Environmental Dynamics for Central Dry Zone Area of Myanmar

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Abstract

The main aim of this research work is to create environmental profile in central dry zone area of Myanmar due to harsh climatic conditions. In the study region the adverse effects of climate change are believed to be a major constraint to uncertain ecosystem. Theses extreme climatic events are likely to increase in frequency and magnitude of serious drought periods and extreme floods. For environmental dynamics, we did vulnerability assessment in ArcGIS software by following indicators: discharge change, climate moisture, drained area, flood risk, irrigation, evapotranspiration, precipitation, surface runoff, nitrogen load and population distribution. The analysis provides some interesting methodological insights about the potential of public macro-scale datasets for environmental assessment. Results show that northeast part and Ayeyarwaddy basin of the study area are the most intensive land use and have high population density. Results were further discussed for land cover classes with their elevation information that experience relatively most pressure in terms of examined indicators in the study area. They are also home to important ecosystems and are sensitive to changes in upstream areas. This research work presents a concise and spatially distributed view of the environmental dynamics of central dry zone of Myanmar with Ayeyarwaddy basin. The spatial approach allowed the analysis of different indicators, providing a platform for data integration as well as a visually powerful overview of the study area.

1. Introduction

The Central Dry Zone lies within Myanmar's central plains, which are bounded by mountains to the east and west. Encompassing parts of Mandalay, Magway and Sagaing, it covers more than 75,000 km^2 and represents 13% of the country's land area. The population of the Dry Zone is estimated to be around 10 million people, out of a total national population of 51.4 million (LIFT 2015 and Department of Population 2014), a majority of whom are engaged in agricultural based livelihoods and is characterized by limited rainfall (Figure 1). The Dry Zone is mostly that, with the Ayeyarwaddy River (joined by the Chindwin River), flowing through it from north to south (Figure 1). The Bago Hills range runs parallel to the Ayeyarwaddy River in the southern part of the Dry Zone, gaining altitude towards the north and ending in southeast Mandalay. Fertile alluvial soil is found along the banks of the major rivers, but the Bago Hills are sandstone and have less fertile sandy soil. As its name suggests, the Dry Zone is the driest region of the country, with annual rainfall between 500 and 1,000 mm. The Central Dry Zone faces two main challenges relating to water: reliable supply of safe water for drinking and domestic purposes and access to water to sustainably increase agricultural production, food security and incomes. At a village level in many cases the distinction is not meaningful, as village water supplies (particularly in the form of small dams and wells) are used for multiple purposes and provision of domestic water impacts directly on food production through availability of water for livestock and home gardens. In the context of a semi-arid monsoonal climate, with average annually rainfall generally greater than 600mm and several major rivers, the issue is not absolute scarcity of water, but seasonal, annual and spatial variability. Three main strategies are being used to manage variability: rainwater harvesting and storage in small multi-purpose reservoirs, accessing groundwater through dug wells and tube wells for domestic and livestock uses and increasingly for supplemental irrigation and formal irrigation schemes. In Myanmar, 44 percent of households had problems meeting food needs (FAO, 2014) despite being part of a major agricultural region (JICA, 2010). According to JICA (2010), 58% of those living in the region are farmers and 25% are farm laborers. Similarly, other studies (World Bank, 2014) also indicate that farming and casual labor in the agriculture sector are the two key livelihood activities in the Dry Zone (Haggblade et al. 2013).

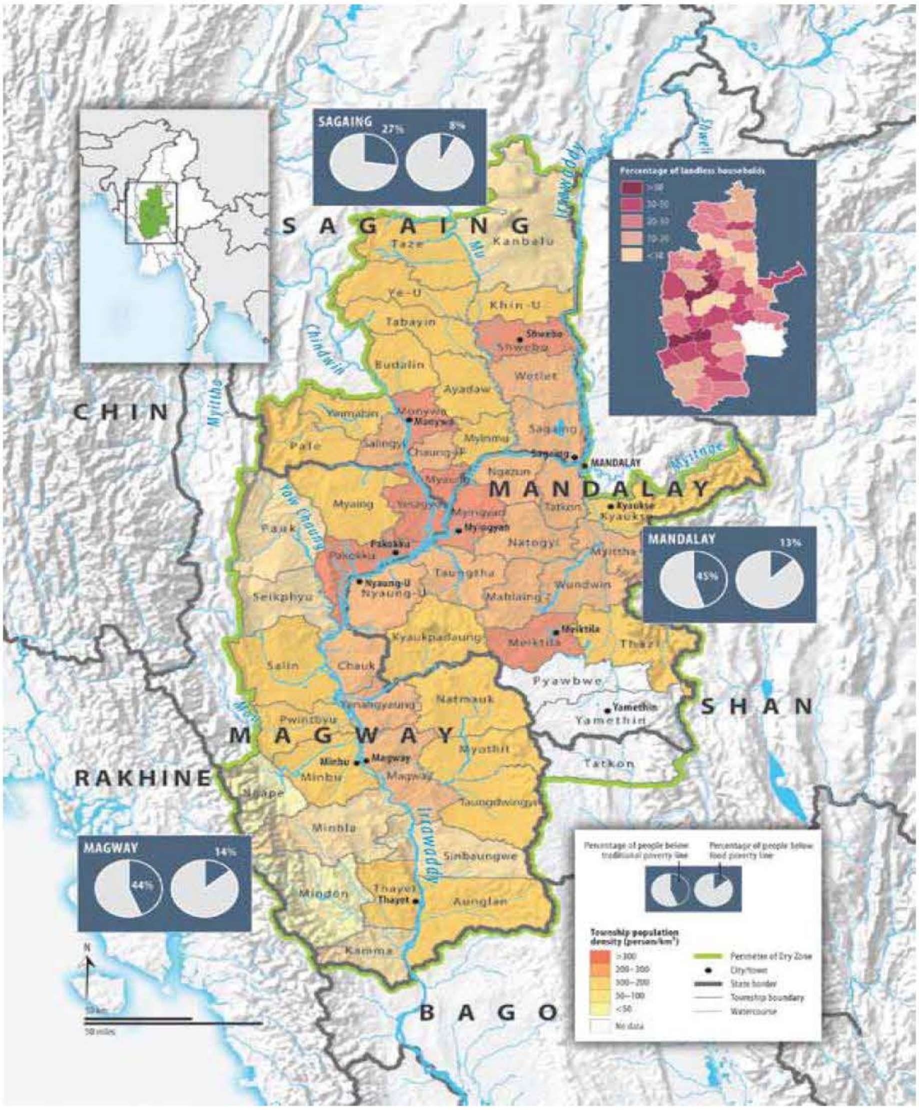


Figure 1: The demographics of Myanmar's dry zone, showing the population density of townships and distribution of landless households. *(Source: Boundary/townships as defined by the Myanmar Information Management Unit [MIMU] [Map Id.: MIMU983V01], March 2013 [www.themimu.info/]; Statistics on population density, poverty and landless households from JICA 2010)*

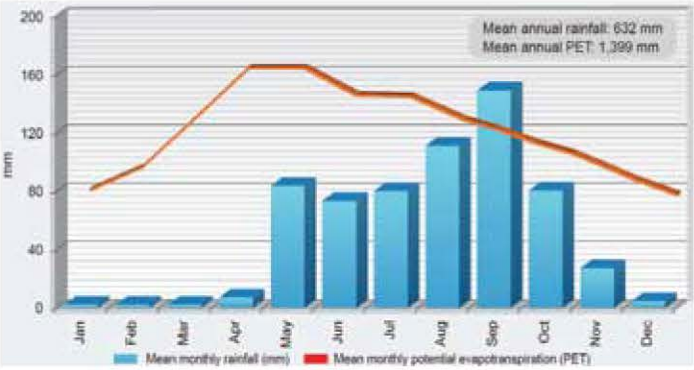


Figure 2: Mean monthly rainfall and potential evapotranspiration (PET) at Pakokku, close to the center of Myanmar`s Dry Zone (Source: FAO LocClim: Local Climate Estimator [http://www.fao.org/nr/climpag/pub/en0201_en.asp])

The vulnerabilities of many farming communities are increasingly complex as Myanmar undergoes unprecedented political, social and environmental changes, making the design of impactful development interventions challenge.

2. Climate Features

Mean annual rainfall in the Dry Zone ranges from 500 to 1,000 mm. This is low compared to the 2,000-5,000 mm range received by the rest of the country (Figure 2). Temperatures commonly reach 40 °C in the dry season. The water collected for use in villages (excluding irrigation), about 15-20% was allocated for drinking purposes, about 50% for other domestic uses and 30-40% for livestock watering. The Dry Zone is the only truly semi-arid area of Southeast Asia; annually rates of evaporation are more than double those of rainfall. The wet season, coinciding with the southwest monsoon, lasts from May to October. The dry season is divided into winter (between November and February) and summer (from March to April).

2.1 Cyclones

The adverse effects of climate change on agriculture in the Ayeyarwady Delta and Costal Regions are higher temperature, changing rainfall pattern and subsequent flow regime and sea-level rise (Rao et al., 2013). Before 2000, cyclones made landfall (i.e. the center of the storm moved across the coast) along Myanmar's coast once every three years. Since the turn of the century, cyclones have made landfall along Myanmar's coastline every year. From 1887 to 2005, 1,248 tropical storms formed at the Bay of Bengal. Eighty of these storms (6.4% of the total) reached Myanmar's coastline. Recent strong cyclones include Cyclone Mala (2006), Nargis (2008) and Giri (2010).

The Ayeyarwady Delta and the eastern part of Yangon were most affected experiencing wind speeds of more than 250 km/h. The cyclone was so detrimental causing these outcomes: i) extensive damage to mangroves, agricultural land, houses and utility infrastructure; ii) salt-water intrusion into agricultural lands and freshwater sources causing economic, social and environmental damage; iii) loss of livelihoods and homes affecting about 3.2 million people and mortality of 138,373; and iv) damage of USD 4.1 billion. Collectively, the four main regions that were affected by Cyclone Nargis account for approximately 4 million hectares of rice which translates to 57% of the country's total production. As an aftermath of intense rains, excessive sedimentation of paddy fields in the Rakhine State in June 2010 occurred. During cyclone Nargis in the year 2008, which was the most devastating cyclone to strike Asia since 1991, the Ayeyarwady River delta region was flooded by a 3.5m wall of water (Thomson Reuters, 2009). Wind speed was in excess of 65ms^{-1} (Webster, 2008). More than 130 000 people died and 2.4 million people were severely affected (van Driel and Nauta, 2013; Thomson Reuters, 2009). Nargis caused severe harm to the winter rice crop and loss of rice seed, and Myanmar faced food shortages after the event (Webster, 2008). Seawater inundated large areas of the Ayeyarwady delta, posing challenges to future rice production (Webster, 2008).

2.2 Scarce Rainfall and Droughts

Normally, annual rainfall is 29.5 inches and rainy days range from 62–41 days per year (1967-1978) and 21% of the Dry Zone townships (54 townships) were affected by drought every year (Saw Myint Tin, 1990). Likewise, the probability of drought occurring in any given township is once every five years (Kyi, 2012). According to the characteristics of identified droughts using rainfall series, the Worst drought that hit the area was during 1979 and 1980 (Kahil et al., 2015). The second Worst drought that hit lower Sagaing and Mandalay took place during 1982 and 1983. The third Worst drought that hit the whole area of Dry Zone was during 1993 and 1994 (UNCSD, 1999). Except for the interval between the second and third worst droughts of some 10 years, recurrence of droughts in the Dry Zone region seems to be showing up at shorter intervals of approximately three years (Hein, 2012).

The most significant drought occurred in 2010, the most severe in several decades. Extreme temperature also rose to 47.2 °C at the Myinmu station in the Dry Zone area on 14 May 2010. The temperature was higher during that year than in previous years and rainfall came in late, causing severe shortage of water in many parts of the region. Most of the wells dried up due to the depletion of underground water supply due to the late onset of the monsoon, and causing the scarcity of drinking water. A lot of crop failures also occurred due to this drought that year (Yi, 2011). Droughts mostly occur in the early monsoon period causing a shortage of soil moisture adversely affecting crop productivity. In the Central Dry Zone area, drought years have significantly affected the production of crops, leading to food shortages for both people and livestock (DMH, 2015). Drought years with moderate intensity were frequent in the 1980s and the 1990s. Extended dry seasons and warming temperatures have increased the prevalence of droughts. Severe droughts have increased in frequency from 1990 to 2002. In 2010, severe drought depleted village water sources across the country and destroyed agricultural yields of peas, sugar cane, tomato and rice. Drought prone rain fed lowland in Myanmar was 7% of total monsoon rice area in the country in 2003. This increased to 16% of total monsoon rice area in 2009 (World Bank, 2014).

2.3 Heavy Rains and Floods

Although the region has long experienced drought, unusual changes have been occurring of late. On 22 October 2010, Cyclone Giri damaged the eastern Rakhine coast, which also affected and hit to some extent the Dry zone. Moreover, on 20 October 2011, Tropical Storm Two, which caused landslides near the Myanmar-Bangladesh border on 19 October, resulted in heavy rains (up to 100-150 mm per day) and subsequently triggered flash floods in Magway, Mandalay and Sagaing Regions of Myanmar. The Magway Region was the worst affected by the floods.

Frequent cyclones result in heavy rains which, sometimes, trigger subsequent flash floods. The torrential rain of a tropical storm on 20 October 2011 triggered heavy flooding in Dry Zone that caused massive losses in the agriculture sector and other sectors and killed many people. Eleven days after the storm, 161 were reported dead or missing and 2,657 households were left homeless. Among the seven townships, including Pakokku, four were worst-affected by the disaster with more than 26,000 people homeless and total damages amounting to approximately USD 271,000. In terms of rice production losses from July to October in 2011, heavy rains and flooding in Bago, which is part of Central Myanmar and Mon, Ayeyarwady, Rakhine Regions/States resulted in losses of about 1.7 million tons of rice (Hein, 2012). In July 2013, severe floods in Ottwin Township, lower part of Centeral Myanmar, caused numerous losses in rice production.

Floods can represent a basic asset for people's well-being, income and cultures but also a drawback for societal and economic development. Myanmar is regularly affected by severe floods comprising river floods, flash floods, pluvial floods and coastal floods. Catastrophic flash floods associated with high rainfall occurred in the central dry zone, e.g. in the year 2011 (Rao et al., 2013). Just recently, the western part of the country was affected by very heavy monsoon rains in August 2015. Particularly, the Ayeyarwady delta zone and the central dry zone are extremely vulnerable to impacts from floods due to associated crop loss and the relatively dense population. In hilly and mountainous rural areas, heavy rainfalls often trigger disastrous landslides, with severe consequences for the Burmese people, who normally live in small wooden huts. The flood risk of Myanmar is assessed as very high due to high vulnerability and low capacity to cope with floods. For the future, the frequency of 100-year floods in Myanmar is likely to increase (Haggblade et al., 2013). In recent years, however, flooding events have been more frequent as indicated by the following:

1. Heavy rains which caused severe flooding in Myanmar's Kayin and Mon States, as well as the Thanintharyi Region in late July and early August 2013.Sittwe, Pauktaw and Myebon areas were rendered vulnerable due to tidal surges in 2013.
2. Flooding by the Sittoung River in the Taungoo District, Bago Region for 6 days and 10 hours in 28 October to 4 November 2013, exceeding 113 cm above its dangerous level. This flood peak was the second highest water level since 1966.
3. Flooding in Pathein in the Ayeyarwady Delta in southern Myanmar which submerged villages and rice fields on August 27, 2012.
4. Heavy rains and flooding in the Ayeyarwady and Rakhine Regions/States from July to October in 2011.
5. Cyclone Nargis hit the coast in May 2008 and was the most devastating cyclone that Myanmar has ever experienced.

3. Data and Methods

This above vast amount of data does not, however, automatically turn into information that would be useful for planning and management for environmental profile. Instead, the available data needs to be further compiled and integrated at relevant levels. As data sources vary in quality, in extent as well as in temporal and spatial scales, such a compilation and integration process is not a straightforward task. The diversity of spatial data analysis concepts has resulted in a variety of approaches (Moench and Dixit, 2007) with divergent views on which issues and indicators to include, how to interpret their impact, as well as how to integrate the information and consider the dynamic nature of natural systems. On a macro scale, assessments have been conducted considering critical drivers such as population growth, changes in water and land resources and climate change (Revenga et al., 1998). This article contributes to the on-going discussion about spatial environmental assessments and their communication. We consider data indicators and methods used in such assessments, with a specific focus on the use and integration of macro-scale spatial data sets in creating environmental dynamics (Boori et al., 2016a). In this research work we use satellite data and secondary data (Table 1), which is related to sensitivity of ecosystem. Table 1 shows all indicators with their sources, preparations and their role. Figure 3 represent spatial distribution of input data. We use land use/cover map as base map for all indicators to identify their influence in the study area for a specific land cover class. Then we combined it with slope map. Slope map was generated from digital elevation map.

In the study area maximum height is 1850m and minimum is 13m. Slope map was classified into 5 classes: low slop 0-4%, then 4-12, 12-24, 24-40 and in last high slope is above 40% (Figure 4). In combined map of slope and land use, major forest and upland farm is present above 24% slope area. Bare land and water classes are present on low land till 4% slope. Major settlements were present in between 12 to 24% slope. In this research work ArcGIS software was used for all spatial analysis.

Table 1: Indicators used to create environmental profiles, with their sources, preparations and role

S. No.	Indicators	Source and background information	Data Preparations	Role in sensitivity
1.	Change in discharge due to deforestation	GWSP Digital Water Atlas (http://atlas.gwsp.org/index.php); 0.5 degree, Preindustrial land cover compared to water flow modeled with current land cover	Shapefile was converted into raster file with 30*30 m cell size by mean value	This indicator determines where the change of both land use and river discharge have been the greatest
2.	Climate moisture index	GWSP Digital Water Atlas (http://atlas.gwsp.org/index.php); 0.5 degree,	Shapefile was converted into raster file with 30*30 m cell size by mean value	This indicator determines moisture in the study area
3.	Drained agriculture area	GWSP Digital Water Atlas (http://atlas.gwsp.org/index.php); 0.5 degree,	Shapefile was converted into raster file with 30*30 m cell size by mean value	This indicator determines drained agriculture area in the study area
4.	Flood risk distribution	GWSP Digital Water Atlas (http://atlas.gwsp.org/index.php); 0.5 degree,	Shapefile was converted into raster file with 30*30 m cell size by mean value	This indicator determines flood risk situation in different part of the study area
5.	Irrigated area	GWSP Digital Water Atlas (http://atlas.gwsp.org/index.php); 0.5 degree,	Shapefile was converted into raster file with 30*30 m cell size by mean value	This indicator show irrigated area in the study area
6.	Mean annual evapotranspiration	GWSP Digital Water Atlas (http://atlas.gwsp.org/index.php); 0.5 degree,	Shapefile was converted into raster file with 30*30 m cell size by mean value	This indicator show dryness in the study area
7.	Mean annual precipitation	GWSP Digital Water Atlas (http://atlas.gwsp.org/index.php); 0.5 degree,	Shapefile was converted into raster file with 30*30 m cell size by mean value	This indicator determines precipitation in the study area
8.	Mean annual surface runoff	GWSP Digital Water Atlas (http://atlas.gwsp.org/index.php); 0.5 degree,	Shapefile was converted into raster file with 30*30 m cell size by mean value	This indicator show rain condition or surface runoff in the study area
9.	Nitrogen load	GWSP Digital Water Atlas (http://atlas.gwsp.org/index.php); 0.5 degree, loading (kgN/km2/yr), based on mass balance model utilizing constituent delivery coefficients	Shapefile was converted into raster file with 30*30 m cell size by mean value	The nitrogen load represents potential for water pollution, as it is based on land use intensity considering nitrogen load from contributors (livestock, fertilizer, atmospheric deposition, human loading) to the land
10.	Population distribution	LANDSCAN (https://www.ornl.gov); 1 km*1 km, dataset includes population counts representing an ambient population distribution. The LandScan algorithm uses spatial data and imagery analysis technologies and a multivariable dasymetric modelling approach to disaggregate census counts within an administrative boundary	Population density per sub-area was calculated. Calculation was exceptionally conducted with WGS1984 projection to avoid errors from reprojection	Areas with high population density might experience pressures in terms of water quality and changes in hydrology and climate. Population density gives also an indication for anthropogenic phosphorus load
11.	Land use/cover	Landsat (https://www.usgs.gov/) 30m resoluation	Raster file interpreted by supervised classification	LULC map show different land cover classes

Firstly, all primary and secondary data were projected as WGS 1984 UTM projection. As slope was calculated from DEM with 90m resolution and the resulted raster was converted into shapefile so that slope can be zonal with land use map. Then we use Zonal Statistics tool to calculate each indicators area (Table 2).

3.1 Standardized the Indicators

It is important to note that each designated indicator system is inevitably subjective (Figure 3). It presents only one possible result of vulnerability assessment. Therefore, it is more meaningful to use these indicators to compare relative values across study area as well as longitudinal comparison within the same area, rather than trying to make sense of the absolute values of indices.

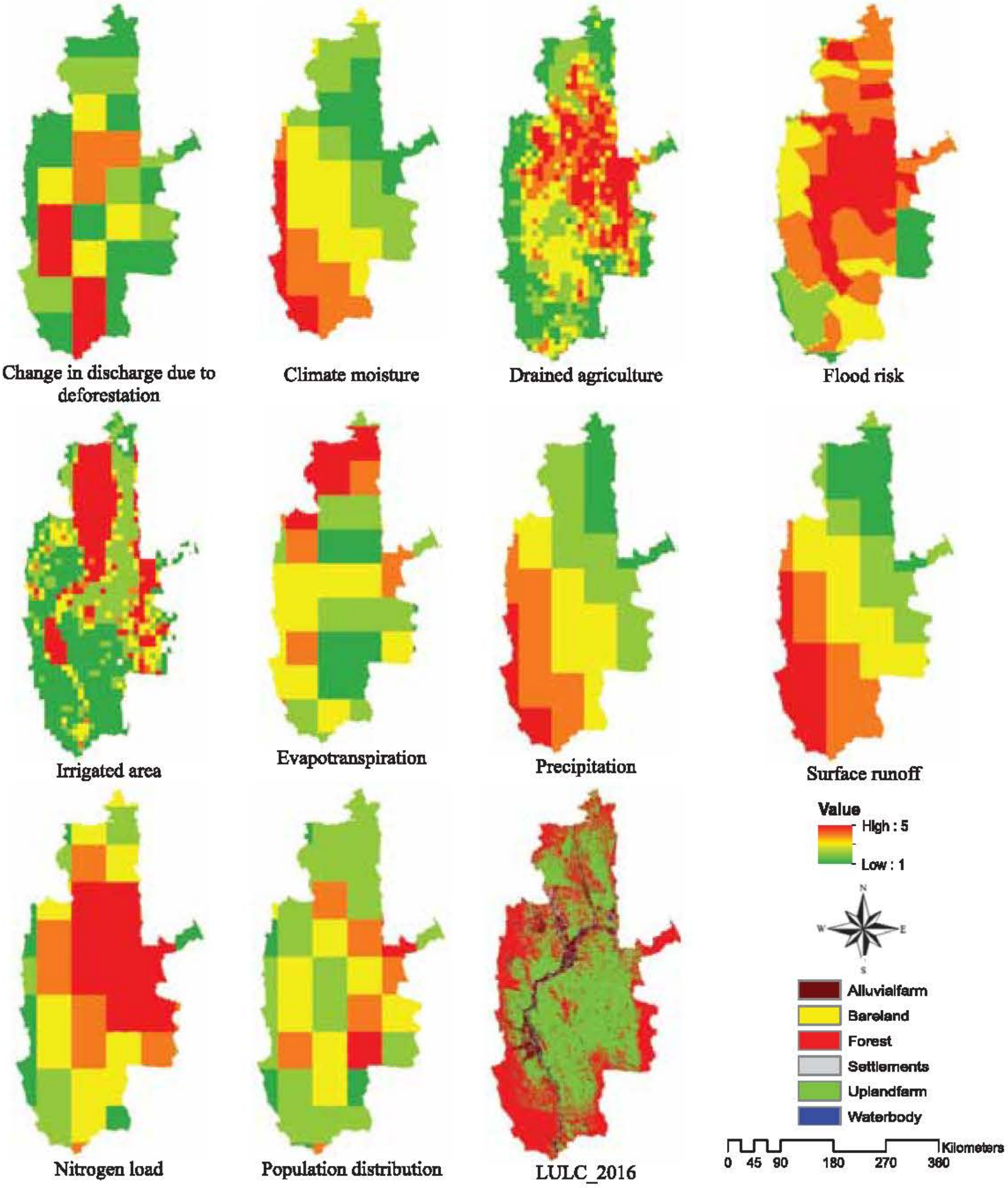
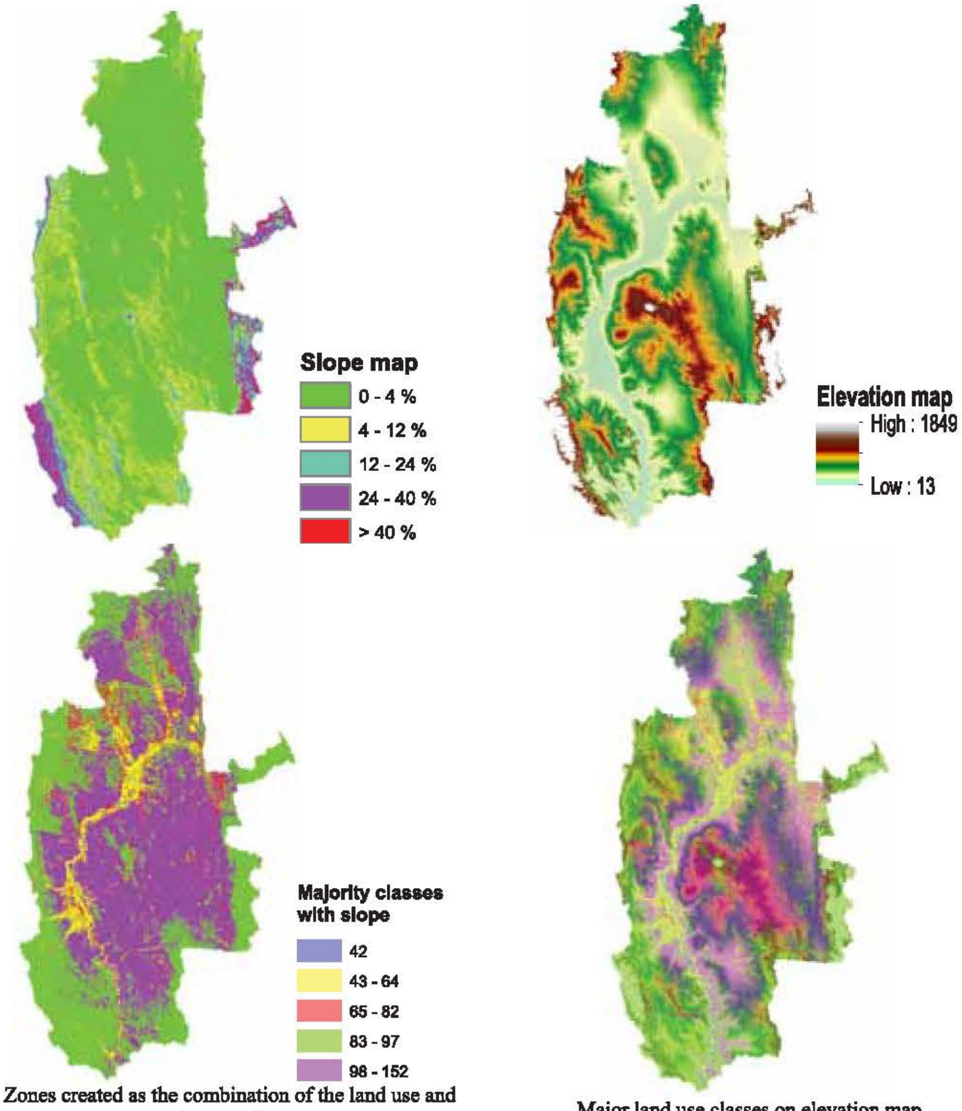


Figure 3: Spatial distribution of indicator data sets. 1) Change in discharge due to deforestation, 2) Climate moisture index, 3) Drained agriculture area, 4) Flood risk distribution, 5) Irrigated area, 6) Mean annual evapotranspiration, 7) Mean annual precipitation, 8) Nitrogen load, 9) Population distribution, 10) Land use/cover. Description and sources of the data sets are presented in Table 1

Table 2: Presents major land cover class on slope map

Class	Majority of Class	Area	Percent	Slop
Bareland/Water	42	23.60	0.15	0-4%
Alluvialfarm	43-64	1190.47	7.51	4-12%
Settlements	65-82	892.93	5.63	12-24%
Forest	83-97	6873.28	43.36	24-40%
Uplandfarm	98-152	6871.38	43.35	>40%



Zones created as the combination of the land use and slope gradient

Major land use classes on elevation map

Figure 4: 1) Slope map; 2) Elevation map; 3) Combined map of slope and land use; 4) Elevation map, overlapped by land use map

In view of different dimensions and magnitudes of the indicators, a standardization of the initial value is required. For indicators associated with the target index, make

$$y_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \; (i\varepsilon[1,m], j\varepsilon[1,n])$$

Equation 1

Where y_{ij} is the standardized value of indicator; x_{ij} is the initial value of indicator; i is the serial number of the study area, j is the serial number of the indicator; m is the number of study areas, n is the number of indicators (Figure 3). The higher value of indicator shows high pressure or vulnerability.

3.2 Principal Component Analysis (PCA)

PCA provides a useful tool for its ability to highlight the spatial arrangement of different aspects of combined stress factors (Abson et al., 2012). In this research work we used PCA to group all indicators and compress information in few bands. The main strength of PCA is its ability to address the cross-correlation of indicators by replacing the original correlated indicators with fewer uncorrelated components (referred to as principal components, PCs) that are produced as the linear combinations of the original indicators (Boori et al., 2016b). The PCs can then be combined as a composite index by summing up the PCs that are weighted according to their contribution ratios. Contribution ratios are calculated by dividing the proportion of variance PC with the total variance accounted. The composite index is used to indicate areas with the most pressure occurrence considering cumulatively all PCs. The indicators with greatest variation as well as the PCs with most contribution to variation coverage influence in the composite index (Boori et al., 2016c).

The PCA process reduces the dimensionality of the input data, while retaining maximum of the variation that is important for sustaining the heterogeneity and representativeness of the data (Jolliffe, 2002). Further, with PCA we can obtain a more detailed understanding about the profiles as we can examine individual PCs by looking at which of the original indicators dominate each of the PCs and how they are distributed within the study area. As the sub-area division takes into account the natural spatial correlation of indicators, the results from PCA can lead to new insights based on the correlation of the indicators in these sub areas. The loading of original indicators is used as weight, and for each sub-area, the original values are multiplied by these weights. So the processes of vulnerability evaluation by PCA method should explained as follows: (1) to standardize data; (2) to establish a covariance matrix R of each variable; (3) to compute an eigenvalue λi of matrix R and its corresponding eigenvectors αi; (4) to group αi by linear combination and put out m principal components (Table 3).

4. Results

PCA approach brings certain benefits for the assessment. These includes the possibility to choose the boundaries and the unit of analysis freely and also to change them to make the results applicable across different kinds of areas (e.g., administrational, hydrological or geographical). Yet, this should not only be seen as freedom but also as a potential element bringing biases to assessments (Lebel, 2009). In addition, we see that spatial analysis provides an attractive and potentially very effective platform for the integration of different types of environmental and, if available, also other information. Top 6 principal components explained 97 % of the total variation. The population density, nitrogen load and surface runoff loaded highly, i.e. they are significant indicators in the PCA based composite index (Table 4). In all indicators, by correlation matrices drainage agriculture area is highly correlated with surface runoff and nitrogen load. Flood risk also highly correlated with population distribution. Nitrogen load also highly correlated with surface runoff (Table 4).

Table 3: Results of PCA in the study (Percent and Accumulative Eigenvalues)

PC Layer	**Eigen Value**	**Percent of Eigen Values**	**Accumulative of Eigen Values**
1	3.33151	41.3519	41.3519
2	1.80485	22.4025	63.7544
3	1.03885	12.8946	76.6489
4	0.74639	9.2645	85.9134
5	0.62696	7.7821	93.6955
6	0.50792	6.3045	100.0000

Table 4: PCA results (Correlation Matrix)

Layer	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	1.00	0.04	-0.13	0.16	0.14	-0.09	-0.07	-0.10	-0.11	0.19	0.12
2	0.04	1.00	0.12	0.20	0.28	0.04	-0.21	0.28	0.28	0.22	0.36
3	-0.13	0.12	1.00	-0.46	-0.36	-0.43	-0.08	**0.90**	**0.87**	-0.65	0.29
4	0.16	0.20	-0.46	1.00	0.38	0.33	-0.18	-0.31	-0.32	**0.69**	0.34
5	0.14	0.28	-0.36	0.38	1.00	0.17	-0.03	-0.26	-0.29	0.38	0.28
6	-0.09	0.04	-0.43	0.33	0.17	1.00	0.19	-0.37	-0.42	0.37	0.14
7	-0.07	-0.21	-0.08	-0.18	-0.03	0.19	1.00	-0.15	-0.27	-0.21	-0.30
8	-0.10	0.28	**0.90**	-0.31	-0.26	-0.37	-0.15	1.00	**0.92**	0.47	-0.10
9	-0.11	0.28	**0.87**	-0.32	-0.29	-0.42	-0.27	0.92	1.00	-0.48	-0.08
10	0.19	0.22	-0.65	**0.69**	0.38	0.37	-0.21	-0.47	-0.48	1.00	0.45
11	0.12	0.36	-0.29	0.34	0.28	0.14	-0.30	-0.10	-0.08	0.45	1.00

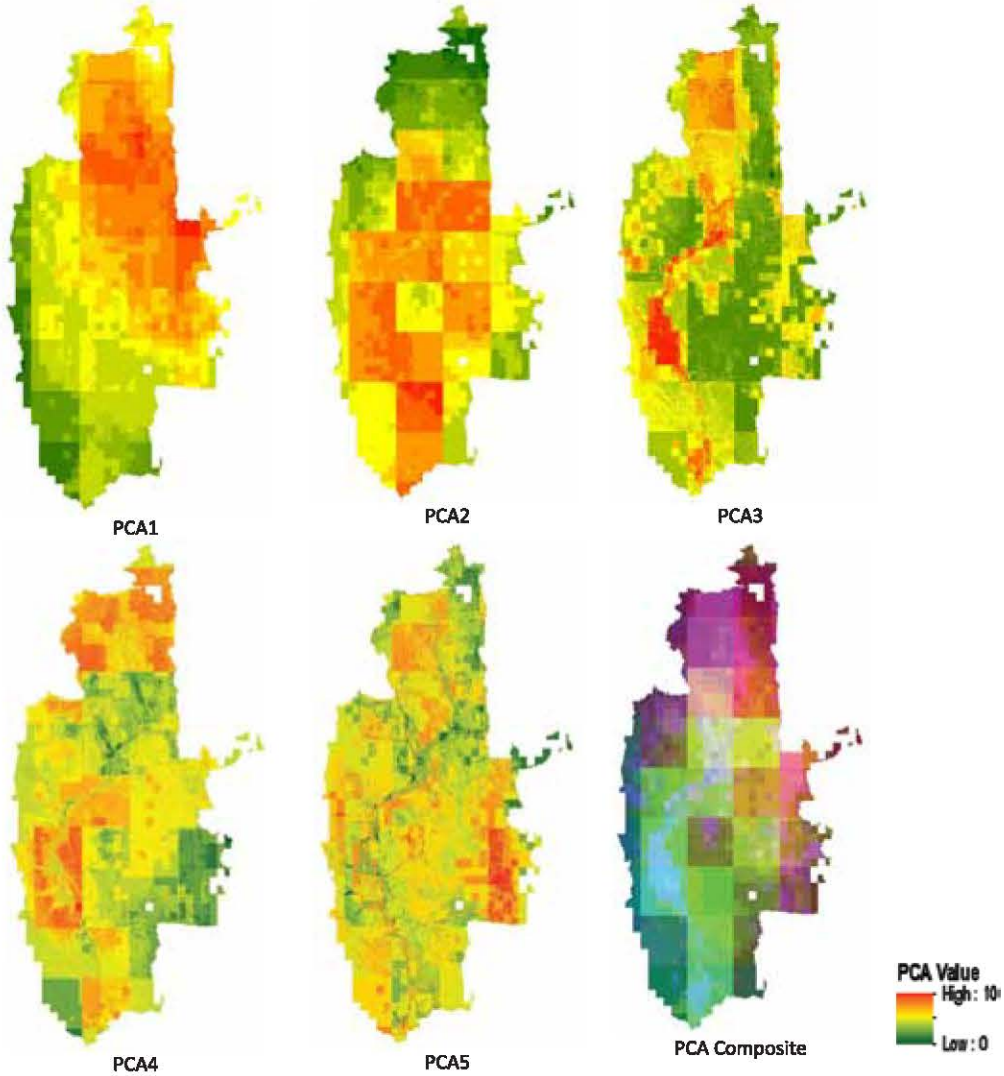


Figure 5: Result maps of PCs and composite index for the central dry zone area of Myanmar

Influence indicators. In PCA 2 expect precipitation all indicators have major contribution and in that intensive land use has maximum influencing indicator. PCA 3 have maximum negative values, means these indicators don`t have any change but surface runoff and nitrogen load have very high value and they change the study area. PCA 4 have irrigated area, evaporation, population distribution and intensive land use is the main cause of change, in which population distribution is highly loaded, it means, it's the highest contributor in the change (Table 4). PCA results show that heaviest environmental pressure is in northeast part of dry zone area as well as Ayeyarwaddy basin area (Figure 5). The main effective indicators are flood risk distribution, irrigated area, population distribution, surface runoff, nitrogen load and intensive land use. Most of the land area is under cultivation while the population density is high as well. These findings are in line with research findings from other large river basins; the deltas of major rivers are found to be at risk and the human impact is commonly among the important factors causing stress on water resources (IPCC 2001 and Vo¨ro¨smarty et al., 2010). Further, different types of freshwater biodiversity (inland wetlands, estuaries, mangrove and marine habitats) are limitedly protected throughout Myanmar and for example in the coastal areas 4 % is protected (Myint Aung, 2007 and Boori et al., 2017).

Our results show that Ayeyarwaddy basin area or lowland area is highly populated and continuously increase, so land is intensely used. Leimgruber et al., (2005) notes that forest cover has been declining with a mean annual rate of 0.3 % between 1990 and 2000 in Myanmar, with central and most populated areas are experiencing the highest rates of decline. The main cause of decreasing forest is increasing population so demands of agriculture conversion, fuel wood consumption, charcoal production and commercial logging and plantation development have been increased. In the study area central low land area is most likely to be exposed to future pressures, such as population growth, urbanization, land use change and climate change (Bates et al., 2008). Potential risks include sea-level rise (in the delta only), changes in the frequency and intensity of cyclones and other climatic extremes such as floods and droughts (Bates et al., 2008). The average population growth rate in the Ayeyarwaddy is estimated to be 0.73–0.89 % between the years 2005 and 2050, depending on the scenario (Gru¨bler et al., 2007). This would increase the population in the Ayeyarwaddy basin from the current 37.2 million to 50–54 million people in the year 2050 (Varis et al., 2012).

Overall, upstream changes including land cover changes but also, e.g., the construction of large-scale water infrastructure are an important part of the downstream vulnerability. The planned hydropower dams, for example, are likely to cause a reduction in sediment yields, which in the case of the Ayeyarwaddy keep the delta expanding to the sea (Hedley et al., 2010). The decrease of sediment yield may have significant impact on the fishing and agriculture in the floodplains as the river brings less nutritious sediment to the aquatic ecosystems and croplands (Kummu et al., 2010 for an example from the Mekong). Blasco and Aizpuru (2002) confirms the vulnerability of delta area to changing sediment balance in the Ayeyarwaddy, for example the mangroves have been in continuous decline.

5. Conclusions

In this research work, we applied a spatial assessment approach for environmental dynamics for central dry zone area of Myanmar. Using a selected set of environment related indicator and PCA approach. Then we find out most and least environmental pressurized area in the study area. As we used publicly available free of cost global datasets, enable us to explore their value for this kind of research work. As results indicate that northeast part and river basin area is the most pressurized area due to population, surface runoff, nitrogen load, irrigation, flood risk and intensive land use. In addition, there are plans for intensive water infrastructure development in the upstream areas of Ayeyarwaddy river basins: such infrastructure would most likely remarkably change both water quality and quantity throughout the river system and possibly lead to land cover changes as well. These findings provide quantitative basis and support for water management issues and institutional analyses in planning and management of the dry zone regions.

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