc., to meet ecological and social (domestic, irrigation and livestock) demands in a river basin.

Environmental flow assessment of Yettinaholé river has been carried out based on the analysis of land use dynamics (using remote sensing data), meteorological data (rainfall, temperature, etc. from IMD, Pune), hydrological data (from gauged streams) apart from field investigations to quantify water yield in a catchment.

Yettinaholé catchment extend from $12^0$44'N to $12^0$58'N Latitude and $75^0$37'E to $75^0$47'E longitude encompassing total area of 179.68 km^2. The terrain is undulating with altitude varying from 666 m above MSL to 1292 m above MSL leading to higher density of stream network. Geologically, rock types consists of Gneiss, the soils are loamy ranging from sandy loamy to clay loamy. Soils in the region are fertile and highly permeable, hence allowing the precipitated water to percolate easily into the subsurface recharging ground water and storing water in the sub surfaces and hence keeping the water source perennial to the catchment and the downstream users during and post monsoon.

Karnataka Neeravari Nigam Limited, Government of Karnataka has proposed to divert and store the water to meet the needs of the water scares regions*: Kaduru, Arsikere, Tipturu, Chikkanayakanahalli, Gubbi, Madhugiri, T.G.Halli, Ramnagara, Gouribidnuru, Nelamangala, Hesaraghatta, Doddaballapura, Hoskote, Devanahalli, Chikkaballapura, Gudibande, Bagepalli, Chintamani, Srinivasapura, Sidlaghatta, Maluru, Kolar, Mulbaglu and Bangarpete* at an estimated cost of 12,912 crores. The proposed weirs have overall catchment area of 176 sq.km with evergreen forests dominating the catchment to an extent of 45.05%, followed by agriculture plantations (coconut/arecanut) about 29.25% and grass lands about 24.06%. The presence of these thick evergreen forests and grass lands in the catchment are responsible for higher infiltration and perennial streams. Any anthropogenic activities involving large scale land cover changes would affect the hydrology of the river basin affecting the dependent biota. The region's ecological and economic importance is evident from

- Yettinaholé and its immediate neighboring catchments falls under the Ecological Sensitive Zone 1 (**ESZ 1**) (HLWG report of Western Ghats conservation, http://envfor.nic.in/sites/default/files/**HLWG**-Report-Part-1_0.pdf) and as per the recommendations of the working group there **shall be strictly no developmental activities**.
- The region is **vulnerable and prone to frequent human animal conflict** (Elephant Human conflict) as per the Karnataka Elephant Task Force (**KETF:** (i) http://envfor.nic.in/content/report-karnataka-elephant-task-force-submitted-

honourable-high-court-karnataka?theme=moef_high, (ii) http://www.atree.org/sites/default/files/KETF%20Final%20Report%20SCREEN%20RES.pdf#page=14&zoom=auto,-12,418), and any alterations in the elephant corridors would enhance human animal conflicts threatening the survival of elephants.

The catchments receive annual rainfall of 3000 – 4500 mm (Department of Statistics, Government of Karnataka). Water yield in the catchment computed for each of sub-catchments based on the current land use and other related hydrological parameters using empirical method. The total runoff yield from the catchments is estimated to be 9.55 TMC in contrast to the estimated 24TMC in the DPR (detailed Project report prepared by Karnataka Neeravari Nigam Limited, Government of Karnataka) or 22 TMC (as per KPC: Karanataka Power Corporation). The inflated values of water yield in the catchment would only lead to the failure of water diversion scheme similar to Telugu Ganga Project. Implementation of the project would affect the livelihood of dependent population (current users in Yettinaholé catchment) and would not benefit the likely beneficiaries in arid regions of Karnataka.

Highlights of the current analysis are:	
Water yield in Yettinholé catchment:	9.55 TMC
Domestic, crop water, livestock water demand:	5.84 TMC
Environmental flow to be maintained (to sustain ecosystems):	2.86 TMC

Yettinaholé diversion project if implemented will not help either the residents of arid regions in Karnataka (Chikballapur, Kolar, Tumkur) or local people in Gundia river basin. Residents of Yettinaholé catchment would be deprived of their right for water, while people in the arid regions would only get to see dry canals, etc. Implementation of Yettinaholé project would lead to water scarcity in Hassan and Mangalore, and will not benefit Chikkballapur, Kolar, etc. Livelihood of Yettinaholé and Gundia catchment would be affected severely due to lowered agricultural and fisheries yield similar to the residents of Nellore district with the implementation of Telugu-Ganga project. The project if implemented deprives the local people their right to water under Article 21 of the constitution of India

In India, the constitutional right to access to water can be drawn from the right to food, the right to clean environment and the right to health, all of which have been protected under the broad rubric of the Right to Life guaranteed under Article 21 of the constitution. In addition to article 21, Article 39 (b) of the directive principles of state policy (DPSP), which the Constitution declares to be non-justiciable, recognizes the principle of equal access to the material resources of the community. Article 39 (b) mandates that 'the State shall, in particular, direct its policy towards securing that the ownership and control of the material resources of the community are so distributed as best to subserve the common good.'

The precautionary principle articulated in the constitution prescribes that: (i) the environmental measures taken by the state and the statutory authorities must anticipate, prevent and attack the causes of environmental degradation; (ii) that where there are threats of serious and irreversible damage, lack of scientific certainty should not be used as a reason for posting measures to prevent environmental degradation; and (iii) that the 'onus of proof' is on the actor or the project proponent to show that his action is environmentally benign.

> "The constitutional and statutory provisions protect a person's right to fresh air, clean water and pollution-free environment, but the source of the right is the inalienable common law right of clean environment."

(Hon'ble Supreme Court's observation in Vellore Citizens Welfare Forum (n 7) at pg. 661)

Gundia River is formed by the streams namely Yettinaholé and Kempholé to which the streams Kadumaneholé and Hongadahallé join in the course. The Gundia catchment region is surrounded Hemavathi river water-shed on its right, Barapole river catchment on its left and Netravathi River on downstream side. The Gundia catchment comes under influence of the South-west monsoon in months of June to September. This region harbours nearly 36% of plant species, 87% of amphibians, and 41% of fishes, which are endemic to Western Ghats. The presence of four critically endangered and 14 endangered animal species in the region further emphasises the need for conservation of this region on priority as it provides a unique habitat and ecological niche (http://wgbis.ces.iisc.ernet.in/biodiversity/pubs/ces_tr/TR122/summary.htm).

The Gundia river basin in central Western Ghats, 'hottest hotspot' with a repository of biological wealth of rare kind, both in its aquatic and terrestrial ecosystems and indicates strongly the need for adoption of holistic eco-system management for conservation of particularly the rare and endemic fauna of the Western Ghats. The premium should be on conservation of the remaining evergreen and semi-evergreen forests, which are vital for the water security (perenniality of streams) and food security (sustenance of biodiversity). Through appropriate management there still exists a chance to restore the lost natural evergreen to semi-evergreen forests. The region is Ecologically Sensitive as it fulfills the criteria of *Eco-sensitive region* as per sub-section (1) with clause (v) of sub-section (2) of section 3 of the Environment (Protection) Act, 1986 (29 of 1986), such as

i) **Species based criteria**:
- ✓ The presence of high endemic, rare and endangered species of flora and fauna
- ✓ Centre of evolution of domesticated species

TAXA	SPECIES	STATUS AS PER WILDLIFE PROTECTION ACT (1972)
Birds	*Anthracoceros coronatus* (Boddaert)	Schedule - I
	Buceros bicornis (L.)	Schedule - I
	Pavo cristatus (L.)	Schedule - I
	Gallus sonneratti Temminck	Schedule - II
Reptiles	*Varnus bengalensis* (Daudin)	Schedule – I
	Python molurus (L.)	Schedule - I
	Naja naja (L.)	Schedule - II
	Ophiophagus hannah (Cantor)	Schedule - II
	Ptyas mucosus (L.)	Schedule - II
	Xenochrophis piscator (Scheidner)	Schedule - II

	Atretium schistosum (Daudin)	Schedule - II
	Daboia russelii (Shaw & Nodder)	Schedule - II
Mammals	*Elephas maximus* (L.)	Schedule - I
	Loris lydekkerianus (Cabrera)	Schedule - I
	Manis crassicaudata (Gray)	Schedule - I
	Petinomys fuscocapillus (Jerdon)	Schedule - I
	Panthera tigris (L.)	Schedule - I
	Macaca silenus (L.)	Schedule - I
	Bos gaurus (H. Smith)	Schedule - I
	Panthera pardus (L.)	Schedule - I
	Tragulus meminna (Erxleben)	Schedule - I
	Macaca radiata (E. Geoffroy)	Schedule - II
	Melursus ursinus (Shaw)	Schedule - II
	Herpestes edwardsi (E. Geoffroy Saint-Hilaire)	Schedule - II
	Presbytis entellus (Prater)	Schedule - II
	Felis chaus (Schreber)	Schedule - II
	Ratufa indica indica (Erxleben)	Schedule - II
Butterflies	*Hypolimnas misippus* (L.)	Schedule - I
	Lampides boeticus (L.)	Schedule - II
	Appias albina (Boisduval)	Schedule - II

ii) **The ecosystem-based criteria**

- ✓ migratory species,
- ✓ specialised habitats,
- ✓ special breeding site/area, areas with intrinsically low resilience,

Gundia River Basin

Habitat for endangered, endemic species – Presence of Schedule I fauna of INDIAN WILDLIFE PROTECTION ACT (1972)
Part of Mysore Elephant Reserve
Part of Elephant Migratory Corridors: These corridors also facilitate multi mega species (tiger, leopard, and gaur) movement. Hence should be given high priority and efforts should be made to jointly secure these corridors along with National Tiger Conservation Authority (NTCA).

iii) Presence of sacred groves and sacred water sources

iv) Geomorphological features – origin of Kumaradhara, Yettinaholé and Kempholé to which the streams Kadumaneholé and Hongadahallé join in the course and form Gundia river

Thus the Gundia River basin is Ecologically Sensitive as per permissible norms of the Government of India:

ECO-SENSITIVENESS OF THE REGION	PERMISSIBLE LAW
This region is declared as 'Eco-sensitive Region' as it is very rich in biodiversity and is a high centre of endemism with 36% of plant species, 87% of amphibians and 41% of fishes present in this region. This region also harbours endangered species like Elephants, Threatened species like Slender Loris, Grey headed bulbul and Malabar pied Hornbill. Presence of Lion Tailed Macaque which acts as a flagship species for rainforests also signifies the ecological importance of this region.	As per sub-section (1) with clause (v) of sub-section (2) of section 3 of the Environment (Protection) Act, 1986 (29 of 1986) and clause (d) of sub-rule (3) of rule 5 of the Environment (Protection) Rules, 1986
Mammals like Slender Loris, Elephant, Leopard cat, Tiger, Lion Tailed Macaque and Gaur present in this region are listed under Schedule-I of WPA (1972) which signifies highest level of legal protection is assigned for them. Whereas, mammals like Jungle cat, Asian Palm civet and Brown Palm civet are included in Schedule-II signifying second highest level of priority assigned for them.	Schedule-I, II and III animals under Indian Wildlife Protection Act (1972)
According to a Gazetted notification by the Karnataka State Govt. this region forms a part of the designated **Mysore Elephant Reserve**. The Mysore Elephant Reserve was notified by the Karnataka Government in November, 2002 (Vide GO FEE 231 FWL 2000, 25/11/2002). It covers the total area of 6,724 sq.km. The Bisle Reserve Forest of Gundia Basin, vide the said GO, constitutes a vital part of the Mysore Elephant Reserve. It covers an area of 3,339 ha (Survey number I and II – Bisle Reserve forest).	Section 36-A of The Wildlife (Protection) Act, 1972as amended by The wildlife (Protection) Amendment Act, 2002

Considering the ecological significance and rich biodiversity, this region is *Eco-sensitive region* as per sub-section (1) with clause (v) of sub-section (2) of section 3 of the Environment (Protection) Act, 1986 (29 of 1986) and clause (d) of sub-rule (3) of rule 5 of the Environment (Protection) Rules, 1986 in concurrence with the provisions of the Indian Forests Act, 1927 (16 of 1927) and Forest (Conservation) Act, 1980 (69 of 1980) the Wildlife (Protection) Act, 1972 (53 of 1972). This is imperative to prevent the erosion of Biodiversity, Ecology and associated Hydrology.

Short sighted developmental projects in ecologically sensitive regions poses a serious threat to the ecology and biodiversity of the area, which affects the sustenance of natural resources. The submergence of forest region and other associated activities will cause habitat fragmentation and shrinkage. This will ultimately enhance the Human – Animal conflicts in this region. The large scale land cover changes will affect the hydrology, biodiversity and ecology. The proposed project is ecologically unsound and economically unviable because of the following reasons (http://wgbis.ces.iisc.ernet.in/biodiversity/pubs/ces_tr/TR122/summary.htm):

1. The implementation of the project will cause large scale land cover changes in the region.
2. The proposed project would alter the hydrologic regime affecting the local ecology, biodiversity and more importantly livelihood of people in the region
3. The proposed project would cause habitat fragmentation and shrinkage resulting in enhanced Human - Animal conflicts.
4. The forests are ecologically and economically beneficial to humans. The economic value of the region is higher (> 200 Billion Rs.) and emphasise the need for conservation to sustain livelihood of dependent population.

Considering these, the proposed project would be ecologically and economically unviable as it would weaken the food and water security of the region. **It is necessary to take note of deliberate attempt in indicating higher water yield and drop the proposal (Yettinaholé diversion project). This would save the state from spending unnecessarily on the project which is bound to fail due to lack of water.**

The proposed Yettinaholé diversion project also violates **National Water Policy** (2012), Govt. of India, Ministry of Water Resources:

Planning, development and management of water resources need to be governed by national perspectives on an integrated and environmentally sound basis, keeping in view the human, social and economic needs. Pg.5, Section 1.3 (i).	Proposed in the ecologically sensitive region threatening the sustenance of natural resources while eroding rich repository of biological resources
Water is essential for sustenance of eco-system, and therefore, ecological needs should be given due consideration. Pg.5, Section 1.3(vii).	Water yield in the catchment is 9.5 TMC Water demand in the catchment is 5.84 TMC Environmental flow to be maintained 2.84 TMC
All the elements of the water cycle, i.e., evapotranspiration, precipitation, runoff, river, lakes, soil moisture, and ground water, sea, etc., are interdependent and the basic hydrological unit is the river basin, which should be considered as the basic unit for planning. Pg.5, Section 1.3(viii).	We have used rainfall data of 100+ years to understand the spatial and temporal patterns of variability. Rainfall in the catchments vary from 3500 mm to 4000 mm. Based on field data (stream gauging) and quantified water yield using empirical relationship indicate the water yield of 9.55TMC in Yettinaholé catchment. Validation is done with the gauged data at Kadumane holé (of 2009 to 2012), where water discharge is 0.813TMC

	compared to the estimated value of 0.702 TMC (86% accuracy). Based on these approaches, water yield is only 9.5 TMC (proponents of Yettinaholé diversion project claim yield of 24 TMC without considering spatial variability of rainfall in the catchment, hydrological losses, water demand in the catchment for subsistence agriculture and horticulture, minimum environmental flow to be maintained to sustain the ecosystem functions)
The Centre, the States and the local bodies (governance institutions) must ensure access to a minimum quantity of potable water for essential health and hygiene to all its citizens, available within easy reach of the household. Pg.9, Section 3.1.	Water yield in the catchment is sufficient to meet the ecological and anthropogenic demand (domestic, agriculture, Horticulture, etc.)
Ecological needs of the river should be determined recognizing that the natural river flows are characterized by low or no flows, small floods (freshets), large floods, etc., and should accommodate developmental needs. A portion of river flows should be kept aside to meet ecological needs ensuring that the low and high flow releases are proportional to the natural flow regime, including base flow contribution in the low flow season through regulated ground water use. Pg.9, Section 3.2.	Environmental flow to be maintained 2.84 TMC Water demand in the catchment is 5.84 TMC Water yield in the catchment is 9.5 TMC (sufficient to meet the current demand in the catchment) Estimate by us using the water balance approach takes into consideration various parameters, such as precipitation (100 years), evapotranspiration, land use characteristics, runoff, topography, crop rotation, population, livestock, etc.
After meeting the minimum quantity of water required for survival of human beings and ecosystem, water must be used as an economic good with higher priority towards basic livelihood support to the poor and ensuring national food security. Pg.9, Section 3.3.	Proponents of Yettinaholé diversion project claim the yield of 24 TMC without considering spatial variability of rainfall in the catchment, hydrological losses, water demand in the catchment for subsistence agriculture and horticulture, minimum environmental flow to be maintained to sustain the ecosystem functions
Community should be sensitized and encouraged to adapt to utilization of water as per local availability of waters. Community based water management should be	More importantly the government agencies (decision makers – politicians, bureaucrats, and local stakeholders) needs understanding of the functioning of aquatic ecosystems.

institutionalized and strengthened. Pg.9, Section 3.5.	The proposed project would be ecologically and economically unviable as it would weaken the food and water security of the region. It is necessary to revisit the proposal (Yettinaholé diversion project) and bring out the anomaly in the computation of water yield and save the state from spending unnecessarily on the project which is bound to fail due to lack of water.
Preservation of river corridors, water bodies and infrastructure should be undertaken in a planned manner through community participation. The storage capacities of water bodies and water courses and/or associated wetlands, the flood plains, ecological buffer and areas required for specific aesthetic recreational and/or social needs may be managed to the extent possible in an integrated manner to balance the flooding, environment and social issues. Pg.17-18, Section 8.1.	Implementation of the project (Yettinaholé diversion project) affects aquatic ecosystems in the region with the associated terrestrial ecosystems
Environmental needs of aquatic eco-system, wet lands and embanked flood plains need to be recognized and taken into consideration while planning. Pg.18, Section 8.3.	Water yield in the catchment is sufficient to meet the ecological and anthropogenic demand (domestic, agriculture, Horticulture, etc.) Environmental flow to be maintained 2.84 TMC Water demand in the catchment is 5.84 TMC Water yield in the catchment is 9.5 TMC (But, the proponent of Yettinaholé diversion project claim the yield of 24 TMC without considering spatial variability of rainfall in the catchment, hydrological losses, water demand in the catchment for subsistence agriculture and horticulture, minimum environmental flow to be maintained to sustain the ecosystem functions).
Optimum development river valleys ensuring scientific planning of land and water resources taking basin/sub-basin as unit with unified perspectives of water in all its forms (including precipitation, soil moisture, ground and surface water) and	The proposed project lacks holistic and balanced development approach, evident from an overestimate of water yield in the catchment and also ignoring social and ecological demand in the catchment.

ensuring holistic and balanced development of both the catchment and the command areas. Pg.7, Section 2.3.	

Execution of the project would lead to deprivation of water in Yettinaholé catchment affecting the livelihood to people apart from affecting local ecology and biodiversity. The proponents of Yettinaholé diversion project should understand the failure of Telugu-ganga project, affecting the regional economy and hydrology. The project has not benefitted planned beneficiaries but has deprived the districts in riparian state their right for water. Considering these, the proposed project would be ecologically and economically unviable as it would weaken the food and water security of the region. It is necessary to revisit the proposal (Yettinaholé diversion project) and bring out the anomaly in the computation of water yield and save the state from spending unnecessarily on the project which is bound to fail due to lack of water.

The sustainable option to meet the water requirements of arid regions in Karnataka is through (i) decentralized water harvesting (through tanks, ponds, lakes, etc.), (ii) rejuvenation or restoration of existing lakes/ponds, (iii) reuse of waste water, (iv) recharging groundwater resources, (v) planting native species of grasses and tree species in the catchment (to enhance percolation of water in the catchment), (vi) implementation of soil and water conservation through micro-watershed approaches. Implementation of these location specific approaches would cost much less compared to the proposed project, which if implemented would help the section of the society involved in decision making, construction and implementation of the project.

"Telugu Ganga Project" – Lessons from failure: Telugu Ganga Project also known as Krishna Water Supply Project, is one of the major project that was executed during 1977 – 2006. The objective of the project was to utilize water from Krishna and Pennar rivers to:

1. Provide 15 TMC of water to Chennai city (later amended as 12 TMC).
2. Irrigate 2,32,702 hectares of drought prone areas of Kurnool, Chittoor and Cuddapah districts of Rayalseema and uplands of Nellore district in Andhra Pradesh (nptel.ac.in)

Water is diverted from Srisailam reservoir, Andhra Pradesh to Poondi reservoir, Tamil Nadu for a distance over 406 km through series of interlinked lined canals and reservoirs, namely SriSailam, Velugondu, Somasila, Kandaleru and Poondi reservoir, Figure 1 depicts line diagram of the Project

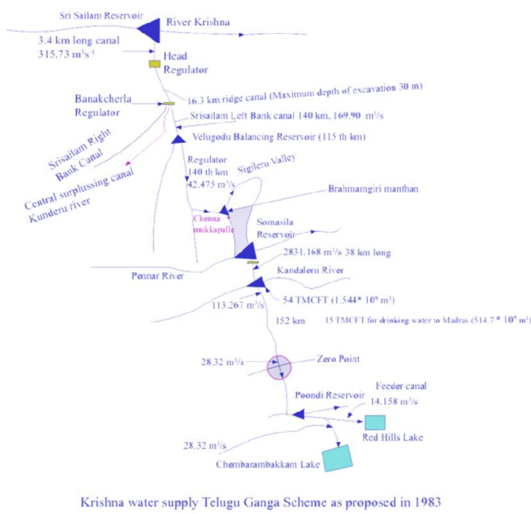


Figure 1: Telugu Ganga Project Scheme (Source: nptel.ac.in)

Figure 2: pumping of water from the canal

In 1983, the quantum of water was reduced to 12 TMC, accounting the seepage and evaporation losses. Between 2002 and 2006 the lining works of the main canal in between Kandaleru and Poondi reservoirs to enhance the canal flows and arrest the seepage losses (part of Sri Satya Sai Ganga Canal Project). Reduction in seepage led to drying of neighboring farm lands forcing farmers to pump water from the canal (Figure 2).

Telugu-Ganga: Bungling of numbers to suit certain lobby (Treachery of Public Money)

- According to the agreement, each of the three riparian states were to contribute 5 TMC of water annually, for a total supply of **15 TMC**. This number was revised down to 12 TMC in 1983 after accounting seepage and evaporation loses.
- Maximum quantity - supply of water to Chennai city in 2006 was **3.7 TMC.**
- The government records show that the highest water released since 1996 was 5 TMC in the year 2000-2001.

Table: Water supply to Chennai city (1996- 2002)

Dates	Quantity in mcft	In TMC
29 Sep 1996 to 28 October 1996	185.000	0.185
July 1997 to June 1998	565.211	0.565
July 1998 to Feb 1999	3298.826	3.299
July 1999 to Jan 2000	1907.124	1.907
May 2000 to June 2000	104.235	0.104
August 2000to May 2001	6594.077	6.594
July 2001 to August 2001	9.654	0.009
March 2002 to July 2002	3260.696	3.261
Total	15924.823	15.924

Source : Telugu Ganga , Krishna Water Supply project reports (confidential)

- Nellore farmers can now grow only one crop compared to three crops per year (before TG)
- Krishna River basin itself is facing severe scarcity in rainfall and lower catchment yield due to land cover changes

The project has failed in catering sufficient drinking water to the people of Chennai evident from the government records which highlights supply of only 5TMC (against assured 15 or 12 TMC, i.e., only 35% of the total planned supply). The implementation of the project has adversely affected farmers in Nellore district who were cultivating multiple crops (2 to 3 crops) are now struggle to grow even one season crop. Figure 3 depicts the series of developments from the day of inauguration in the early 90's to 2010's.

Figure 3: Misery of Telugu Ganga (public to politicians)

The sustainable option to meet the water requirements of arid regions in Karnataka is through (i) decentralized water harvesting (through tanks, ponds, lakes, etc.), (ii) rejuvenation or restoration of existing lakes/ponds, (iii) reuse of waste water, (iv) recharging groundwater resources, (v) planting native species of grasses and tree species in the catchment (to enhance percolation of water in the catchment), (vi) implementation of soil and water conservation through micro-watershed approaches. Implementation of these location specific approaches would cost much less compared to the proposed project, which if implemented would help the section of the society involved in decision making, construction and implementation of the project.

Environmental Flow Assessment in Yettinaholé

2.0 INTRODUCTION:

The Western Ghats is one among the 34 global hotspots of biodiversity and it lies in the western part of peninsular India in a series of hills stretching over a distance of 1,600 km from north to south and covering an area of about 1,60,000 sq.km. It harbours very rich flora and fauna and there are records of over 4,000 species of flowering plants with 38% endemics, 330 butterflies with 11% endemics, 156 reptiles with 62% endemics, 508 birds with 4% endemics, 120 mammals with 12% endemics, 289 fishes with 41% endemics and 135 amphibians with 75% endemics (http://wgbis.ces.iisc.ernet.in/biodiversity/pubs/ ces_tr/TR122/index.htm).

Western Ghats has numerous watersheds that feed perennial rivers of peninsular India. It encompasses series of West and East flowing rivers that originates from the Western Ghats, supporting as source of sustenance for existing life forms in the environment. One such source of perennial waters is Yettina holé originating at an altitude of 950 m in Sakaleshpura taluk of Hassan district, and tributary of river Gundia, which joins Kumaradhara and finally drains to Netravathi River. Yettinaholé and its immediate neighboring catchments falls under the Ecological Sensitive Zone 1 (ESZ 1) [as per the HLWG report (Chairman: Kasturirangan)] with severe restrictions to any developmental activities. As per the Karnataka Elephant Task Force (KETF), the catchment and its surroundings are one of the vulnerable regions for human animal conflict (Elephant Human conflict) and any developmental activities would directly have impact on elephant conservation, leading to increasing human animal conflicts. This necessitates conservation of the region and restrictions on any developmental and infrastructural projects.

Infrastructure development proposals have been proposed to divert the water sources such as flood waters during the monsoon and use the same to supply water to the regions having deficit in water reserves for agriculture and other activities. The project proponents ignores the implications on the surrounding environment such as loss of biodiversity both in fauna and flora, loss of endemics, riparian's, variation in the upstream and downstream hydrologic regimes due to the variations in the natural flows etc. Many studies have clearly established implication of construction of dams or weirs across the streams or rivers have affected the downstream users with less productive estuaries, conversation of the wetlands to plantations due to scarcity of water resource during post monsoons and etc. Literatures and reports have also highlighted that with non-availability or due to the controlled water flow, many of the flood plains, river banks and beds are being converted to agriculture fields for better yield; large number of farmers tend to extract water from the ground water through deep bore wells in deprivation of higher yield and thus fluctuating or depleting the ground water table during non-monsoons. This report is aimed to express the effects of water diversion scheme in a very sensitive and pristine environment by assessing the environmental water availability through water balance studies considering various aspects of water demand.

3.0 STUDY AREA:

Yettinaholé catchment as a whole has a pristine ecosystem with rich biodiversity. The proposed dam/weir sites falls in Sakaleshpura taluk of Hassan district of Karnataka. In order to tap electricity from the stream water, multiple weirs area proposed across various catchments of the yettinaholé and immediate water sheds, the details of the same are as depicted in Figure 4 and table 1, the catchments extend from $12^0$44'N to $12^0$58'N Latitude and $75^0$37'E to $75^0$47'E longitude encompassing total area of 179.68 km^2. The terrain (figure 5) is undulating with altitude varying from 666m above MSL to 1292m above MSL leading to higher density of stream network (figure 6). Geologically, rock types consists of Gneiss, the soils are loamy ranging from sandy loamy to clay loamy. Soils (figure 7) in the region are fertile and highly permeable, hence allowing the precipitated water to percolate easily into the subsurface recharging ground water and storing water in the sub surfaces and hence keeping the water source perennial to the catchment and the downstream users during and post monsoon.

Decadal Population in Sakleshpura taluk of Hassan is as depicted in figure 8 and table 2 shows a declining trend post 2001, this could be attributed to the migrated population. Population dynamics of the catchments also follows the dynamics of Sakleshpura taluk. Total Population of all the catchments with respect to census data was estimated as 17005 in 2001, has declined to 16345 in 2011 at a decadal rate of 3.88%. Population for the year 2014 was calculated as 16156 based on the temporal data. Population density for each of the sub catchments are as depicted in figure 9 and table 3.

Table 1: Study Area

Sub basin id	Stream Name	Area (Ha)
1	Yettinaholé	4878.7
2	Yettinaholé T2	781.1
3	Yettinaholé T1	991.1
4	Kadumane holé 2	761.4
5	Kadumane holé 1	1362.4
6	Keri holé	5676.6
7	Hongada halla	2198.3
8	Yettinaholé lower reach	1319.1

Table 2: Population Growth of Sakleshpura Taluk

Census Year	**1921**	**1931**	**1941**	**1951**	**1961**
Population	44115	44300	43765	53398	77522
Census Year	**1971**	**1981**	**1991**	**2001**	**2011**
Population	91175	114008	124753	133657	128633

Source: Census India, http://www.hassan.nic.in/htmls/stat.htm

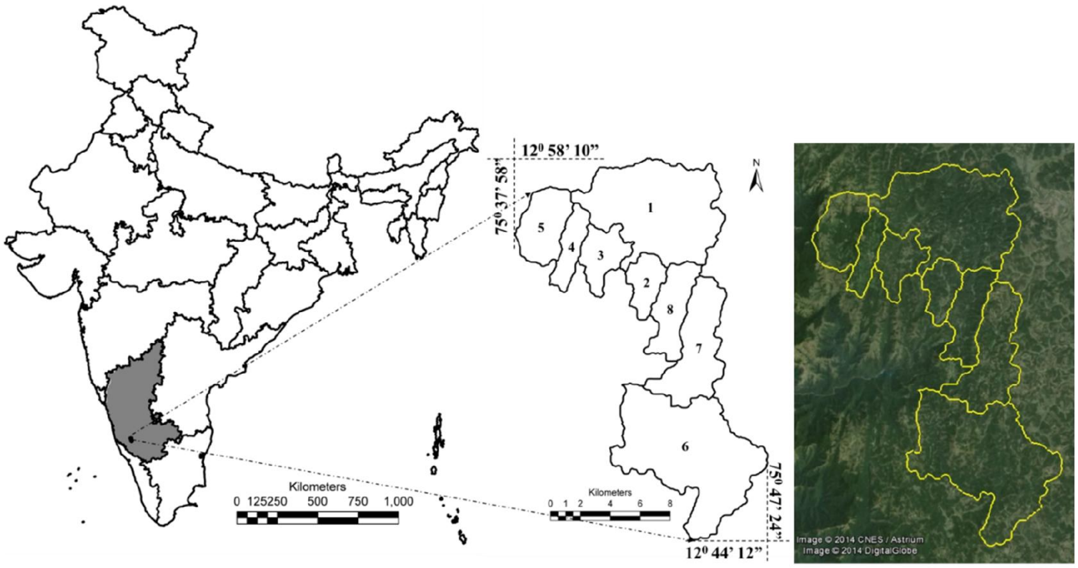
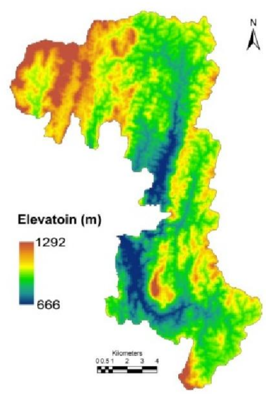
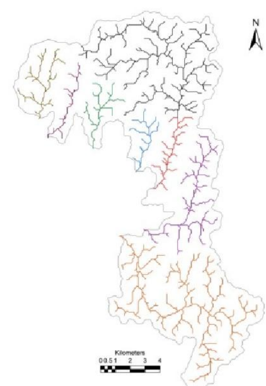


Figure 4: Study Area





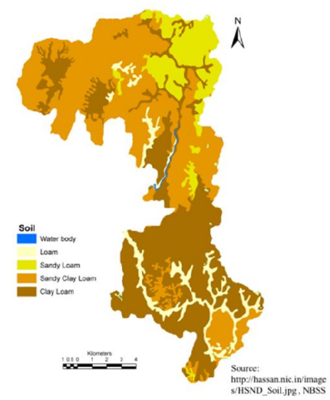


Figure 5: Digital Elevation Model Figure 6: Stream Network Figure 7: Soil

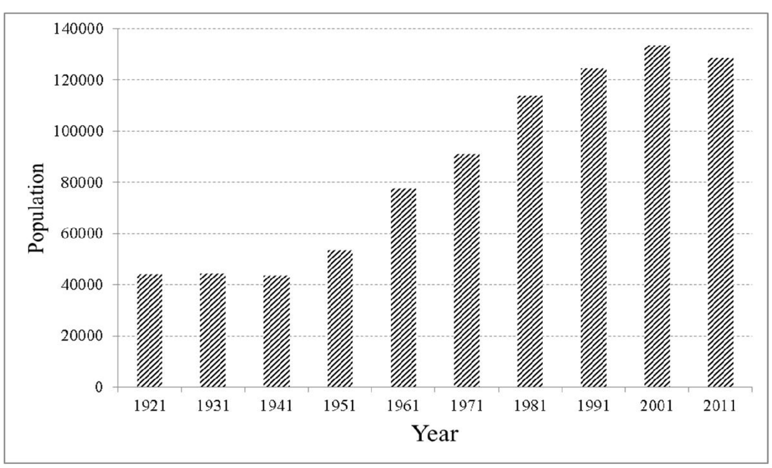


Figure 8: Population Growth of Sakleshpura Taluk

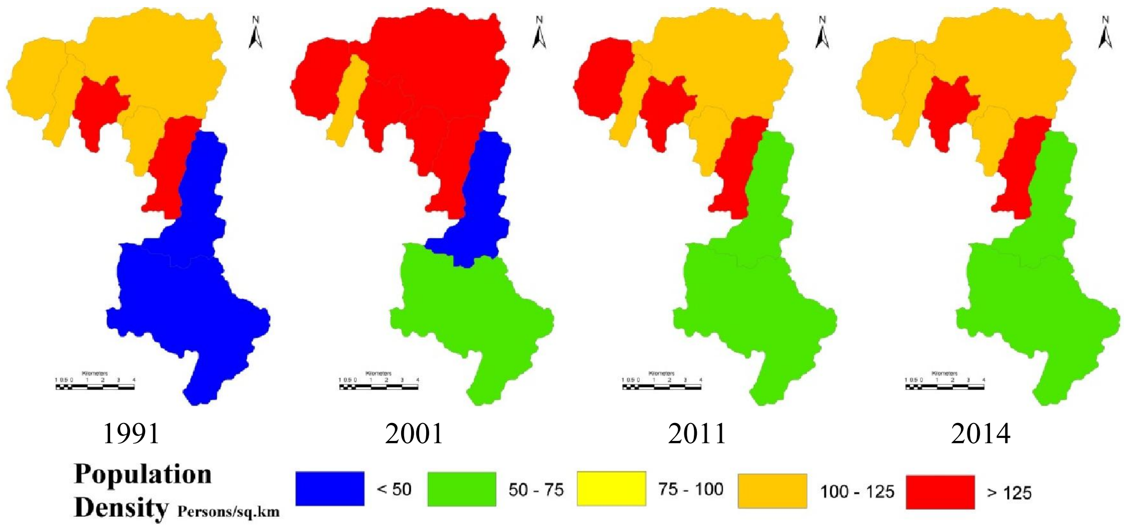


Figure 9: Population Dynamics of Sub Catchments

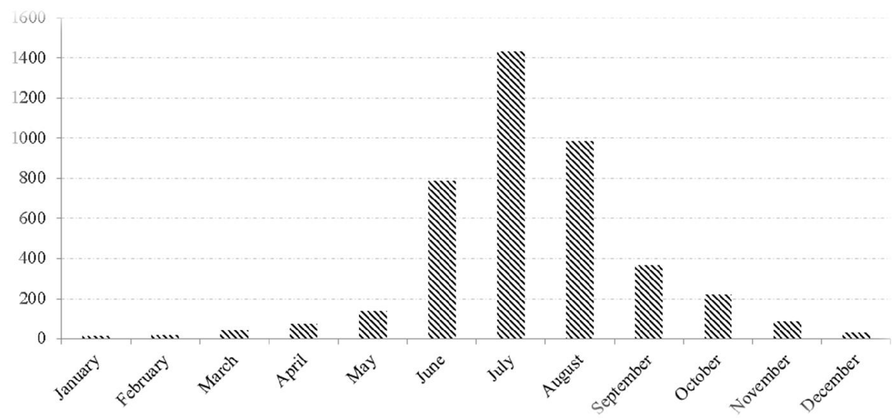


Figure 10: Rainfall in mm

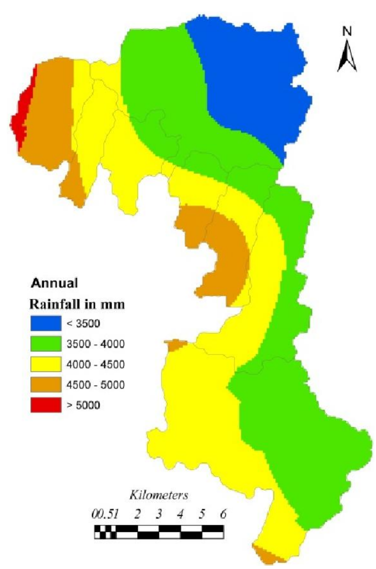


Figure 11: Rainfall distribution

Table 3: Population density (persons per sq.km)

Sub Basin Id	Sub basin	1991	2001	2011	2014
1	Yettina holé	117.86	126.92	122.00	120.59
2	Yettina holé T2	116.12	125.08	120.22	118.81
3	Yettina holé T1	126.52	136.31	130.96	129.45
4	Kadumane holé 2	108.36	116.76	112.17	110.98
5	Kadumane holé 1	121.33	130.65	125.58	124.12
6	Hongadahalla	47.26	50.89	48.92	48.36
7	Keri hole	32.71	35.25	33.89	33.48
8	Yettina holé lower reach	151.46	163.14	156.85	155.03

The region receives an annual rainfall of 3500 to 5000 mm across the catchment. Monthly variation of rainfall is as depicted in Figure 10 (Directorate of Economics and Statistics, Karnataka). Precipitation in the catchment during June to September is due to the southwest monsoons, with July having maximum rainfall over 1300 mm. Spatial variation of rainfall across the catchments was assessed based on 110 years data (1901 to 2010) from the rain gauge stations in and around the catchment (depicted in Figure 11). Monthly temperatures variations are as depicted in Figure 12 (http://worldclim.org), temperature in the catchment vary from as low as 14.7 °C in January to as high as 31.6 °C in March.

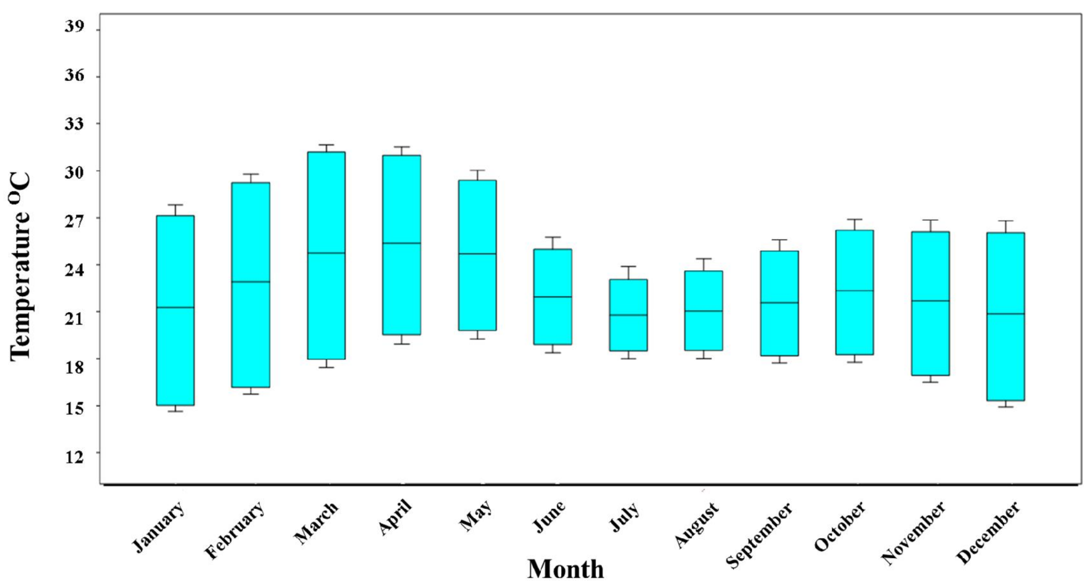


Figure 12: Monthly temperature variations

3.1 DATA: Data required for hydrological and spatial analyses were compiled from multiple agencies. Table 4 describes the various data used for assessment of the hydrological regime across the catchments. Data used include satellite remote sensing data acquired through Landsat 8 series of 2014. Rainfall data was acquired from Bureau of Economics and Statistics, Karnataka, Temperature data was sourced from worldclim of 1km resolution. Census data from government of India, state and district census departments. This data was supplemented with secondary data from various sources as tabulated in table 4. Data inventory was also done through field investigations and feedback from public

Table 4: Data used for land use and assessment of hydrologic regime

Data	Source	Description
Remote sensing data – spatial data	Landsat 8 Satellite, 2014 from USGS earth explorer (http://landsat.usgs.gov, http:// glcf.umd.edu/data/landsat/, http:// landsat.gsfc.nasa.gov/, http:// www.landsat.org/	Remote sensing data of 30m spatial resolution and 16 bit radiometric resolution were used to analyse the land use at catchment level
Rainfall	Rain gauge station wise – compiled from Directorate of Economics and Statistics – Karnataka (http://des.kar.nic.in/), India Meteorological Department (IMD), Pune (http://imdpune.gov.in).	Daily rainfall data for 110 year between 1901 and 2010. Used to assess the rainfall distribution over the basin
Crop Calendar	Agriculture Department of Karnataka, (http://raitamitra.**kar**.nic.in/*), iKisan (http://* www.**ikisan**.com)*,* National Food Security Mission *(http://*www.**nfsm**.gov.in*/*.	To understand when, where and which crops are grown which helps in understanding the crop water requirement based on the growth phases
Crop Coefficient	Food and Agriculture Organization- FAO (http://www.fao.org), Agriculture Department of Karnataka (http:// http://raitamitra.kar.nic.in/KAN/index.asp).	Each land use has its own evaporative coefficients, used to estimate the Actual Evapotranspiration.
Temperature (max, min, mean), Extraterrestrial solar radiation	Worldclim (http://www.worldclim.org/), FAO (http://www.fao.org), http://www.cru.uea.ac.uk, http:// climate.nasa.gov/, http:// data.giss.nasa.gov/gistemp/	Temperature data of 1km spatial resolution, available for each month. Extra-terrestrial solar radiation, every 1^0 North latitude available across different hemispheres for various months. Used to estimate the Potential Evapotranspiration
Population Census	Census India (http://censusindia. gov.in) 1991, 2001 and 2011	Data available at village level, used to estimate the population at sub basin level for the year 2014, and estimate the water requirement for domestic use at sub basin level

Livestock Census	Hassan District at a glance 2012-2013 (http://www.hassan.nic.in)	Taluk level data was used to estimate the livestock population and estimate water requirement at each of the river basins.
Digital Elevation data	Cartosat DEM from NRSC-Bhuvan (http://bhuvan.nrsc.gov.in)	Carto-DEM of 30m resolution. Used to derive the catchment boundaries, stream networks in association with Google earth and Toposheets
Secondary Data	Google Earth (http://earth. google.com), Bhuvan (http://bhuvan.nrsc.gov.in), French Institute Maps (http://www.ifpindia.org/.), Western Ghats biodiversity portal (http:// thewesternghats.indiabiodiversity.org/), the Survey of India topographic maps (http://www.surveyofindia.gov.in/)	Supporting data in order to assist land use classification, delineation of streams/rivers/ Catchment, Geometric correction
Field data	GPS based field data, data form public (stratified random sampling of households)	Geometric Corrections, Land use classification, Crop water requirement, livestock water requirement estimate

4.0 METHOD:

The method involved in evaluation of the hydrological status is as depicted in figure 13.

Hydrologic assessment in the catchment involved 1) delineation of catchment boundary 2) land use analysis, 3) assessment of the hydro meteorological data, 4) analysis of population census data, 5) compilation of data through public interactions for assessing the water needs for livestock, agriculture/horticulture and cropping pattern, and 6) evaluation of hydrologic regime.

4.1 Delineation of catchment boundary: Catchment boundaries (Figure 4) and the stream networks (Figure 6) considering the topography of the terrain based on CartoSat DEM were delineated using the hydrologic modeling tool in GRASS GIS. These catchment boundaries were overlaid on the extracted boundaries from the Survey of India topographic maps in order to check and correct the variations (if any due to errors in DEM), Corrected catchment boundaries were further overlaid on Google earth in order to visualize the terrain variations (Figure 5).

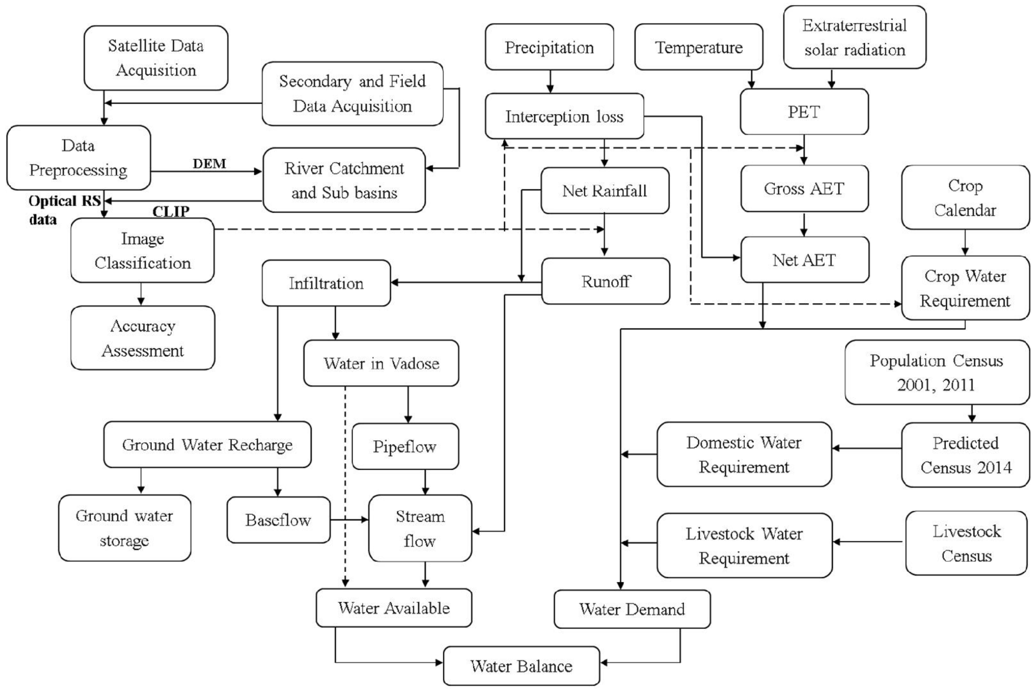


Figure 13: Method involved

4.2 Land use Assessment: Land use refers to heterogeneous terrain with the interacting ecosystems in the landscape and is characterized by its dynamics, which are governed by human activities and natural processes. Human induced land use and land cover (LULC) changes have been the major driver of the landscape dynamics at local levels. Land use assessment was carried using the maximum likelihood classification technique. Understanding of landscape dynamics helps in the sustainable management of natural resources.

Land use analysis involved i) generation of False Colour Composite (FCC) of remote sensing data (bands – green, red and NIR). This helped in locating heterogeneous patches in the landscape ii) selection of training polygons (these correspond to heterogeneous patches in FCC) covering 15% of the study area and uniformly distributed over the entire study area, iii) loading these training polygons co-ordinates into pre-calibrated GPS, vi) collection of the corresponding attribute data (land use types) for these polygons from the field. GPS helped in locating respective training polygons in the field, iv) supplementing this information with Google Earth v) 65% of the training data has been used for classification, while the balance is used for validation or accuracy assessment.

The process of assessing land use is as follows:

1) ***Satellite data acquisition:*** Satellite data sets for the whole world (earth) at different resolutions are available since 1972 (Landsat1) up to date. For the land use analysis, Landsat 8 (2013) data was obtained from the public domain (USGS: http://earthexplorer.usgs.gov/). Survey of India (SOI) topo-sheets of 1:50000 and 1:250000 scales were used to generate base layers of catchment boundary, stream network, etc.

2) ***Data pre-processing:*** The remote sensing data obtained were geo-referenced, rectified and cropped pertaining to the study area. Geo-registration of remote sensing data (Landsat data) has been done using ground control points collected from the field using pre calibrated GPS (Global Positioning System) and also from known points (such as road intersections, etc.) collected from geo-referenced topographic maps published by the Survey of India and from online BHUVAN portal (http://bhuvan.nrsc.gov.in). The Landsat satellite 1972 images have a spatial resolution of 57.5 m x 57.5 m (nominal resolution) were resampled to 28.5m comparable to the 2013 data which are 28.5 m x 28.5 m (nominal resolution).
3) ***Preparation of False Colour Composite:*** False colour composite is the representation of earth features in their non-original colours in order to identify the heterogeneity in various landscapes. FCC is prepared by combination of spectral bands NIR, GREEN and RED bands. Figure 14 depicts FCC of the catchments.

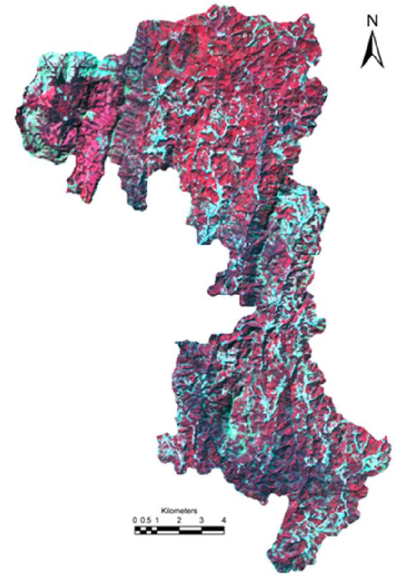
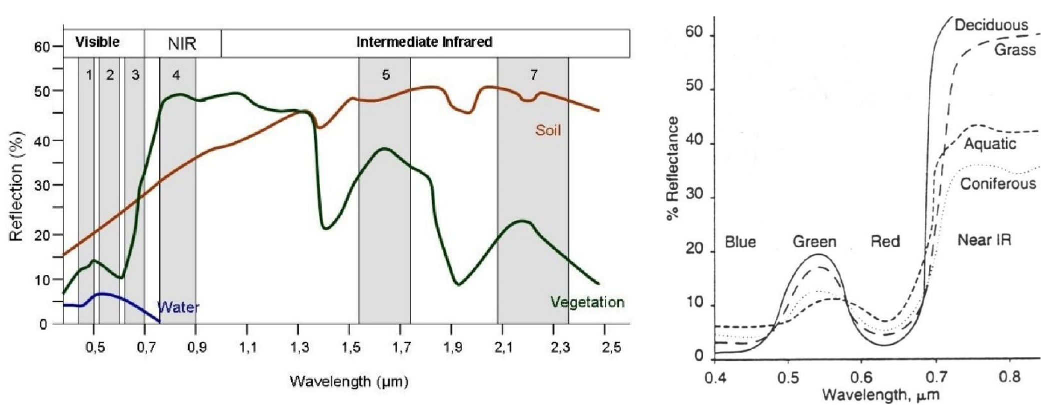


Figure 14: False Colour Composite

4) ***Preparation of signature data set:*** Signatures are the training datasets (training polygons) which are used to classify the satellite image into various land use classes based. Signatures were developed for various land use categories based on the site knowledge [Field data, Topographic maps (the Survey of India), Google earth (http://www.googleearth.com), Bhuvan (http://bhuvan.nrsc.gov.in), Western Ghats Biodiversity Portal (thewesternghats.indiabiodiversity.org/), French institute vegetation, geoclimate and soil maps (www.ifpindia.org/.../data-paper—-high-resolution-**vegetation**-cover-data-southern-western-ghats-india)] and based on spectral properties of landscape elements (Figure 15). Training data collected spread uniformly across the study area covering at least 15% of the total area.



Source: www.seos-project.eu *Source: http://www.geog.ucsb.edu*

Figure 15: Spectral reflectance curve

5) ***Classification of Satellite image:*** Land use analysis was carried out using supervised pattern classifier - Gaussian maximum likelihood algorithm. The classifier computes the mean and variance of digital numbers under each training data set, based on which unknown pixel is categorized under a land use class. Recent remote sensing data (2013) was classified using the collected training samples. Statistical assessment of classifier performance based on the performance of spectral classification considering reference pixels is done which include computation of kappa (κ) statistics and overall (producer's and user's) accuracies. For earlier time data, training polygon along with attribute details were compiled from the historical published topographic maps, vegetation maps, revenue maps, etc. Of the overall signatures, 65% of the total signatures are considered in classification of the image and 35% of the pure signatures are used for assessing the accuracy. Land use was computed using the temporal data through open source program GRASS - Geographic Resource Analysis Support System (http://ces.iisc.ernet.in/grass). Land use categories include i) Water bodies (Lakes/tanks, rivers, streams, ii) Built up (buildings, roads or any paved surface, iii) Open Spaces iv) Evergreen forest (Evergreen and Semi Evergreen), v) Deciduous forest (Moist deciduous and dry deciduous) vi) Scrub land and grass land, vii) Agriculture Plantation (coconut, arecanut, rubber) viii) Forest plantations (Acacia, Teak)

6) ***Accuracy assessment:*** Accuracy is necessary in order to check if the classified remote sensing data agrees with the reference data. The reference data is based on the field data, or collateral data. Kappa is estimated as a measure of agreement between the reference map and the classified map.

4.3 Assessment of the hydro meteorological data: The method involved assessment of the rainfall data obtained from various sources such as TRMM (http://trmm.gsfc.nasa.gov/), data from local rain gauge stations (http://des.kar.nic.in) in and around the study site. Long term precipitation data helped in understanding the rainfall variability over decades. Iso-lines across the months were developed based on the spatial rainfall variation of rainfall w.r.t the rain gauge stations across the basin. Along with rainfall, temperature (minimum, maximum and average), extra-terrestrial solar radiation across the catchment were used to hydrological behaviors of the catchments which enables to understand the hydrological status.

Rainfall: Point based daily rainfall data from various rain gauge stations in and around the study area between 1901 and 2010 were considered for analysis of rainfall. The rainfall data used for the study were obtained from

i. Directorate of economics and statistics, Government of Karnataka (http://des.kar.nic.in)
ii. Indian metrological data (IMD), Government of India (http://imdpune.gov.in)
iii. Tropical rainfall Measuring Mission (TRMM), NASA (http://trmm.gsfc.nasa.gov/),

Some rain gauge stations had incomplete records with missing data for few months. Missing data's were computed based on neighboring stations and also through regression analysis. Rainfall trend analysis was done for select rain gauge stations to assess the variability of rainfall at different locations in the study area.

Long term daily rainfall data were used to compute the monthly and annual rainfall in each rain gauge station based on mean and standard deviation of select rain gauge stations in the study region. The average monthly and annual rainfall data were used to derive rainfall throughout the study area through the process of interpolation (isohyets). The interpolated rainfall data was used to derive the gross yield (R_G) in the basin (given in equation 1). Net yield (R_N) was quantified (equation 2) as the difference between gross rainfall and interception (In).

$$\mathbf{R_G = A * P} \text{ ....(1)}$$

$$\mathbf{R_N = R_G - In} \text{ ......(2)}$$

Where

R_G : Gross rainfall yield volume,
A: Area in Hectares,
P: Precipitation in mm,
R_N: Net rainfall yield volume
In: Interception volume

Runoff: This is the portion of rainfall that flows in the streams after precipitation. Runoff can be typically divided into two categories 1) Surface runoff or direct runoff 2) sub surface runoff

Surface runoff: Portion of water that directly enters into the streams during rainfall, which is estimated based on the empirical equation 3.

$$\mathbf{Q = \Sigma(C_i * P_R * A_i)} \text{ ......(3)}$$

Where Q : Runoff in cubic meters per month
C : Runoff Coefficient which is dependent upon various land uses (listed in table 5 based on land use type)
P_R : Net rainfall in mm (Gross rainfall – Interception)
i : Land use type

Table 5: Runoff Coefficients

Land Use	Run-off Coefficient
Urban	**0.85**
Agriculture	**0.6**
Open lands	**0.7**
Evergreen forest	**0.15**
Scrub/Grassland	**0.6**
Forest Planation	**0.65**
Agriculture Plantation	**0.5**
Deciduous Forest	**0.15**

Interception: During monsoons, portion of rainfall does not reach the surface of the earth, it remains on the canopy of trees, roof tops, etc. and gets evaporated. Field studies in Western Ghats show that, losses due to interception is about 15% to 30%, based on the land use. Table 6 shows the interception loss across various rainy months and land uses.

Table 6: Interception loss

Vegetation types	**Period**	**Interception**
Evergreen/semi evergreen forests	June-October	I = 5.5 + 0.3 (P)
Moist deciduous forests	June-October	I = 5 + 0.3 (P)
Plantations	June-October	I = 5 + 0.2 (P)
Agricultural crops (paddy)	June	0
	July-August	I = 1.8+ 0.1 (P)
	September	I = 2 + .18 (P)
	October	0
Grasslands and scrubs	June-September	I = 3.5 +0.18 (P)
	October	I = 2.5 + 0.1 (P)

Infiltration: Due to precipitation, the portion of water enters the subsurface of the earth (vadoze and groundwater zones). Only after saturation of sub surfaces, overland flow is noticed in streams. The water stored in sub-surfaces will flow laterally towards streams and contributes to stream flow during non-monsoon periods, which are referred as pipe flow (during post monsoon) and base flow (during summer).

$$\mathbf{Inf = R_N - Q} \text{ ......(4)}$$

Ground water recharge: This is the portion of water that is percolated below the soil stratum (vadose) after soil gets saturated. Recharge is considered the fraction of infiltrated water that recharges the aquifer after satisfying available water capacity and pipe flow. Equation 5 (Krishna Rao equation, 1970) was used to determine the ground water recharge.

$$\mathbf{GWR = R_C * (P_R - C) * A} \text{ ......(5)}$$

Where

GWR : Ground water recharge
R_C : Ground water recharge coefficient (listed in table 7)
C : Rainfall Coefficient
A : Area of the catchment

The recharge coefficient and the constant vary from location to location based on the annual rainfall.

Table 7: Ground water recharge coefficients

Annual Rainfall	R_C	C
400 to 600mm	0.20	400
600 to 1000 mm	0.25	400
> 2000 mm	0.35	600

***Sub Surface Flow (Pipe flow)*:** Part of the infiltrated effective rainfall circulates more or less horizontally (lateral flow) in the superior soil layer and appears at the surface through stream channels is referred as subsurface flow. The presence of a relatively impermeable shallow layer favours this flow. Subsurface flows in water bearing formations have a drainage capacity slower than superficial flows, but faster than groundwater flows. Pipe flow is considered to be the fraction of water that remains after infiltrated water satisfies the available water capacities under each soil. Pipe flow is estimated for all the basins as function of infiltration, ground water recharge and pipe flow coefficient, given by equation 6

$$P_F = (Inf - GWR) * K_P \text{ …….(6)}$$

Where

P_F : Pipeflow

Inf : Infiltration volume

K_P : Pipe flow coefficient

Groundwater Discharge: Groundwater discharge or base flow is estimated by multiplying the average specific yield of aquifer under each land use with the recharged water. Specific yield represents the water yielded from water bearing material. In other words, it is the ratio of the volume of water that the material, after being saturated, will yield by gravity to its own volume. Base flow appears after monsoon and pipeflow has receded. This water generally sustains flow in the rivers during the dry season.

$$GWD = GWR * Y_S \text{ …… (7)}$$

Where

GWD = Ground water discharge

GWR = Ground water recharge

Y_S = Specific yield

4.5 Estimation of Water Demand

Evapotranspiration: Evaporation is a process where in water is transferred to atmosphere as vapour. Transpiration is the process by which water is released to the atmosphere from plants through leaves and other parts above ground. In the process of transpiration water is taken into the atmosphere from ground (soil) through the roots. On the other hand, evaporation continues throughout the day and night at different rates. The process of evaporation takes place on all different land uses. Evapotranspiration is the total water lost from different land use due to evaporation from soil, water and transpiration by vegetation. Some of the important factors that affect the rate of evapotranspiration are: (i) temperature, (ii) wind, (iii) light intensity, (iv) sunlight hours, (v) humidity, (vi) plant characteristics, (vii) land use type and (viii) soil moisture. If sufficient moisture is available to completely meet the needs of vegetation in the catchment, the resulting evapotranspiration is termed as potential evapotranspiration (PET). The real evapotranspiration occurring in specific situation is called as actual evapotranspiration (AET). These evapotranspiration rates from forests are more difficult to describe and estimate than for other vegetation types.

Potential evapotranspiration (PET) is determined using Hargreaves method (Hargreaves, 1972) an empirical based radiation based equation, which is shown to perform well in humid climates. PET is estimated as mm using the Hargreaves equation is given by equation 8.

$$\mathbf{PET = 0.0023 * (R_A/\lambda) * \sqrt{Tmax - Tmin} * \left(\frac{Tmax+Tmin}{2} + 17.8\right)} \ldots\ldots (8)$$

Where

R_A = Extra-terrestrial radiation (MJ/m2/day) (FAO)

Tmax = Maximum temperature

Tmin = Minimum temperature

λ = latent heat of vapourisation of water (2.501 MJ/kg)

Actual evapotranspiration is estimated as a product of Potential evapotranspiration (PET) and Evapotranspiration coefficient (K_C) (table 8), given in equation 9. The evapotranspiration coefficient is a function of land use varies with respect to different land use. Table 8 gives the evapotranspiration coefficients for different land use

$$\mathbf{AET = PET * K_C} \ldots\ldots (9)$$

Table 8: Evapotranspiration coefficient

Land use	K_C
Built-up	0.15
Water	1.05
Open space	0.3
Evergreen forest	0.95
Scrub and grassland	0.8
Forest Plantation	0.85
Agriculture Plantation	0.8
Deciduous forest	0.85

Note: *the crop water requirement was estimated for different crops and different seasons based on land use, assumption is individual crop water requirement and different growth phases (need different quantum of water for their development inclusive of evaporation).*

Domestic water demand: Understanding the population dynamics in a region is necessary to quantify and also to predict the domestic water demand. Population census for villages during 2001 and 2011 were considered in order to compute the population of the basin level. Based on the rate of change of population (equation 10), the population for the year 2014 was predicted as given in equation 11.

$$r = (P_{2011}/P_{2001} - 1)/n \;\ldots\ldots(10)$$

Where

P_{2001} and P_{2011} are population for the year 2001 and 2011 respectively

n is the number of decades which is equal to 1

r is the rate of change

$$P_{2014} = P_{2011} * (1 + n*r) \;\ldots\ldots(11)$$

Where

P2014 is the population for the year 2014

n is the number of decades which is equal to 0.3

Domestic water demand is assessed as the function of water requirement per person per day, population and season. Water required per person include water required for bathing, washing, drinking and other basic needs. Water requirements across various seasons are as depicted in table 9.

Table 9: Seasonal water requirement

Season	Water lpcd
Summer	150
Monsoon	125
Winter	135

Livestock water requirement: Household surveys were conducted with the structured questionnaires to understand the agricultural cropping pattern and water needed for various crops in the catchment. Livestock population details were obtained from the district statistics office and water requirement for different animals were quantified based on the interviews. Table 10 gives the water requirement for various animals.

Table 10: Livestock water requirement

	Water Requirement in Liters per animal							
Season\Animal	**Cattle**	**Buffalo**	**Sheep**	**Goat**	**Pigs**	**Rabbits**	**Dogs**	**Poultry**
Summer	100	105	20	22	30	2	10	0.35
Monsoon	70	75	15	15	20	1	6	0.25
Winter	85	90	18	20	25	1.5	8	0.3

Crop water requirement: The crop water requirement for various crops was estimated considering their growth phase and details of the cropping pattern in the catchment (based on the data compiled from household surveys and publications such as the district at a glance, department of agriculture). Land use information was used in order to estimate the cropping area under various crops. Figure 16 provides the information of various crop water requirements based on their growth phase as cubic meter per hectare.

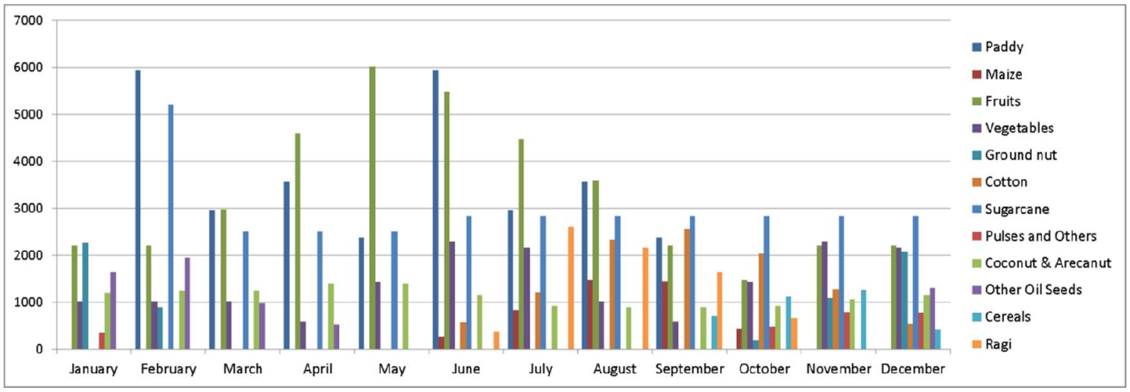


Figure 16: Crop water requirement (as cum per hectare per month)

4.6 Evaluating Hydrological Status.

The hydrological status in the catchment is analysed for each month based on the water balance which take into account the water available to that of the demand. The water available in the catchment is function of water in the soil, run off (streams and river) and water available in the water bodies (Lentic water bodies such as lakes, etc.). Water demand in the catchment is estimated as the function of crop water demand, domestic and livestock demand and the evapotranspiration. The catchment is considered hydrological sufficient, if the water available caters the water demand completely else the deficit catchment, if the water demand is more than the water available in the system.

5.0 RESULTS

Land use analysis: Land use analysis was carried out using remote sensing data of 2013, and results are given in figure 17 and table 11. Major portion of the catchment is covered with evergreen forest (45.08%) followed by agriculture plantations (29.05%) and grass lands (24.06%). The valleys along the stream are dominated by agriculture lands and horticulture plantations, the hill tops dominated by grass lands, slopes covered with forest cover. The accuracy of the land use classification is 87% with kappa of 0.82.

Table 11: Land use in Yettinaholé catchment

Land use	**Area (%)**
Built up	0.07
Agriculture Plantation	29.25
Evergreen	45.08
Forest Plantation	0.001
Water	0.002
Open land	0.91
Agriculture	0.62
Grassland	24.06

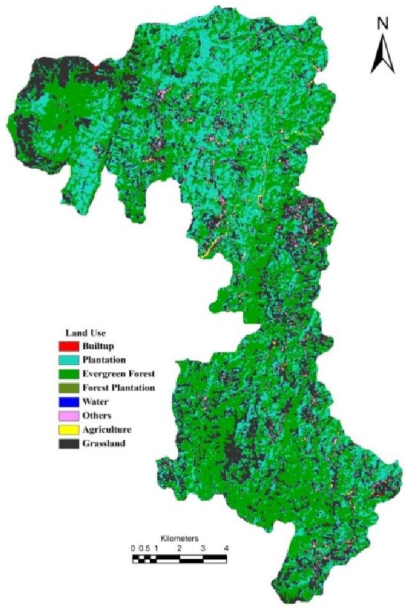


Figure 17: Land use in Yettinaholé catchment

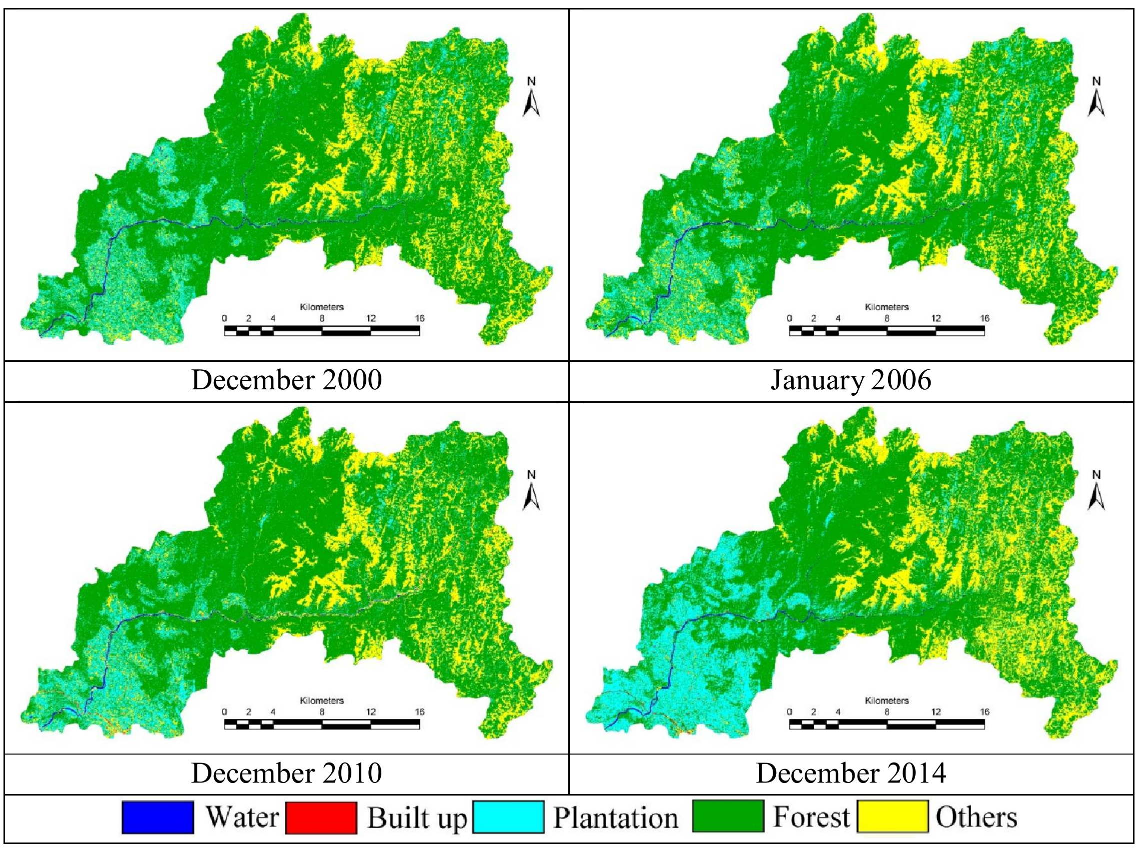


Figure 18: Land use dynamics – Gundia river basin

Table.12: Land use dynamics. – Gundia river basin

Land use	2000 December		2006 January		2010 December		2014 December	
	Area (sq.km)	% Area	Area (sq.km)	% Area	Area (sq.km)	% Area	Area (sq.km)	% Area
Water	4.05	0.63	3.61	0.56	2.96	0.46	3.11	0.49
Built up	0.44	0.07	0.17	0.03	2.41	0.38	2.72	0.43
Plantation	74.61	11.66	77.55	12.11	79.29	12.39	121.29	18.95
Forest	452.80	70.74	443.36	69.26	443.27	69.25	391.43	61.15
Others	108.22	16.91	115.44	18.03	112.18	17.53	121.56	18.99

Yettinaholé is a tributary of Gundia river. Temporal land use in the Gundia river catchment during 2000, 2006, 2010 and 2014 are depicted in Figure 18 and details are provided in table.12. Results reveal that area under forests has reduced from 70.74% (in 2000) to 61.15% (in 2014).

Variability of rainfall was assessed based on 11 rain gauge stations in the catchment and is given in Figure 19. Month-wise rainfall variations are depicted in Figure 20. The region receives annual rainfall ranging from 3000 mm to 4500 mm.

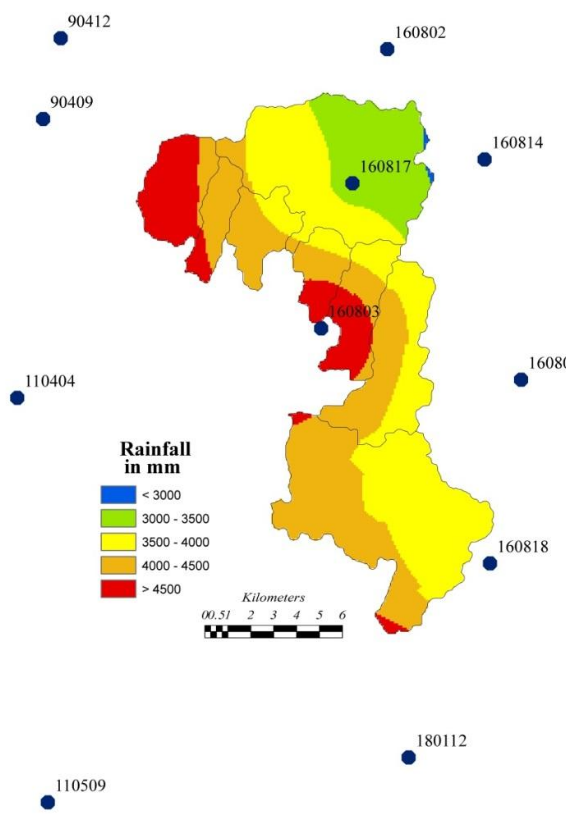


Figure 19: Spatial patterns of rainfall and rain gauge stations

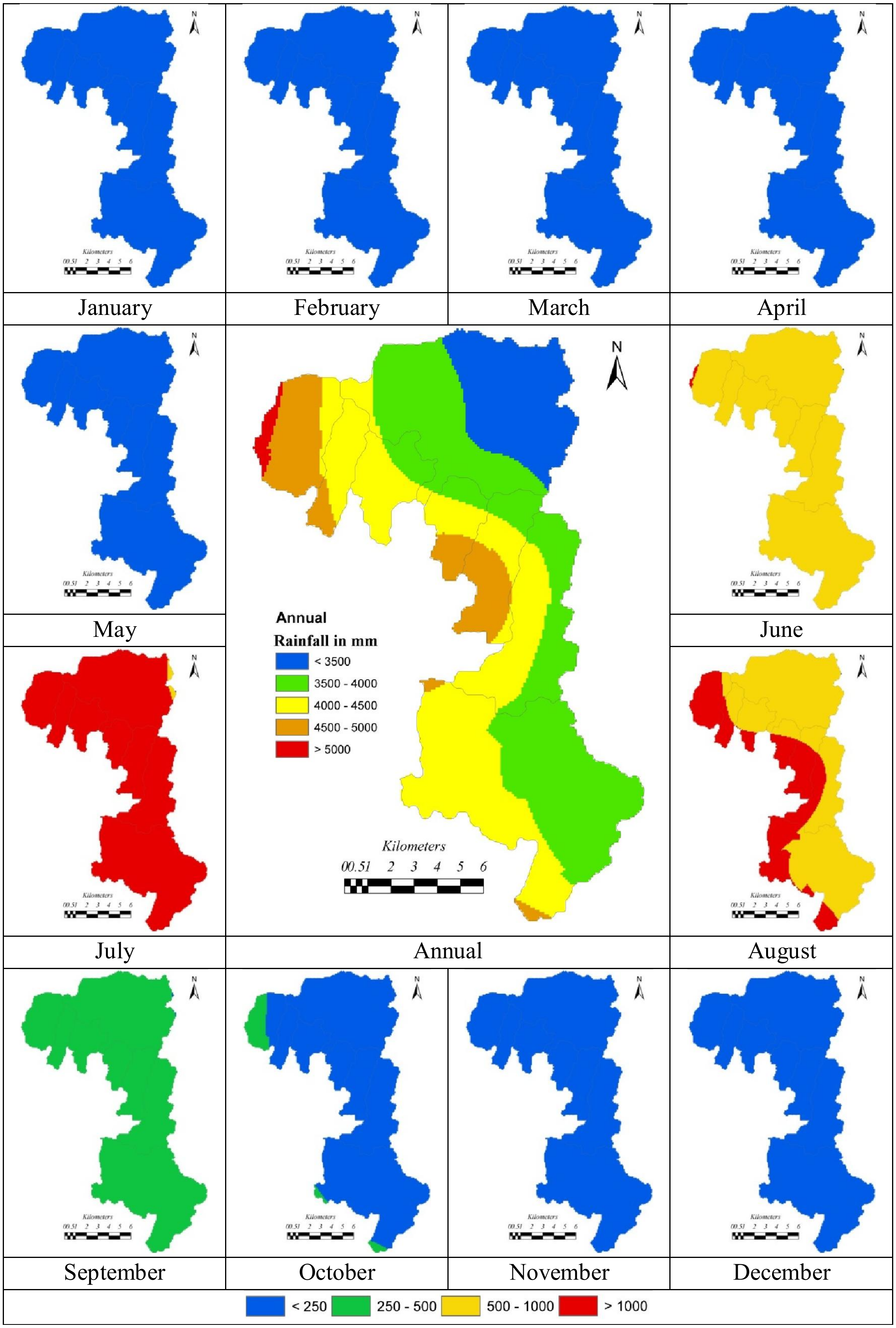


Figure 20: Rainfall in mm

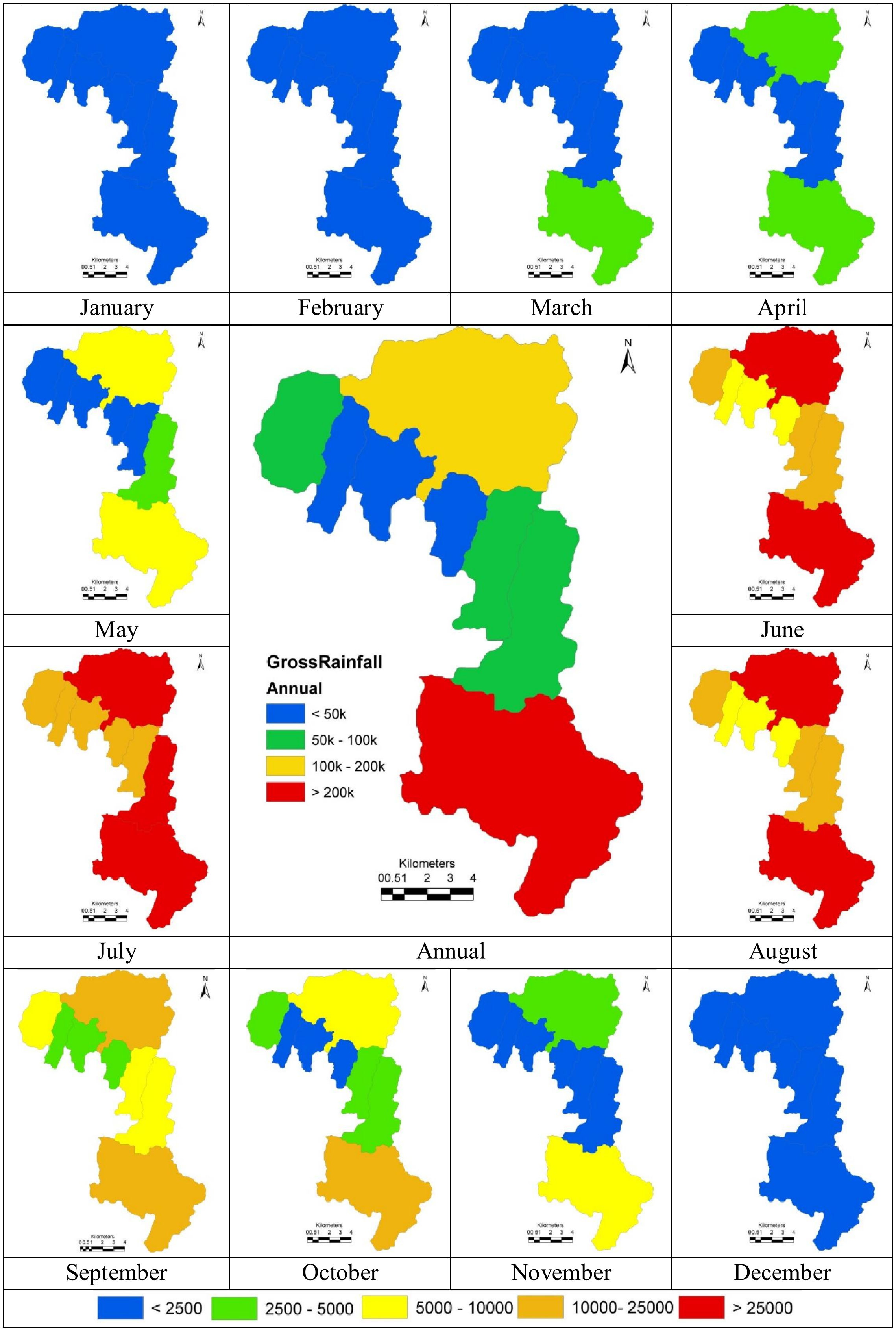


Figure 21: Gross Rainfall in kilo.cum

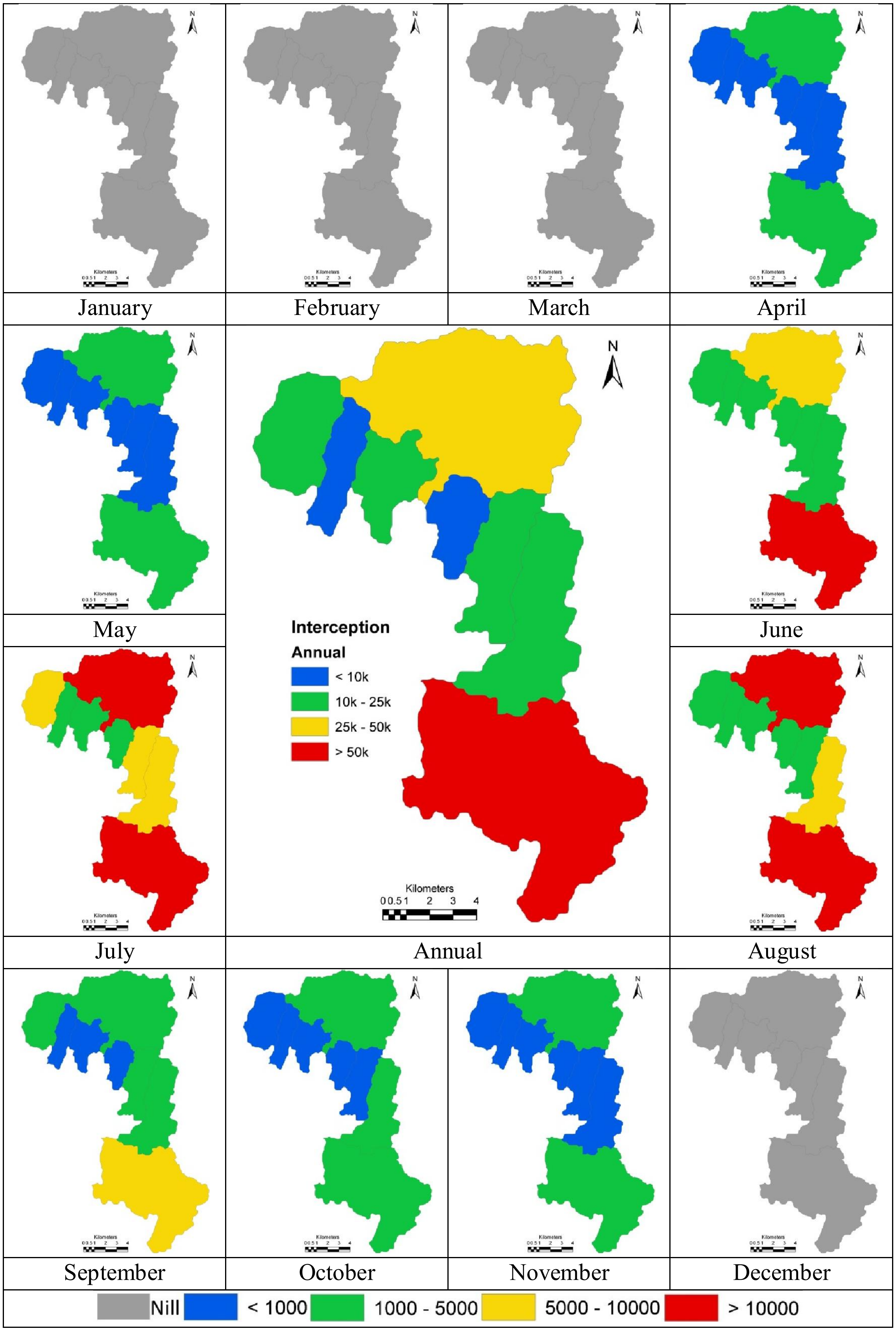


Figure 22: Interception in kilo.cum

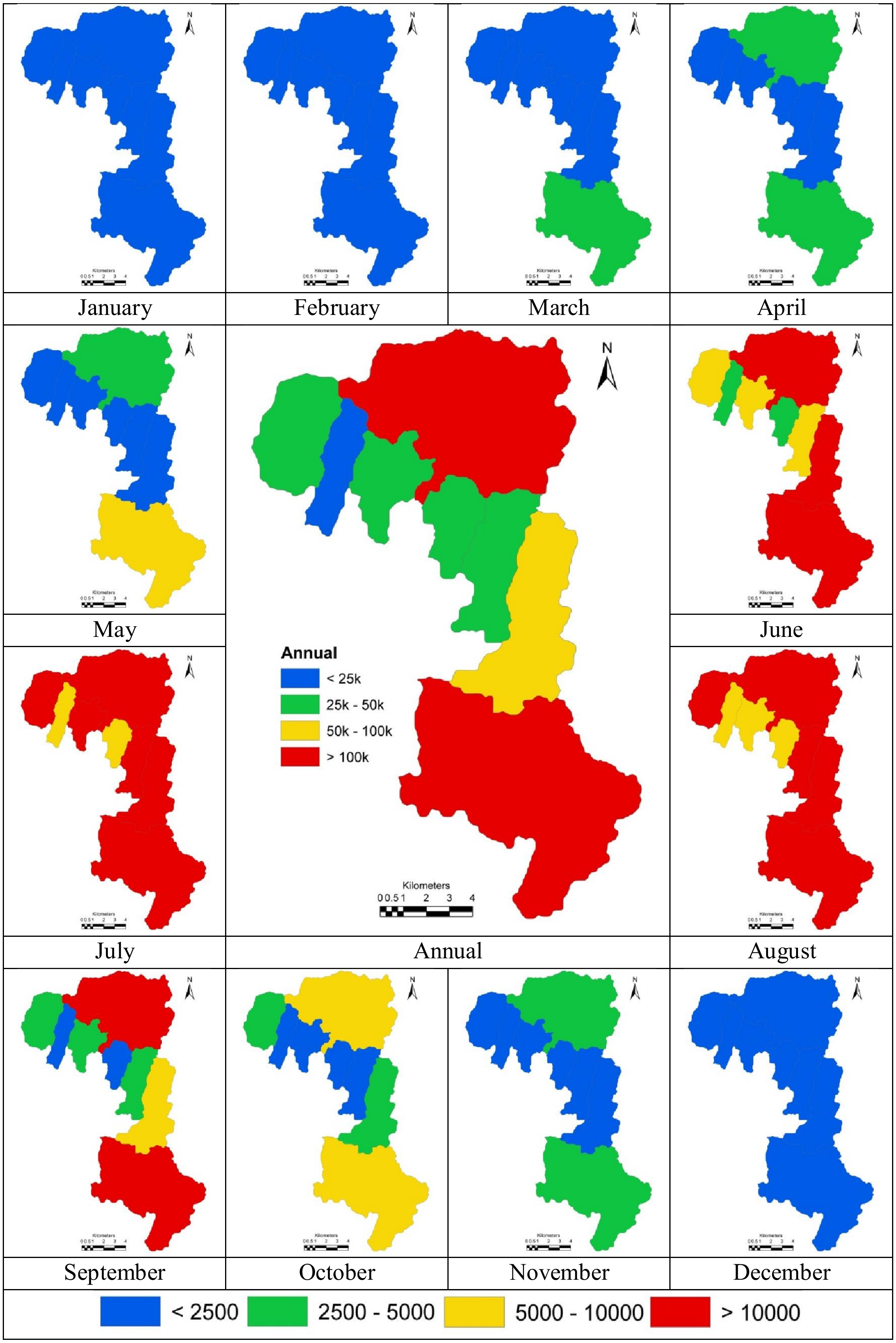


Figure 23: Net Rainfall in kilo.cum

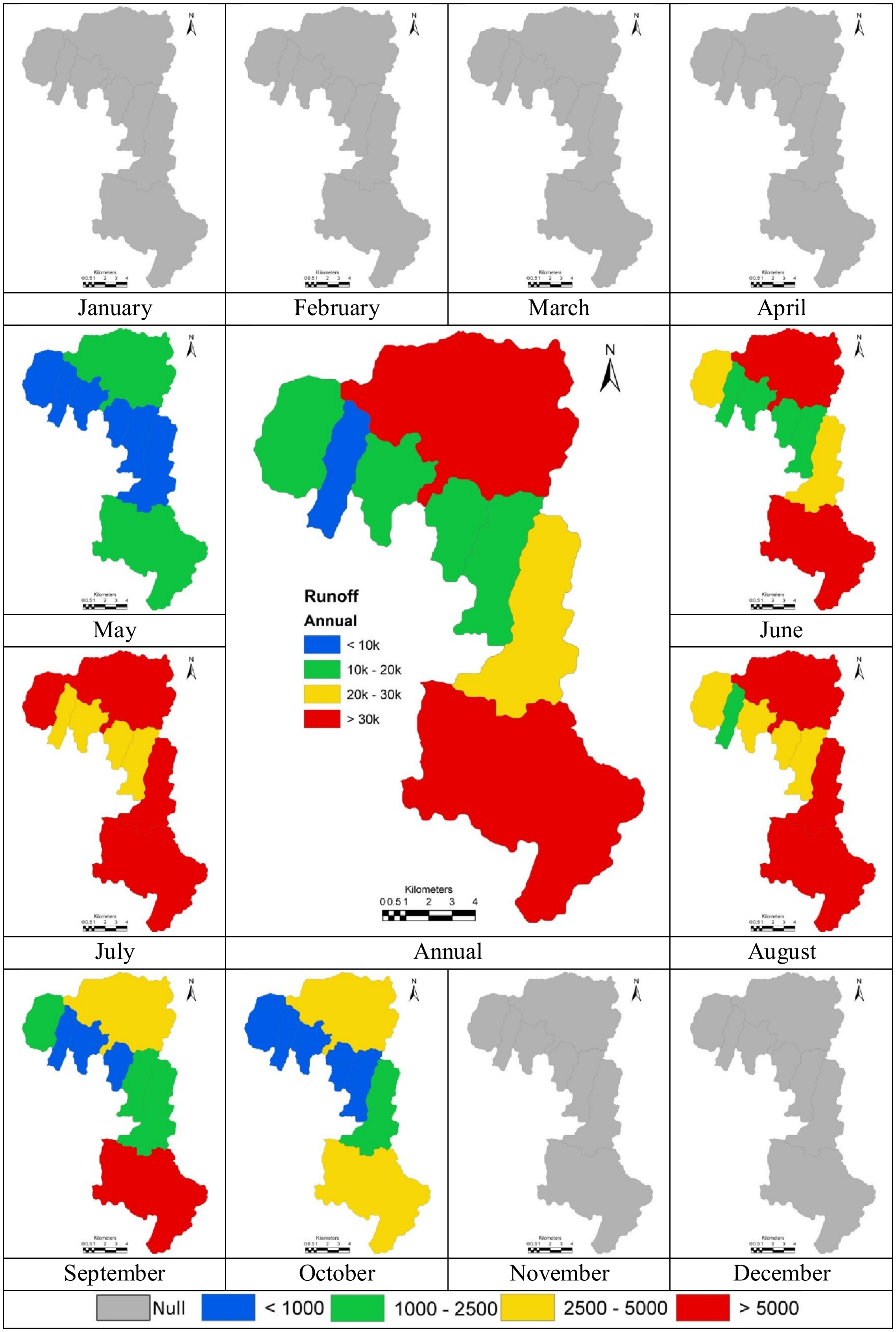


Figure 24: Runoff in kilo.cum

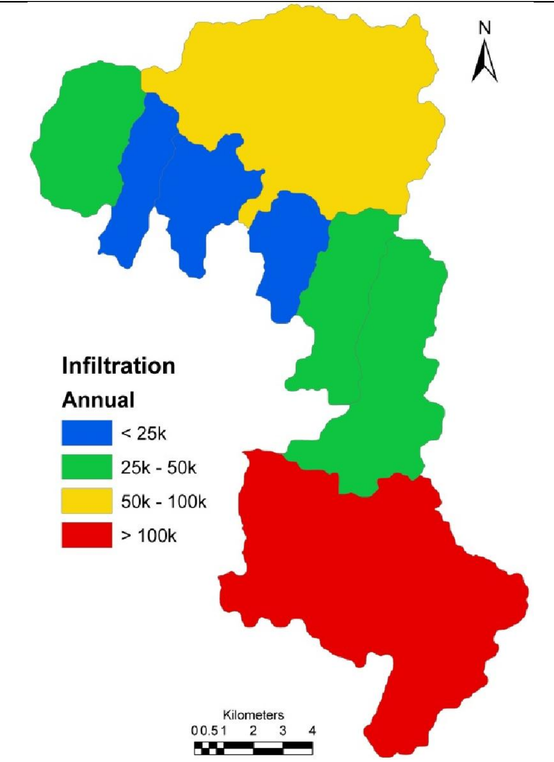


Figure 25: Annual Infiltration*

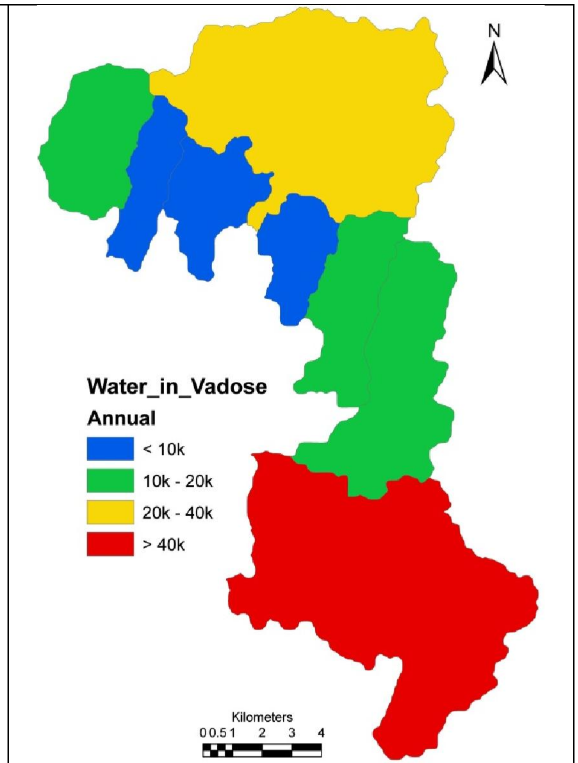


Figure 26: Annual Vadose Water*

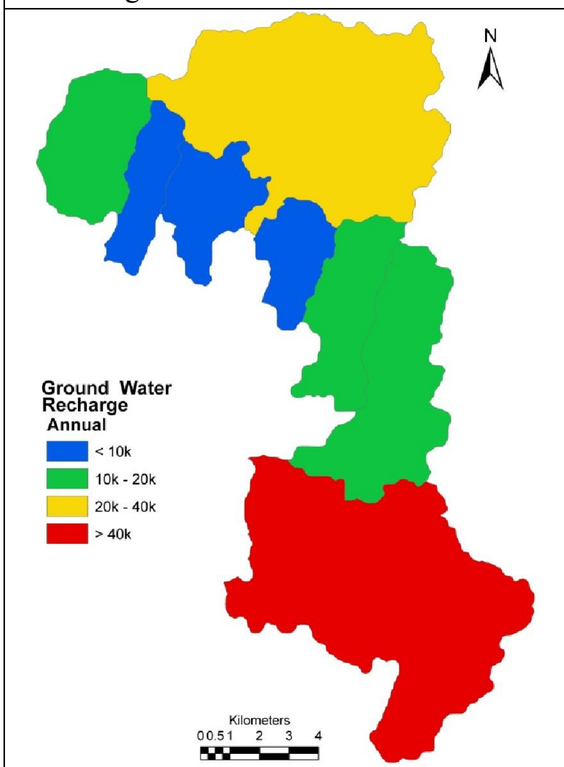


Figure 27: Annual Ground Water Recharge*

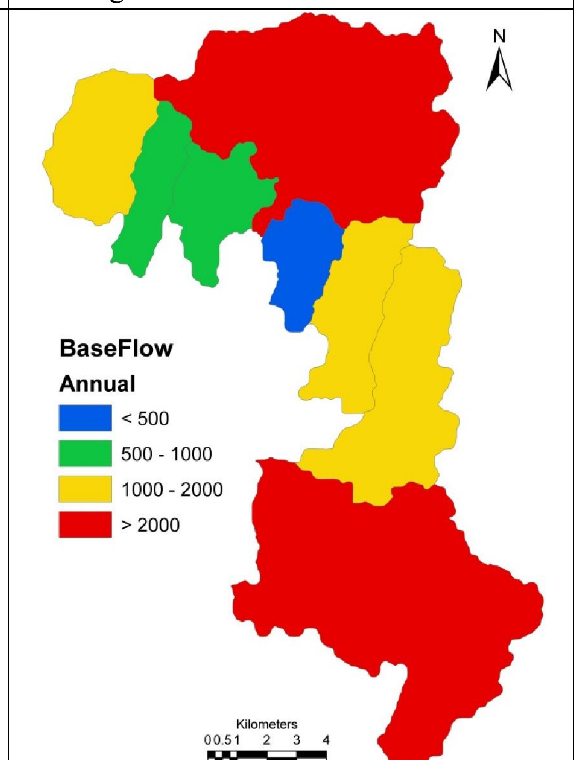


Figure 28:Annual Base Flow*

* All units in kilo cubic metre

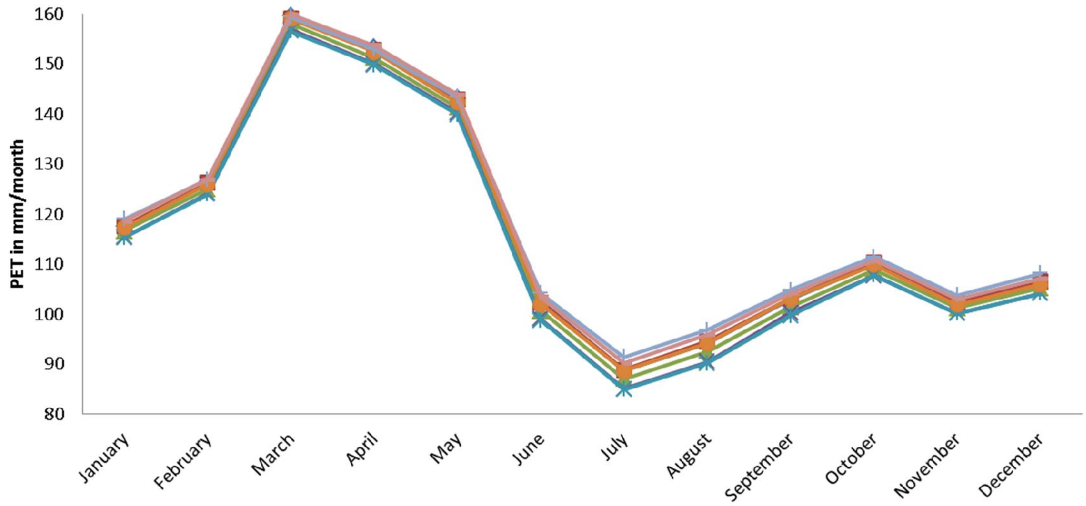


Figure 29: Potential Evapotranspiration

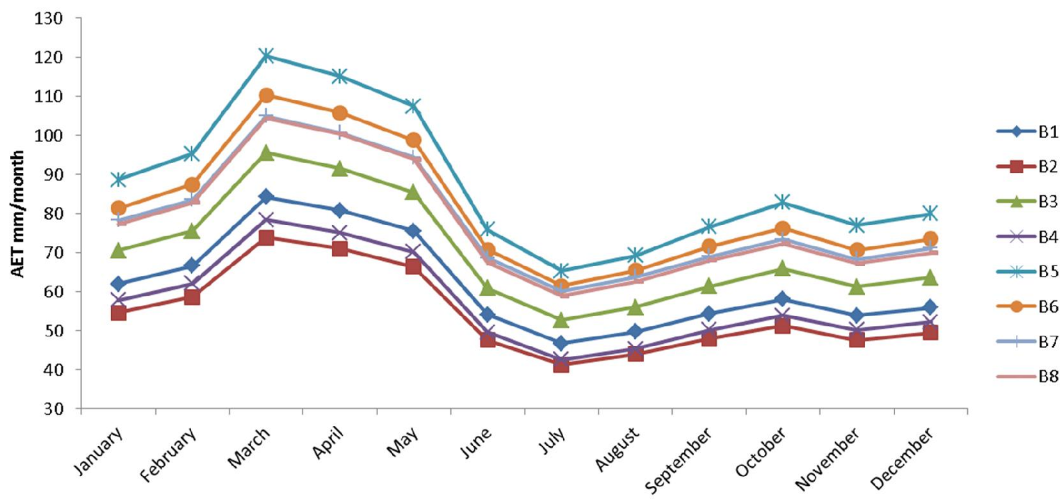


Figure 30: Actual Evapotranspiration

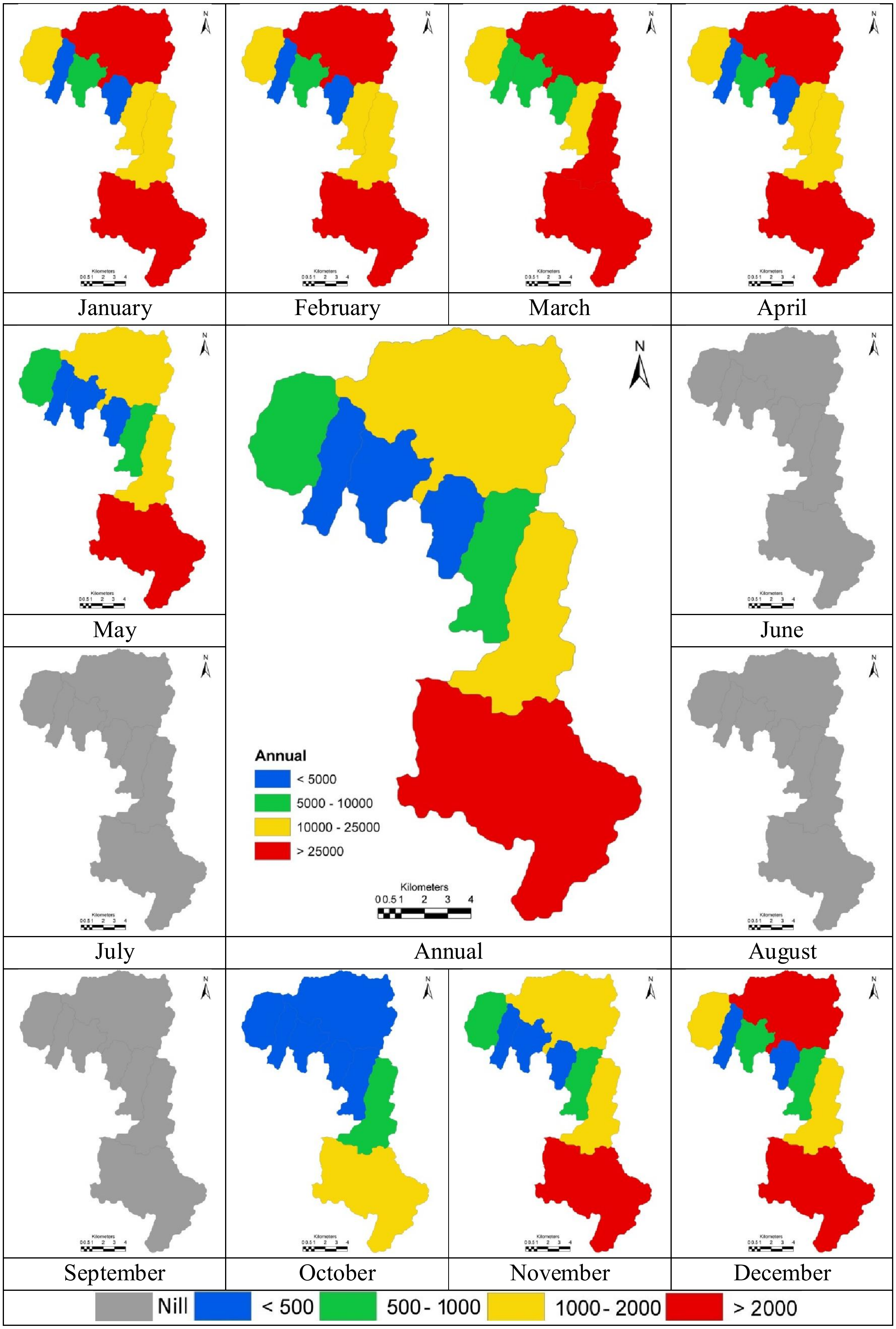
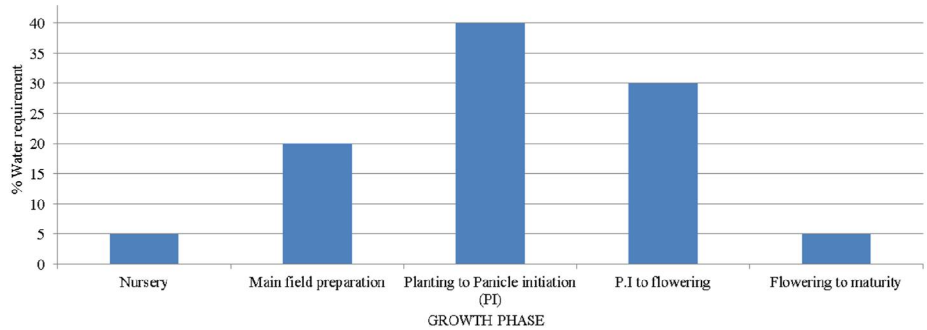


Figure 31: Evapotranspiration in kilo.cum



Source: http://agropedia.iitk.ac.in

Figure 32: Phase wise crop water requirement for paddy

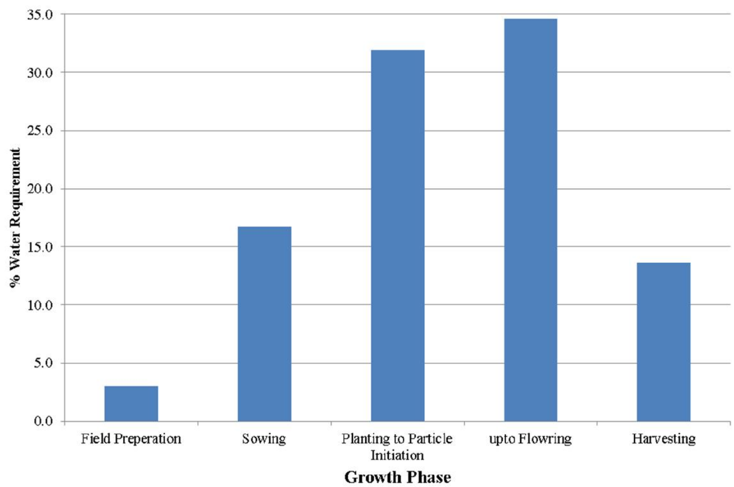


Figure 33: Phase wise crop water requirement for Oilseeds

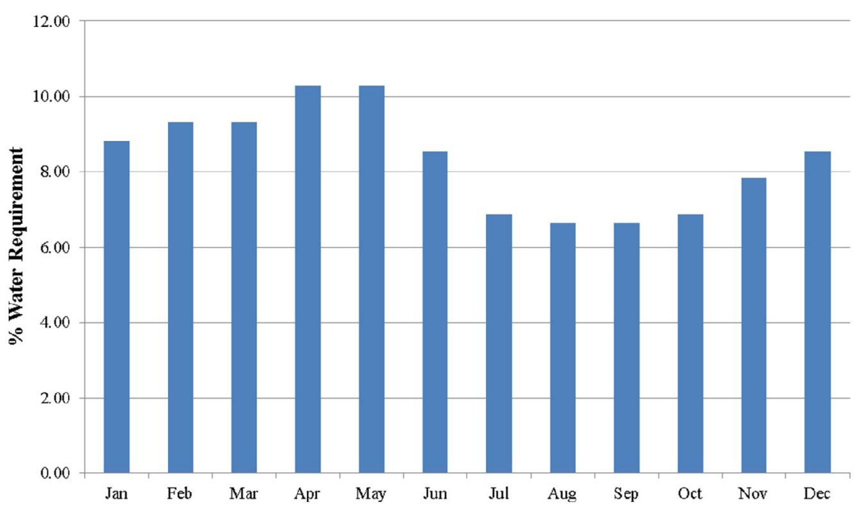


Figure 34: Phase wise crop water requirement for Horticulture plantations

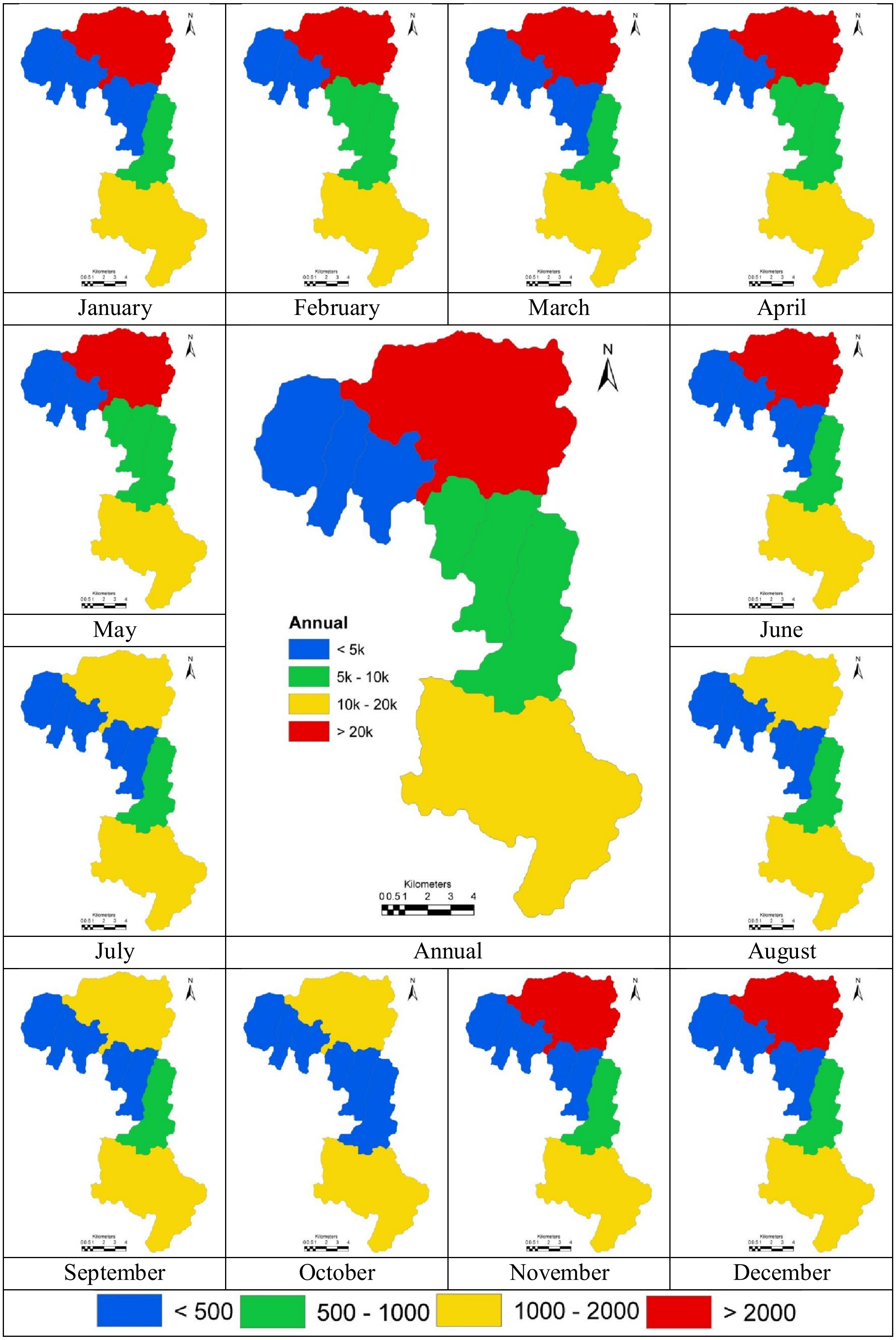


Figure 35: Crop Water Demand in kilo.cum

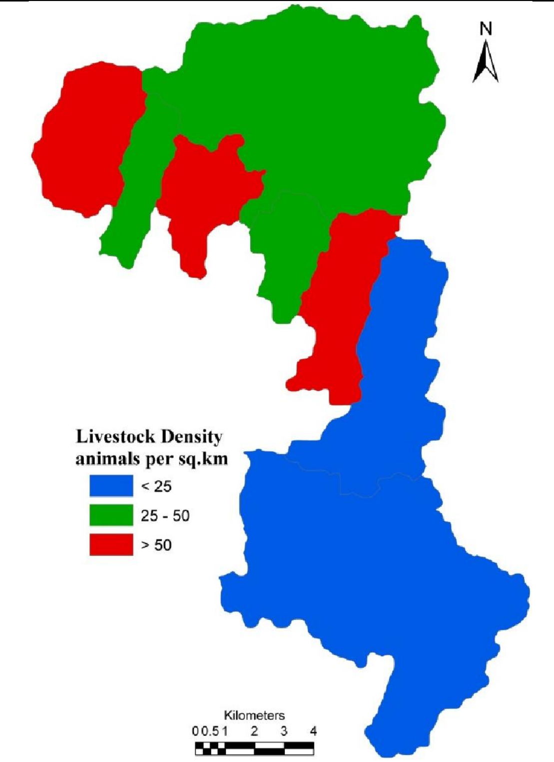


Figure 36: Livestock Density

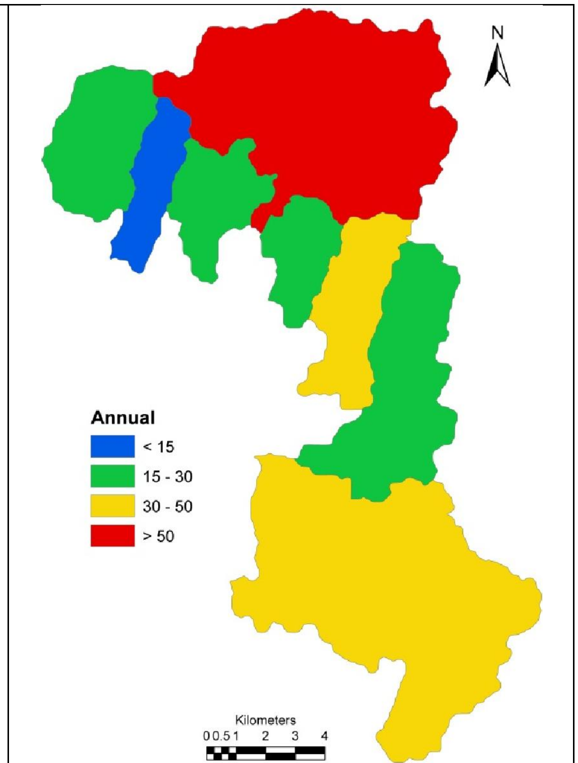


Figure 37: Livestock Demand*

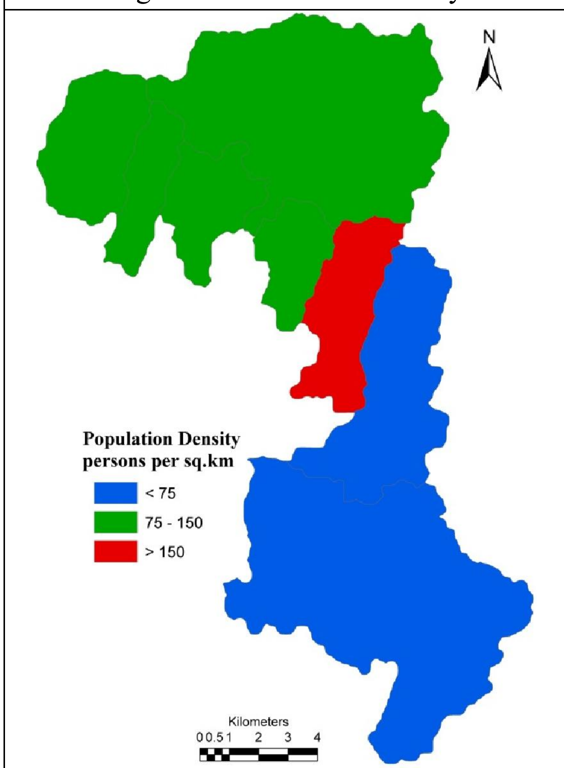


Figure 38: Population Density

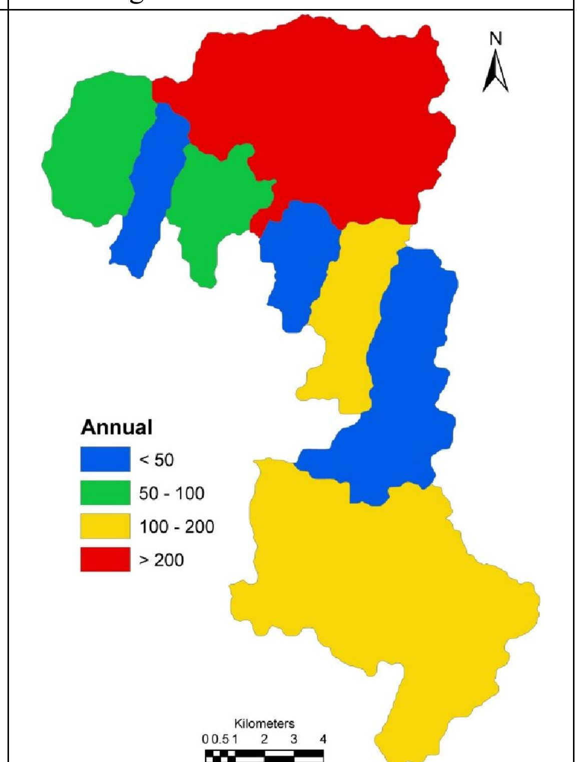


Figure 39: Domestic Demand*

* All units in kilo cubic metre

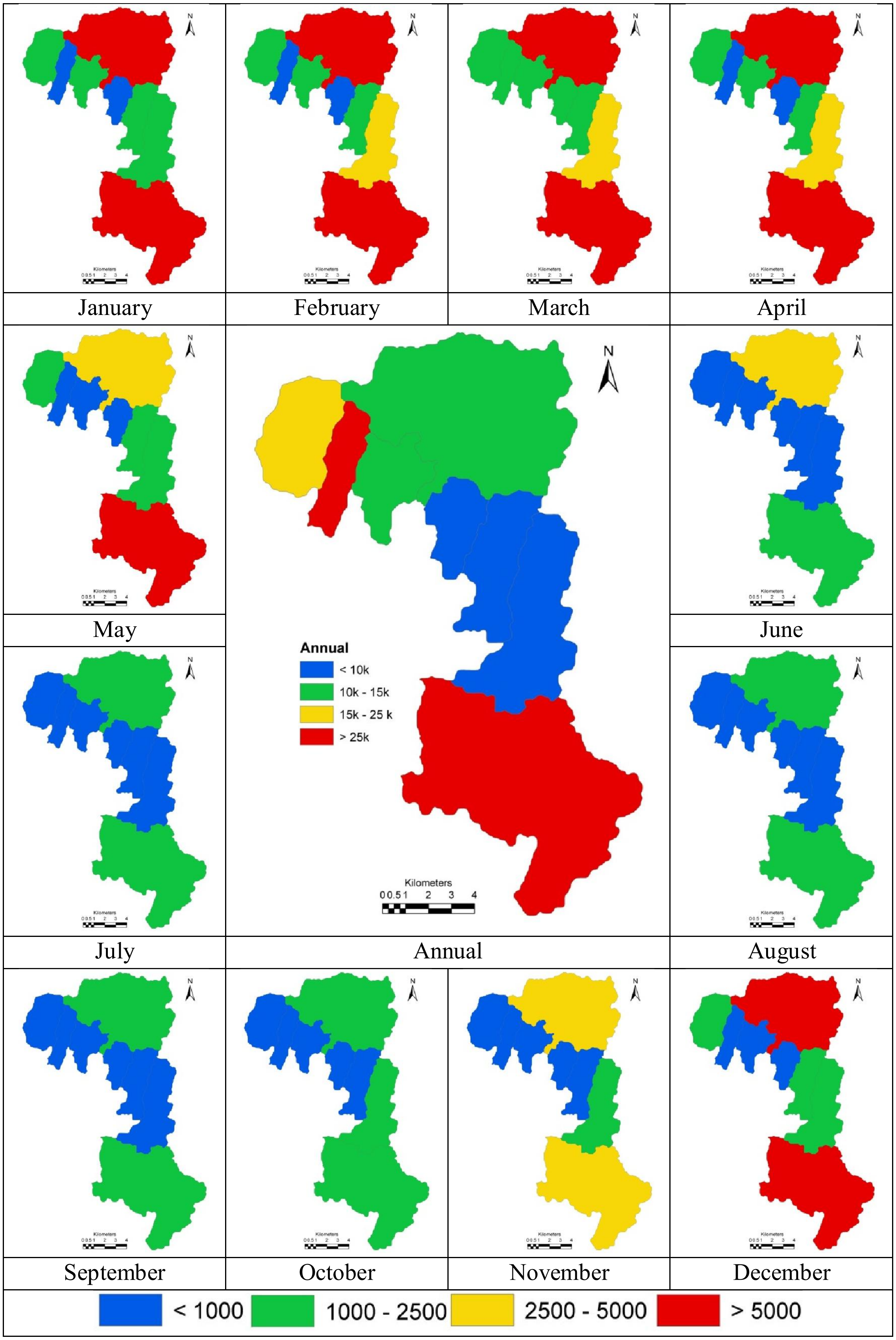


Figure 40: Total Demand in kilo.cum

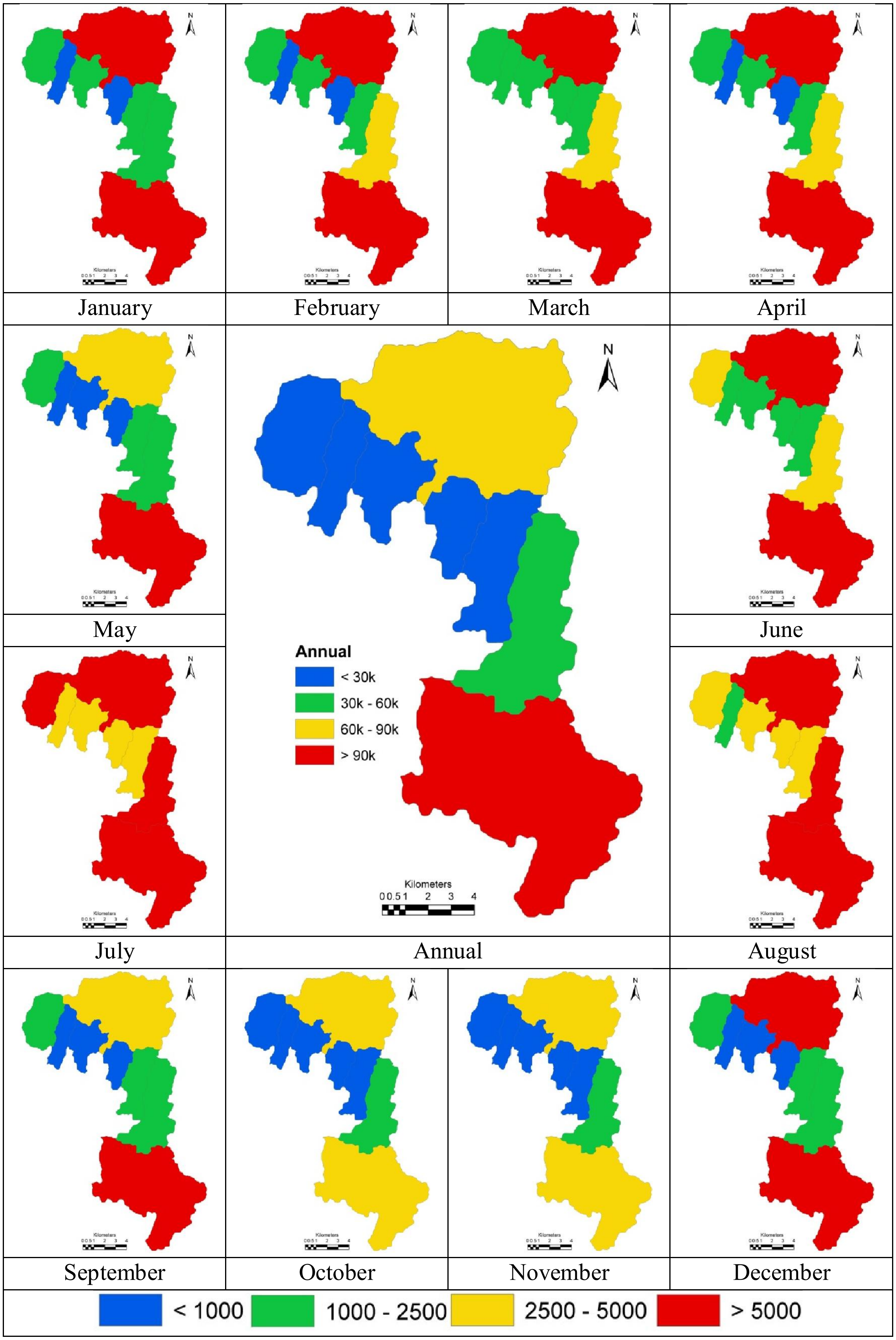


Figure 41: Water Available in kilo.cum

Figure 21 to Figure 41 describes monthly variability of hydrological parameters for understanding the hydrological regime. Gross rainfall (Figure 21), estimated as product of catchment area and rainfall. The gross rainfall varies from 33232 kilo.cum (in Kadumane holé 2 and Yettina holé 2) and over 2000000 kilo.cum (in Yettina holé and Hongada halla catchments). Portion of the water doesn't reach the earth surface, but is intercepted by the earth features namely the tree canopy, building tops, pavements etc. (Figure 22), which contributes to evaporation. In regions where monthly rainfall less than 50 mm, interception losses are assumed to be zero, and is accounted directly in the evapotranspiration estimates. Net rainfall was estimated for each of the sub catchments is given in Figure 23, accounting the interception losses. Runoff (Figure 24) in the basin is estimated as a function of catchment characteristics along with rainfall. Yettin holé, catchment is covered predominantly by evergreen forests, has aided in recharging groundwater zone (Figure 25) and sub surfaces (Figure 26). Infiltration of significant amount of precipitation to underlying layers, has reduced the overland flow and thus retarded the flash floods. The infiltration of water to sub-surface takes place during monsoon, and overland flow (surface runoff) happens during the monsoon (rainfall > 50 mm per month) and quantity depends on the catchment characteristics namely land use / land cover in the catchment, soil porosity, texture, presence of organic matter (leave debris, decayed matter etc.). The portion of water percolates through the sub surfaces and thus recharges ground water resources (Figure 27). Water stored in vadoze zone (sub-surface) moves laterally (Figure 28) to streams with cessation of rain. Forests in the catchment have played a prominent role in maintaining stream flow, water holding capacity of soil, ground water discharge (base flow), which also plays a pivotal role in catering the ecological and environmental demand of water. Sub basin wise yields are listed in table 13; the surface runoff during the monsoon is estimated to be 9.55 TMC.

Table 13: Catchment yield

Sub basin	Average Annual Rainfall mm	Gross Rainfall TMC	Runoff yield as TMC
Yettina holé	3539.73	5.98	2.62
Yettina holé T2	4311.44	1.23	0.58
Yettina holé T1	4109.99	1.33	0.57
Kadumane holé 2	4364.85	1.20	0.53
Kadumane holé 1	4725.54	1.79	0.70
Hongadahalla	4000.77	6.70	2.68
Keri holé	4013.09	2.69	1.17
Yettina holé lower reach	4385.25	1.81	0.69
GROSS Yield (TMC)			**9.55**

Evapotranspiration in the catchment depends on the land use, solar radiation, variations in temperature, precipitation, etc. Potential evapotranspiration (Figure 29) was estimated using Hargreaves method. PET indicates the maximum possible water that can evaporate, PET varies between 160 mm/month (March) to 85 mm/month (monsoon season). Considering the various land use characteristics in the catchments, actual evapotranspiration (Figure 30) was estimated in the catchments show variation of 40mm/month (monsoon) to 120mm/month (March). Considering the interception losses, net evaporation (Figure 31) was computed as a difference between actual and interception, which highlights that intercepted water, takes care of evaporation during monsoon. Similarly, evaporation from the crops (horticulture and agriculture) is also accounted.

Crop water demand (Figure 35) was calculated for each catchment based on cropping pattern, area under each crop, and water required across the growth phases of the crops, which were compiled from various literatures (local, national and international) public opinions, practices and experiences. Table11 and Figure 32 - 35, details season-wise crop water requirements and growth phases. The agricultural water demand of 2.6 TMC in the catchments is due to the horticultural and paddy cultivation. Livestock water demand given in Table 10 (Figure 37) was estimated based on the livestock population (Figure 36) compiled from District at a glance of Hassan (2012-13).

Census data for the year 2001 and 2011 with the decadal rate of change in population was used compute the population for 2014. Catchment had a population of 17005 (in 2001), which decreased to 16345 (in 2011) at a decadal decline of 3.88%. Population for the year 2014 was estimated as 16156 persons. The population density (Figure 38) in the catchments varies from 33 persons per sq.km (in Keriholé) to about 150 persons per sq.km holé (Yettinaholé lower reach). Overall population density in the catchment is about 89 persons per sq.km. Based on the population and seasonality, monthly water demand was computed for each of catchments and is given in Figure 39.

Total demand (5.84 TMC of water) across the catchments was obtained as a function of evaporation, livestock, and domestic and agriculture demands and is depicted in Figure 40. Availability of water in the catchment was assessed as a function of runoff, water in vadose, base flow, etc. and are depicted in Figure 41.

The assessment showed that the currently available water is sufficient only to cater existing water demand (social, ecological and environmental) throughout the year and most streams in the forested catchment are perennial. The summary of the hydrological analysis are as described in table 14 and in Figure 42.

Table 14: Hydrological findings in the catchment

Description	Quantity
Gross Area	179.68 sq.km
Average Annual Rainfall	3500 – 4500 mm
Water Yield in the catchment	268828 kilo.cum (9.55 TMC)
Ground Water Recharge	13745.4 kilo.cum (0.49 TMC)
Evapotranspiration	89053.1 kilo.cum (3.16 TMC)
Irrigation Water Requirement	74372.5 kilo.cum (2.64 TMC)
Domestic Water Requirement	795.6 kilo.cum (0.03 TMC)
Livestock Water Requirement	258.7 kilo.cum (0.01 TMC)
Total Water Demand	164479.9 kilo.cum (5.84 TMC)

* Conversion of Units, kilo.cum to TMC

Note: 1 ft = 0.3048m, 1cft = 0.028317 cum,
1 TMC = 1 Thousand Million Cubic feet (1000000000 cft), 1TMC = 28316847 cum,
1TMC = 28316.847 kilo.cum, 164479.9 kilo.cum = 5.84 TMC

TMC (is one thousand million cubic feet) is a term used by the British to quantify water supply. It is roughly equal to 30 million cubic metres of water.

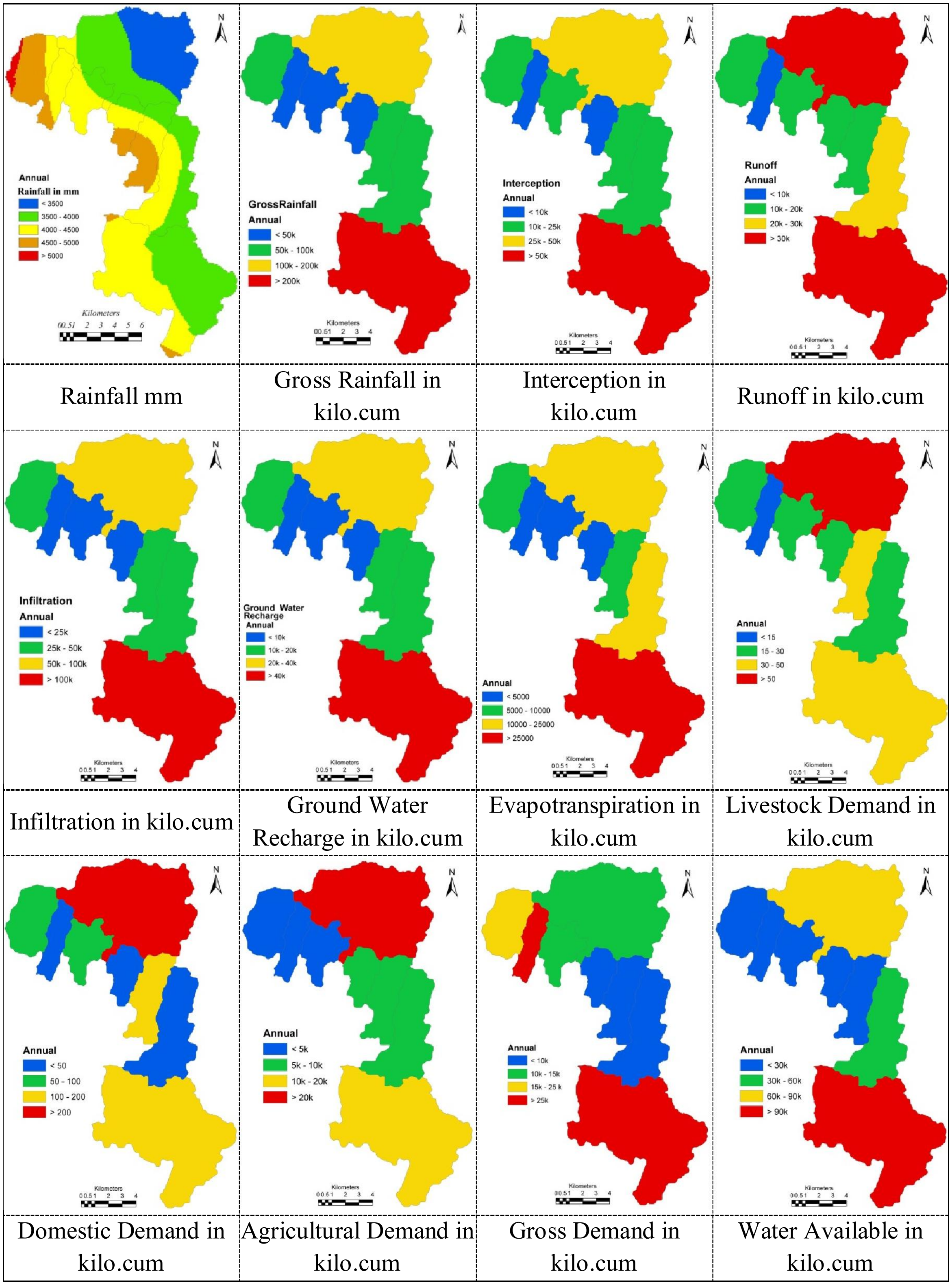


Figure 42: Hydrologic assessment in Yennaeholé catchment

COMPARATIVE ASSESSMENT WITH DPR [Karnataka Neeravari Nigam Limited**]**

[DPR (Detailed project report for diversion of Yettinaholé to dry arid regions)]

Yettinaholé and streams in the catchment are perennial which cater to the users demand in the downstream. Karnataka Neeravari Nigam Limited, Government of Karnataka has proposed to divert and store the water to meet the needs of the water scares regions*: Kaduru, Arsikere, Tipturu, Chikkanayakanahalli, Gubbi, Madhugiri, T.G.Halli, Ramnagara, Gouribidnuru, Nelamangala, Hesaraghatta, Doddaballapura, Hoskote, Devanahalli, Chikkaballapura, Gudibande, Bagepalli, Chintamani, Srinivasapura, Sidlaghatta, Maluru, Kolar, Mulbaglu and Bangarpete* at an estimated cost of 12912 crores. The proposed weirs have overall catchment area of 176 sq.km with evergreen forests dominating the catchment to an extent of 45.05%, followed by agriculture plantations (coconut/arecanut) about 29.25% and grass lands about 24.06%. The presence of these thick evergreen forests and grass lands in the catchment are responsible for higher infiltration and perennial streams. Any anthropogenic activities involving large scale land cover changes would affect the hydrology of the river basin affecting the dependent biota. The region's ecological and economic importance is evident from

- Yettinaholé and its immediate neighboring catchments falls under the Ecological Sensitive Zone 1 (**ESZ 1**) (HLWG report of Western Ghats conservation, http://envfor.nic.in/sites/default/files/**HLWG**-Report-Part-1_0.pdf*)* and as per the recommendations of the working group there **shall be strictly no developmental activities**.
- The region is **vulnerable and prone to frequent human animal conflict** (Elephant Human conflict) as per the Karnataka Elephant Task Force (**KETF:** (i) http://envfor.nic.in/content/report-karnataka-elephant-task-force-submitted-honourable-high-court-karnataka?theme=moef_high**,** (ii) http://www.atree.org/sites/default/files/KETF%20Final%20Report%20SCREEN%20RES.pdf#page=14&zoom=auto,-12,418), and any alterations in the elephant corridors would enhance human animal conflicts threatening the survival of elephants.

As per DPR (Detailed project report for diversion of Yettinaholé to dry arid regions) by the Karnataka Neeravari Nigam Limited the hydrologic yield in the catchment is 24 TMC. But actual water yield in the catchment is 9.55 TMC based on field data collection coupled with the assessment based on the rainfall data (the directorate of economics and statistics (GOK) and India Meteorological Department, Pune). Water yield in the catchment is 9.55TMC based on the stream gauging in select streams, and indirect estimation considering rainfall in the catchment (vary from 3500mm to 4000 mm) and current land uses. Computed catchment yield (based on the empirical relationship - hydrological model) compared with the gauged values of the runoff (maintained by KPC: Karnataka Power Corporation Limited), indicate that estimated values are comparable to gauged values: estimated value of the water yield is 0.702 TMC compared to 0.813 TMC (gauged at Kadumane holé 1- maintained between 2009 and 2012, Annexure Table 18). An accuracy of the model is 86.1% (Table 15) and hence the current approach was used for estimating the yield in the catchment of ungauged streams. Table 15 lists water yield in the catchment based on the current study and values mentioned in the DPR, which indicates exaggeration of values (total water yield is only 9.55 TMC compared to 24.03 TMC indicated in DPR).

Table 15: Comparison of DPR and the Hydro-meteorological analysis

Catchment	Name of Catchment	Rainfall in mm		Runoff Yield TMC	
		DPR	Data compiled from IMD	DPR	Computation based on field study
1	Yettina holéé	6280	3539.7	**6.62**	**2.62**
2	Yettina holé T2	6280	4311.4	**1.4**	**0.58**
3	Yettina holé T1	6280	4110.0	**1.02**	**0.57**
4	Kadumane holé 2	6280	4364.8	**1.73**	**0.53**
5	Kadumane holé 1	6280	4725.5	**0.98**	**0.70**
6	Hongadahalla	6280	4000.8	**7.76**	**2.68**
7	Keri holé	6280	4013.1	**2.01**	**1.17**
8	Yettina holé lower reach	6280	4385.3	**2.51**	**0.69**
			Total	**24.03**	**9.55**

Estimate of water yield of 24.03 TMC in Yennaeholé catchment in the DPR is on the assumption of annual rainfall of 6280 mm, without considering the variability across regions. Rainfall varies between 3500mm (Yettinaholé catchment) and 4700 mm (Kadumaneholé 1 catchment). Table 19 depicts variations in the runoff yield in 8 catchments, which was estimated (i) based on the gauged readings at Bantwala by CWC, (ii) proportional areas and spatial variation in the rainfall pattern were considered to derive the catchment yield, as per equation 12.

$$Q_n = \frac{Q.*A_n*P_n}{A*P} \qquad ......(12)$$

Where

Q_n = Flow at weir ***n***

Q = Flow at Bantwal

A_n = Catchment area at weir ***n***

A = Catchment area at Bantwal

P_n = Weir ***n*** catchment average rainfall

P = Bantwal catchment average rainfall

Computation of the catchment yield in Yennaeholé catchment shows a yield of 9.55 TMC in contrast to the claim of 24TMC as per DPR. The hydrological model considers the spatial extent and type of elements of the landscape (namely forests, agriculture, horticulture, grass lands, plantations, open lands *etc*,) with the meteorological information. The hydrological model also takes into consideration various demands namely: crop water requirement, domestic water requirement, livestock water requirement, evaporation losses; which accounts to be 5.8 TMC in a year (table 14), which are not accounted in the DPR.

Hydrology yield computed is comparable to

- Computations by Mayya S G (NITK Surathkal), Paramashivaiah (Hydrologist) *[TV 9 news channel discussion dated: Jul 23, 2013- **https://www.youtube.com/watch?v=dQDaaA6W8mI**]* indicate that the water yield is about 8 – 10 TMC (comparable to our calculated value of 9.55 TMC per year). This highlights that drawing waters to cater the needs of drinking water in the neighboring district would be an illusion as there is insufficient water to meet all demand in the catchment.

7.0 DISCUSSION

Yettina holé River is catering water needs in the catchment and downstream users with the existing natural flow regime. Higher discharge of water during monsoon transport nutrients, silt, etc., which gets deposited in the flood plains, river bed and estuaries. This helps the riparian's, aquatic life, human activities such as fishing, horticulture, agriculture etc. As many streams are perennial, helps to sustain aquatic life with rich diversity; and horticultural, agricultural activities (up to 3 crops are grown due to the availability of water), and fishery.

Our computation shows the water yield in the catchment is only 9.5 TMC, which is required to sustain the current level of activities in the catchment (agricultural, horticultural) apart from ecological and environmental needs. The diversion of water would lead to reduced crop yield in the catchments and downstream, and silt and nutrients that otherwise flow downstream, gets trapped in the weirs constructed across the streams. This would result in the variation in the natural flow regime affecting the biodiversity of riparian's and aquatic habitats and more importantly people's livelihood who are dependent on fisheries, etc. in the downstream.

Now, Karnataka Neeravari Nigam Limited, Govt of Karnataka has planned construction of weirs along the 8 streams (Yettina holé, Yettina holé T1, Yettina holé T2, Yettina holé lower reach, Keri holé, Hongadahalla, Kadumane holé1, Kadumane holé2) and divert the water uphill by pumping to a common storage point, then allowing the water to flow by gravity to supply water for i) agricultural and industrial usage, ii) filling the major tanks to cater the domestic needs.

The diversion scheme planned to supply 24 TMC water to (i) *Kolar district comprising of all taluks,* (ii) *Chickaballapura district comprising of all taluks,* (iii) *Tumkur district comprising of areas in Palar and Pennar basins including Chiknayakanahalli and Sira Taluks along with selected villages in Tiptur and Gubbi Taluks*, (iv) *Hassan district comprising of villages in Arasikere taluk,* (v) *Chikamagalore district comprising of selected villages in Kadur taluk* (vi) *Ramanagara district,* (vii) *Bangalore Rural district comprising of Nelamangala, Doddaballapura, Devanahalli and Hoskote Taluks,* (viii) *Augmenting the water to T.G.Halli reservoir,* (ix) *Augmenting water to Hesaraghatta reservoir,* (x) *Drinking water supply to Devanahalli Industrial area and surrounding areas.*

Combined yield of 24 TMC (DPR) is arrived at considering discharge measurements at the gauged station near Bantwala of Netravathi river (maintained by the Central Water Commission) and the proportional area of individual catchments relative the Netravathi catchment. Due to variations in rainfall across space and time, and also variations in land use, measurements at one location cannot be extrapolated to other regions in the catchment.

In contrast to this approach, water yield estimated using parameters at catchment level such as rainfall, land use, evaporation, etc. show the water yield of 9.55 TMC which is about 40% of the yield obtained by DPR. Based on measurements by KPC (Karnataka Power Corporation) at Kadumane holé 1, the yield in the catchment is 0.813 TMC, whereas the yield computed by us at this location is 0.702 TMC (based on the hydrological model). Thus the accuracy of the hydrological model is 86% in relation with the measurements of KPC. Based on these validations, model was used to estimate the water yield in other catchments. Higher water yield in DPR is mainly due to (i) considering uniform rainfall of 6000 mm in all catchments (though it varies from 3500 to 4700 mm), (ii) spatial variations in land cover / land use. Also, during the process of transporting water through gravity canals would account to loss of 1 TMC of water due to evaporation. Implementation of Yettinaholé project would lead to water scarcity in Hassan and Mangalore, while not benefitting Chikkballapur, Kolar, etc. Livelihood of Yettinaholé and Gundia catchment would be affected severely due to lowered agricultural and fisheries yield similar to the residents of Nellore district with the implementation of Telugu-Ganga project.

The sustainable option to meet the water requirements of arid regions in Karnataka is through (i) decentralized water harvesting (through tanks, ponds, lakes, etc.), (ii) rejuvenation or restoration of existing lakes/ponds, (iii) reuse of waste water, (iv) recharging groundwater resources, (v) planting native species of herbs and plants in the catchment, (vi) implementation of soil and water conservation through micro-watershed approaches.

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Annexure

YETTINAHOLÉ DPR (DETAILED PROJECT REPORT):

Yettinaholé Project, proposed in order to derive water for the people and to recharge the ground water resources of south east Karnataka which is a rain shadow area. The taluks planned for providing drinking water are Sakleshpura, Hassan, Belur, Arsikere, Tiptur, Tumkur, Kortagere, Doddaballapura, Chikkaballapura and Devanahalli taluks of Hassan, Tumkur, Bangalore rural, Kolar and Chikkaballapur districts respectively. The project proposal is to draw the excess runoff water during the monsoon i.e., May to November about 24 TMC of water by construction of check dams, pumping the water in order to cater the demands of the rain shadow regions. The total cost of the project estimated as 12915 crore Rupees. The following as components of DPR were adapted on *6th November 2013.*

***Phase 1** component comprising of the following:*

- *Construction of 8 diversion weirs across Yettinaholé, Kadumaneholé, Keriholé and Hongadahalla stream.*
- *Diverting water from Weirs 3, 4 and 5 to Delivery Chamber (DC 2) beyond which, a gravity canal is proposed to carry water to the Delivery chamber (DC 3) located beyond Hemavathi River near Doddanagara.*
- *The water from Weir 1 received from the independent catchment of Yettinaholé is pumped and conveyed through a raising main up to DC 3 near Doddanagara.*
- *The water from Weir 2 is proposed to be conveyed to Weir 8 through a raising main and then by gravity. The water from Weirs 6, 7 and 8 will then be conveyed through pumping and independent raising mains up to the Jack well cum Pump house situated near Weir 1.*
- *The two Jack well cum Pump houses near Weir 1 will then be used to pump the water received from Weirs 1, 6, 7 and 8 to DC-3 located near Doddanagara in Sakleshpura Taluk. From DC 3, the water will be pumped and conveyed to De livery chamber (DC-4) located near Haravanahalli in Sakleshpura taluk, the starting point of the gravity canal.*

***Phase 2** component comprises of the following*

- *Construction of Gravity canal for a length of 273Km +865m including an aqueduct of 12.5 Km.to reach the proposed balancing reservoir at Bhairagondlu.*
- *Construction of storage reservoirs identified in the beneficiary taluks.*
- *Construction of balancing reservoir at Bhairagondlu in Koratagere taluk.*
- *Construction of raising main of length 45 Km to convey the water for Kolar, Chickaballapura and Bangalore rural districts.*
- *Construction of feeder canals to supply required quantum of water to the beneficiary areas through dedicated feeder canals / conveyance system.*

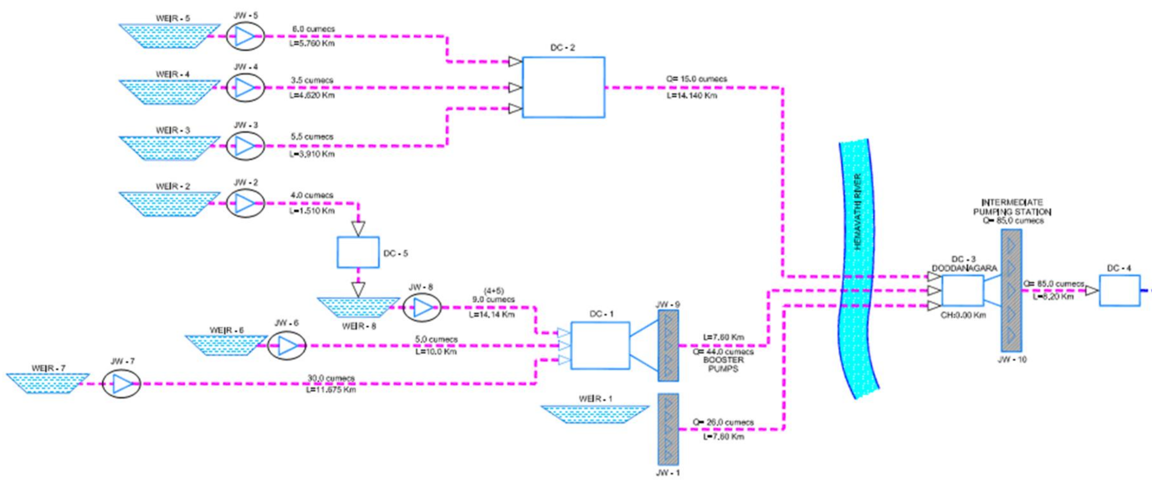


Figure 43: Yettinaholé scheme *(Source: Detailed Project Report)*.

The scheme (given in Figure 43) proposes to install 8 weirs across various streams and locations namely the yettinaholé, hongadahalla, keriholé and kadumaneholé respectively. The water stored at the weirs whose height varies upto 15m from the ground level and further pumped into a common storage area(s) as depicted in Figure 43 and as in table 16. The location of the weirs, their catchments and the distribution chambers under the scheme are as depicted in Figure 34.

Table 16: Proposed Diversion plan

Structure	Discharge cum/s	Distance km	Structure	Structure	Discharge cum/s	Distance km	Structure	Discharge cum/s	Distance km	Structure	Discharge cum/s	Distance km	Structure	Structure
Weir 5	**6**	**5.76**					**DC2**	**15**	**14.14**	**DC3**	**85**	**8.2**	**DC4**	**Gravity Canal**
Weir 4	**3.5**	**4.62**												
Weir 3	**5.5**	**3.91**												
Weir 2	**4**	**1.51**	**DC5**	**Weir 8**	**9**	**14.14**	**DC1**	**44**	**7.6**					
Weir 6	**5**	**10**												
Weir 7	**30**	**11.65**												
Weir 1	**26**	**7.6**												

DC: Distribution chamber

Table 17: Reduced Levels at various weir sites

Structure	W1	W2	W3	W4	W5	W6	W7	W8	DC3	DC4
Reduced Level (m)	802	815	860	755	903	775	733	743	925	965

The water from the catchments stored at various up stream locations of the weirs and the distribution chambers is pumped to a common distribution chamber [DC4] from an RL of 733m AMSL [Weir 7] to 925 m AMLS [DC3], further 85cumec water is pumped to DC4 located at an RL of 965m near Haravanahalli and allowed to flow by gravity canals for about 274 km (table 17, Figure 44).

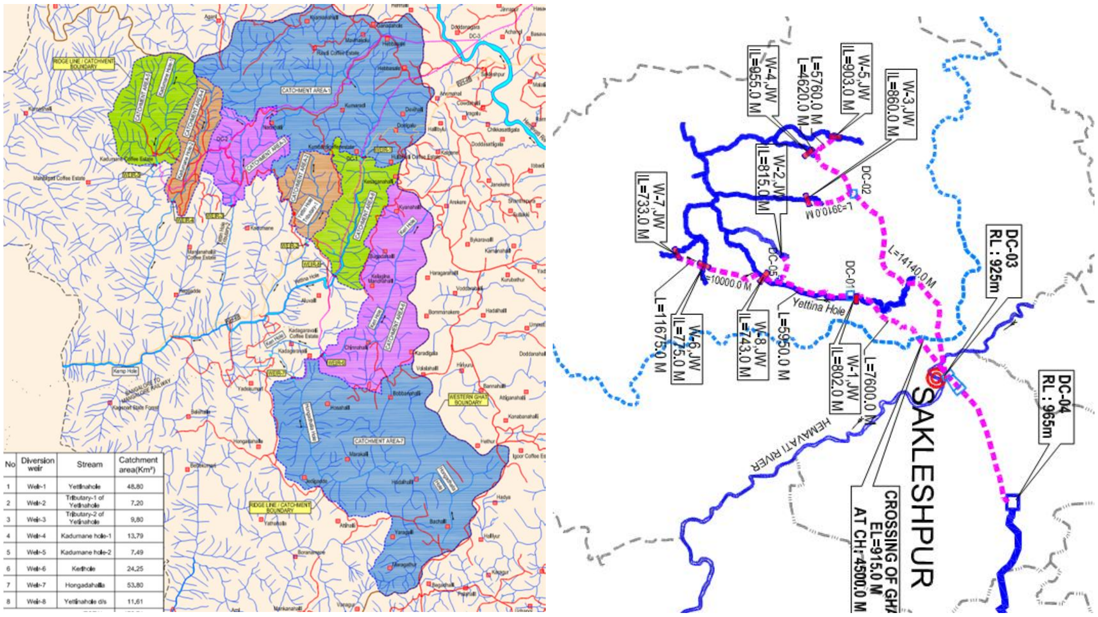


Figure 44: Catchments and Diversion works as per the Detailed Project Report

Private rain gauge stations and Kadumane estate were used in order to quantify the rainfall in the catchment (Pg 103), the catchment receives an average annual rainfall of 6280mm.The runoff yield in the catchment was estimated by taking the proportion of catchment area (since the streams belong to the same catchment) to that of based on the data available at the downstream gauging station maintained by the central water commission (CWC) across Netravati river at Bantwala. Daily flows between 1971 – 2008 between June and November were considered in order to estimate the yield in all the sub catchments of Bantwala (proposed 8 weirs and their catchments) as the diversion of flows after November would affect livelihood of the people downstream.

Weirs were proposed to be constructed across the streams selected to store water up to their banks and divert the water during the peak monsoon months from June to November, The combined quantum of water which can be diverted from the 8 Weirs is estimated to be about 24.01 TMC. On an average weirs are proposed to store water upto 5 Mcft (141 kilo.cum) to

The available 24.01 TMC of water is proposed to be utilized under two components namely drinking water and tank filling in the selected areas

Providing drinking water to:

- *Kolar district comprising of all Taluks*
- *Chickaballapura distrct comprisnig of all Taluks*
- *Tumkur district comprising of areas in Palar and Pennar basins including Chiknayakanahalli*
- *and Sira Taluks along with selected villages in Tiptur and Gubbi Taluks.*
- *Hassan district comprising of villages in Arasikere taluk*
- *Chikamagalore district comprising of selected villages in Kadur taluk*

- *Ramanagara district*
- *Bangalore Rural district comprising of Nelamangala, Doddaballapura, Devanahalli and Hoskote Taluks*
- *Augmenting the water to T.G.Halli reservoir*
- *Augmenting water to Hesaraghatta reservoir*
- *Drinking water supply to Devanahalli Industrial area and surrounding areas*

Providing water for tank filling purposes to fill selected M I Tanks to their 50 % capacity in the M I tanks falling under Palar and Pennar basins and Arasikere taluk

As per the Karnataka Power Corporation, specified yield of 24 TMC cannot be achieved based on monitoring the daily runoff at various places along the Netravathi river basin. As per the Annexure-2 of the DPR, Kadumane holé 1, daily gauged values between 2009 and 2012 were used in order to understand the yield in the catchment, and is listed in table 18 and the rainfall runoff curve is given in Figure 45. Rainfall data is based on the110 year data from the rain gauge stations in and around the catchments obtained from department of statistics.

The runoff yield derived from the hydrological model was compared with the measured runoff (KPC), the derived (estimated) yield in the catchment is 0.702 TMC, whereas the measured was 0.813 TMC.

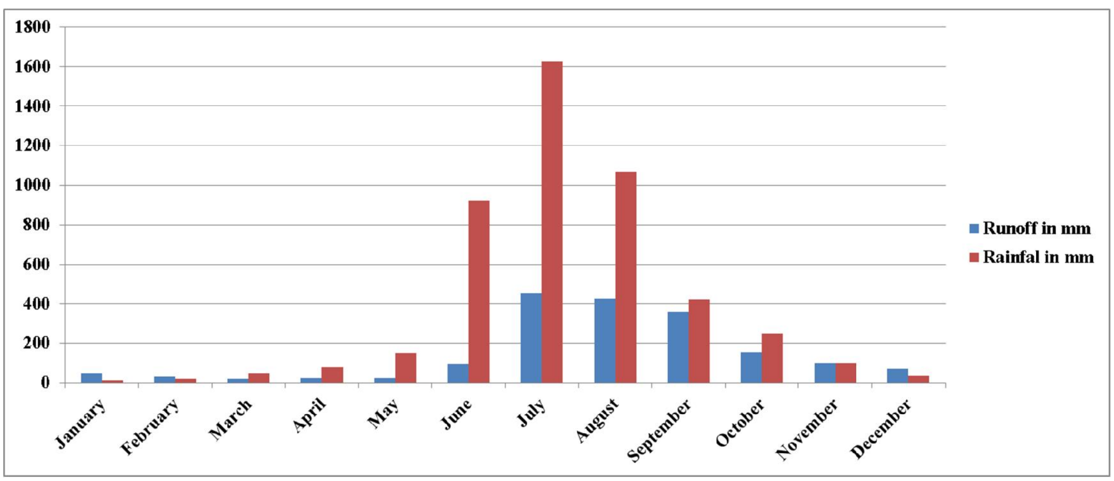
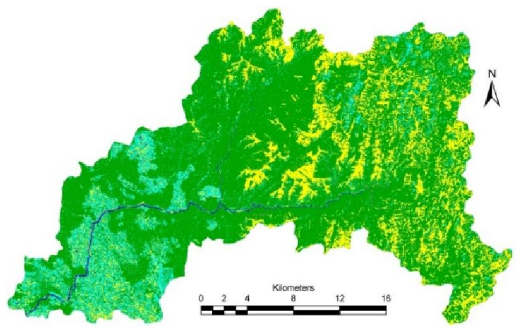
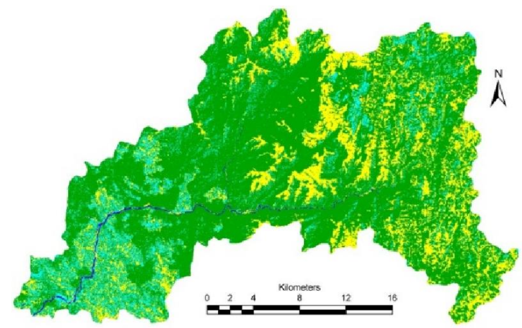


Figure 45: Rainfall Runoff of Kadumane holé 1

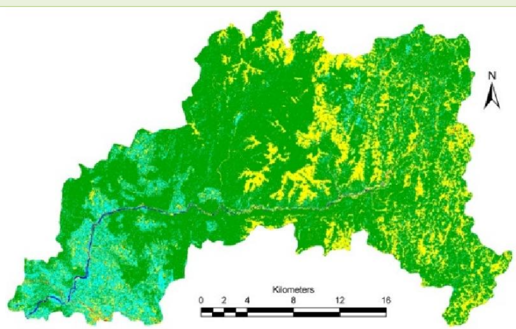
Table 18: Runoff Data KPC (Annexure 2-DPR)

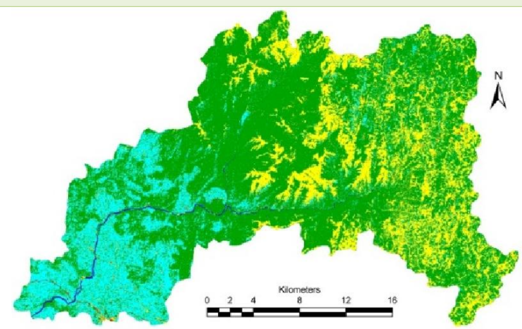
	Runoff in kilo.cum					Runoff in mm	Rainfall in mm
Month	2009	2010	2011	2012	Average		
January	-	647.6	913.7	681.3	780.6	49	13.1
February	-	460.8	639.4	297.3	550.1	30	18.8
March	-	319.3	447.6	190.3	383.4	21	47.6
April	-	494.8	404.3	249.6	449.5	25	76.9
May	-	330.8	252.6	479	291.7	23	151.5
June	-	947.2	2424.9	1022.9	1686.1	95	920.4
July	14500.5	3135.6	5627.2	4654.7	7754.5	453	1625.5
August	4697.1	5564.2	7473.5	8537.1	5911.6	426	1065.7
September	4621.7	4761.3	6975.5	5883.9	5452.8	361	422
October	3080.8	2682.6	1864.3	1859.3	2542.6	154	251.4
November	1255.6	1872.2	1476.2	-	1534.7	100	98.8
December	1109	1383.3	759.9	-	1084.1	70	33.7
Annual Rainfall in TMC : 2.345							
Annual Runoff in TMC : 0.813 (KPC), 0.702 (hydrological analysis)							
Accuracy of the Hydrological Model **86.1%**							





December 2000	January 2006

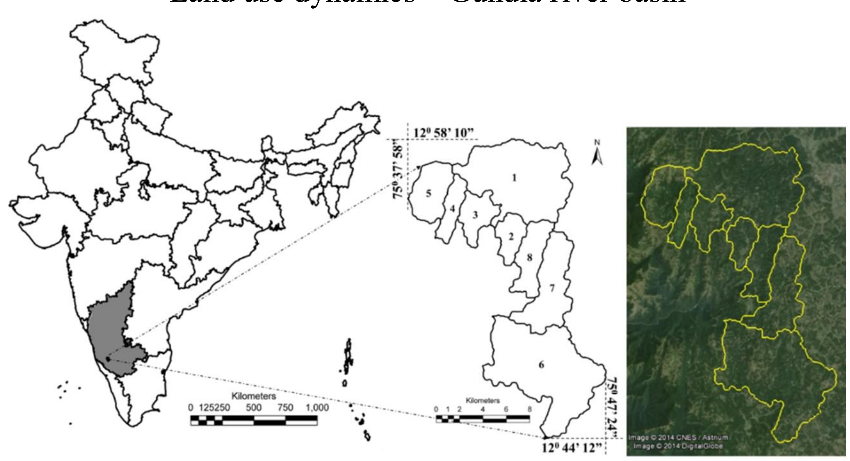




December 2010	December 2014

Water Built up Plantation Forest Others

Land use dynamics – Gundia river basin



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