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Land use and land cover (LULC) change detection using multi-temporal landsat imagery: A case study in Allah Valley Landscape in Southern, Philippines

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Abstract

The widely used application on remote sensing using Landsat imagery is on monitoring changes. With the progressive dynamics of land cover change in the different parts of the world and especially in the Philippines at a fast rate, satellite remote sensing is playing an important role in mapping the spatial distribution and the temporal dynamics of land cover change. Feature extraction and change detection using Landsat imagery are an effective means of collecting information on temporal changes. Monitoring the extent of changes is critical for understanding environmental and socioeconomic impacts. The primary objectives of this study are to detect the temporal dynamics of LULC change in Allah valley landscape through integrating remote sensing and GIS in extracting and analyzing the spatial distribution of land cover changes from the year 1989 to 2002 and 2002 to 2015. Allah valley is more or less 261,000ha of valley landscape located specifically in the Provinces of South Cotabato and Sultan Kudarat in Mindanao and considered as watershed forest reserve under Proclamation No. 2455 by President Ferdinand Marcos. The valley landscape supports the existence of two watersheds namely Allah and Kapingkong Watershed. The detected land cover change in Allah valley using multi-temporal Landsat imagery posed a serious trend, by which forest resources are decreasing that is driven by the continuously increasing need for agricultural land, built-up areas, and industrial plantation expansion.

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Introduction

The availability of different satellite imagery data boosted the application of remote sensing technology. One of the most common and freely available satellite image data for remote sensing is Landsat imagery. The widely used application on remote sensing using Landsat imagery is on monitoring different environmental changes. The basic premise in using remote sensing data for change detection is that the process can identify a change between two or more dates that is uncharacteristic of normal variation (Shalaby and Gad, 2010; Hegazy and Kaloop, 2015). Further, change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times, most satellite images often exhibit a strong contrast between a two or more time scene images (Song *et al.,* 2014; Hegazy and Kaloop, 2015). Landsat provides one of the longest and most consistent satellite records of the land surface with a spatial resolution suitable for monitoring many types of anthropogenic land cover change (Townshend and Justice, 1988).

In recent times the availability of Landsat satellites since 1972 has made available a lot more information such as large volumes of multi-temporal data which can be used for land cover change investigation (Shodimu, 2016). Remote sensing has increasingly been recognized and used effectively as a powerful tool and source of information for characterizing land use and land cover change at local, regional, and global scales (Jing, 201; Doung, 2004; Sader *et al.,* 2001; Pol and Marvine, 1996). Monitoring the extent of changes is critical for understanding environmental and socioeconomic impacts. With the progressive sprawling of different land use and land cover changes in the different parts of the world and especially in the Philippines at a fast rate. Remote sensing using satellite imagery is playing an important role in mapping the spatial distribution and temporal dynamics of such environmental changes happening everywhere (Shodimu, 2016; Torbick *et al.*, 2016).

For the past two decades, the international community became aware of changes happening in the environ-ment. Allah valley landscape in Southern Mindanao, Philippines is one of the key examples of watershed areas around the country having boundless changes in land cover. Allah valley is more or less 261,000 ha of valley landscape located specifically in the Province of South Cotabato and Sultan Kudarat in Mindanao and considered as watershed forest reserve under Proclamation No. 2455 by President Ferdinand Marcos (Proclamation No.2455). Despite the procla-mation for forest reserve in the mountain range of the watershed area, the area did not have complete protection against environmental changes. Weak enforcement of the policy and forestry laws lead to massive deforestation in the area that resulted to land cover changes. Most of these changes were the conversion of forest to grassland that later on leads to the proliferation and expansion of agricultural lands and development settlement areas. Also with the continued increasing success and demand on the global market of highly valued industrial plantation products, added other pressures for land cover change (Pohl, 2012). According to Jing (2014), human activities in many years have become recognized as a major force shaping the biosphere. Further, the land transformation did not abate, but rather accelerated and diversified with the onset of the industrial revolution, the globalization of the world economy, and the expansion of the population and technological capacity.

Therefore, understanding the actions and forces that drive the land cover change is a crucial importance for understanding such changes. A major objective of land use land cover change detection is to better understand the relationships and interactions between humans and its environment in order to manage and use resources in a better way for sustainable development (Lu *et al.*, 2004). This study focuses on the 13 year land cover changes of Allah valley landscape in Southern Mindanao using multi-temporal Landsat imagery of 1989, 2002 and 2015 in order (i) assess the trends of land cover change in whole Allah valley landscape; (ii) identify, quantify and classify the nature, magnitude and direction of land cover changes within the period of the study.

Materials and method

Location of the Study

The study was carried out in Allah valley landscape in Southern, Mindanao. Its exact location is from 6.917054N, 124.464297E to 6.045127N, 124.951139. The whole Allah valley landscape is traversing two provinces in Mindanao, Philippines namely Sultan Kudarat and South Cotabato. Wherein 76% of total area of Allah valley lies in South Cotabato and the remaining 24% part of the valley lies in Sultan Kudarat (Fig. 1). Allah valley landscape is considered as large valley by Roxas-Matulas range in the north and the Daguma mountain range in the south.

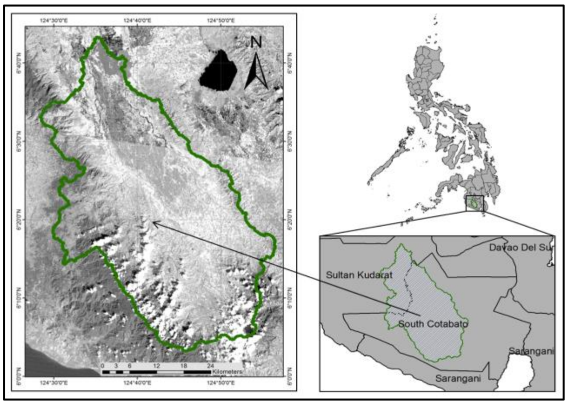


Fig. 1. Geographical Location of Allah Valley in Southern Mindanao, Philippines.

Data Used

The 30 m resolution Landsat 4, 5, 7, and L8 OLI/TIRS was used and selected satellite imageries captured on the year 1989, 2002 and 2015 (Path:112 Row:55; Path: 112 Row: 56 and Path: 113 Row: 56) were acquired from earth explorer site (http://earthexplorer.usgs.gov/). With all the downloaded data timely and clear skies or free clouds is being considered in selecting Landsat satellite data images (Janiola *et al.*, 2015). Secondary data on delineated Allah valley boundary was gathered from CMU-GeoSAFER research project.

Software Used

All downloaded Landsat satellite imageries (L4, L5, L7, L8 OLI/TIRS) were pre-processed, classified and accuracy assessed in ENVI 5.0 Classic. The final classified image was then exported to ArcGIS 10.2.2 for further information extraction and map lay-outing. Microsoft Excel 2010 has been used for some statistical analysis. Also, Google Earth has been used also for visual validation and image reference.

Image pre-processing and classification

Downloaded Landsat satellite images data were undergone radiometric calibration and atmospheric correction using FLAASH in ENVI 5.0 Classic. For Landsat Satellite sensors capture images of Land cover as Digital Number (DN) value rather than Top of Atmosphere (ToA) reflectance, the main purpose is to convert the digital numbers to Top of Atmosphere reflectance units (Haque, 2017). After correction and calibration, resizing was done using the extent of gathered secondary data on delineated Allah valley boundary. Allah valley involves three different satellite image scenes Path:112 Row:55, Path: 112 Row: 56 and Path: 113 Row: 56, completing the whole Allah valley landscape coverage, mosaicking of three scenes for each year was done. After mosaicking, the satellite image for Allah valley for the year 1989, 2002 and 2015, a region of interest (ROI) was then determined and created from each mosaic satellite image for each year defined in the study. Construction of ROI was based on how the authors visually interpret the feature in the image especially on the major feature class present and necessary to be extracted (Table 1.). The process of visually interpreting digital imagery attempts to optimize the complementary abilities of the human mind and the computer (Shalaby and Gad, 2010). The mind is excellent at interpreting spatial attributes on an image and is capable of identifying obscure or subtle features (Lillesand and Kiefer, 1994). With the used of determined ROI, supervised classification using maximum-likelihood was then used for classifying the mosaic satellite image scenes of 1989, 2002 and 2015.

Change Detection Analysis

Land cover and land use change were determined by using the classified images of 1989, 2002 and 2015 and bringing it to ArcGIS 10.2.2 for GIS analysis, information extraction and map lay-outing. In which the classified features produced in ENVI 5.0 was converted to shape-file and inputted in ArcGIS 10.2.2

in which the method of analysis was to determine the extent of alteration from a particular land cover in 1989 and to other land cover category of 2002 and respectively for 2002 and 2015 LULC change.

Statistical Analysis

Accuracy assessment using confusion matrix in ENVI 5.0 software was done in the classified image of Allah valley in order to determine the accuracy of classification done. And graphically showing the extracted information on detected change of LULC on Allah Watershed, Microsoft Excel 2010 was used in graphing the extracted LULC changes from the year 1989 to 2002 and 2002 to 2015.

Results and discussion

Allah Watershed Land Cover Change Detection and Mapping

Supervise maximum-likelihood classification used in this study is the most common method in remote sensing on satellite data image analysis. The maximum-likelihood algorithm is a method based on the probability that a pixel belongs to a particular class (Rawat and Kumar, 2015). In order to effectively understand the 13 years changes of Allah valley from 1989 to 2002 and 2002 to 2015, using the aid of satellite imagery from Landsat and the use of remote sensing technology and with the assistance of GIS, the land cover change was monitored and mapped in Allah valley landscape. The map produce can be a baseline map that can be used by local government and stakeholders on the overall management of Allah valley landscape in Southern Mindanao, Philippines. The produce land cover trend map could be benchmark information on the historical event on land cover change happen in the whole valley landscape area.

Mapping change detection using satellite remote like Landsat proves to be an effective way of understanding spatial and temporal activities happen in the past. Comparing images taken at two different time periods for change detection is classical but provide a useful way of determining land cover/use change (Lillesand and Kiefer, 2008; Chemura, 2012). The maps produced in this study shows the trend of land cover change of 1989, 2002 and 2015. Based on the map produce visually there was a decreased trend in the forest of Allah watershed and increase in grassland, built-up areas, and perennial plantation.

Classification Accuracy Assessment

Running the confusion matrix analysis on each classified image on ENVI it showed that for the year 1989 it had confusion matrix of 81.8338%. For the year 2002 and 2015, it had confusion matrix analysis of 78.0740% and 83.5970% respectively. Among all accuracy assessment results showed that year 2002 had the lowest accuracy analysis and year 2015 had the highest overall accuracy assessment. Base in our classification and as we observe among the class types built-up areas had the most misclassified features. Objects such as buildings and roads were difficult to identify in low and medium spatial resolution (Bouzekri *et al.*, 2015). With the misclassification of built-up, it drags the overall accuracy to decrease, that's why we had just an average accuracy for our classification and low accuracy for the classified image of the year 2002.

Quantifying Land Cover Present

By quantifying the land cover present in each year (1989, 2002 and 2015) the classified feature were converted from raster to shapefile and brought to ArcMap 10.2.2 for spatial analysis through GIS techniques by extracting the area for each classified feature and computing the area in a hectare. Fig. 4 shows the extracted features from each year together with their corresponding area present on a specific year (1989, 2002, 2015). For the year 1989 of Allah valley landscapes forest had still the highest area of about 90,594.1 ha then followed by agriculture with 71,129.1 ha and the remaining class features were grassland (19,633.4ha), perennial plantation (7,523.25ha), built-up (5,064.9 ha), water (4,241.8 ha) and lastly bare land (1,423.2ha). Then after thirteen years by year 2002 agricultural lands dominates the area of Allah valley landscapes of about 81,751.1ha then followed by forest of 77,704.1ha while other feature still in the same order with grassland (20,584ha), perennial plantation (7,169.32ha), built-up (7,017.18ha), water (4,222.88ha) and lastly bare land (1,161.14ha).

And for the final year of the study by 2015 forest had the highest area of 61,745ha and followed by agricultural land with 60,140.3ha, then remaining class features were as follow grassland (37,797.8ha), perennial plantation (21,622.4ha), built-up (13,061.66ha), water (4,232.75ha) and bare land (1,009.909 ha).

In this case, using GIS as another strategy is a helpful one for the exploratory system in recognizing regions that have changed by comparing the values of each year. With the combination of remote sensing (RS) and geographical information system (GIS) made the study of remotely sensed data at ease and especially on having good quality information for land cover change detection. Land use/cover change detection is essential for better understanding of landscape dynamic during a known period of time (Rawat and Kumar, 2015). Looking on extracted information of land cover present and their corresponding area each year, in the 1989 land cover of Allah valley landscape, the forest had still the highest area then followed by agricultural lands. Seeing the overall results of extracted values from each year 1989, 2002 and 2015 there were significant changes in the values of each feature the most obvious was on the forest, agricultural land, grassland, perennial plantation and built-up.

In this study, the feature we use as a reference for understanding the dynamic of cover change in Allah valley landscape was just those classes that had a major impact and visually identified in a coarse resolution. Even behind its widely used application on remote sensing, Landsat data offers only a coarse resolution that makes its application with limitation. Thus in this study conducted on land cover change detection, we limited the classes that can be visually defined given the course 30m resolution of Landsat data use in the study. We limit our class to seven feature that we visually interpret and can describe easily given the satellite image data used (Table 1). The study just focuses on agricultural land, bare land, built-up, forest, grassland, perennial plantation, and water only.

Table 1. Class features characteristics.

Class	Class Features
Agricultural Lands	Lands of agricultural crops and fallow, cultivated for agri. purpose.
Bare Land	Patches in upper mountain areas without canopy vegetal cover.
Built-up	Settlement areas, industrial centers, buildings, and roads.
Forest	Regions in the mountain areas with canopy vegetation cover.
Grassland	Grass-dominated areas.
Perennial Plantation	Stand of industrial agricultural crops (coconut, rubber and etc.).
Water	Water bodies (river and lake).

Land Cover Trend Change

With changing land cover values of each class Fig. 5 presents the extracted spatial information of each year's trend that happens within Allah valley landscape for a span of 13 years from 1989 to 2002 then 2002 to 2015. The trend results show's that among all class features forest class had the most obvious decreasing trend form 1989 to 2015. For grassland, perennial plantation and built-up had increasing trend from 1989 to 2002 and it blows up higher from 2002 to 2015. Then for agricultural land from 1989 to 2002, it shows an increasing trend but between 2002 and 2015 it decreases. Finally, for water and bare land, there's no major changes trend form 1989 to 2015.

The reason for the evident decrease in forest degradation can be related to the increasing trend for built-up area due to increasing population, agricultural areas expansion, accumulation of different industrial plantation and the extending cover areas of grassland that expose the effect and remains of massive logging activity in the forest of Allah valley landscape in the past between 1989 and 2015. These changes in land use were brought about by industrialization and developments that have affected the natural forests. The agricultural sector in the Philippines remains an important sector in the economy that makes agricultural expansion to expand to the upland and watershed areas of the country (Tiongco *et al.,* 2015). Further, agriculture has been among the major drivers of land use and cover change in the Philippines since the 1930s.

The productiveness of agricultural activities in Allah valley landscape shows the richness of Mindanao for cultivation. In terms of noteworthy properties in Mindanao industry, the island has a booming agriculture with rich soil, suitable agro-climatic condition well suited to cultivating many agricultural products (METI, 2017; Dingal, 2005, DAR, 2006). In the trend result for agriculture in this study, it showed that agriculture had been decreased by the year 2002, this could only be explained and supported by the trend that the possibility of land use change from agriculture to the industrial plantation. But despite of decrease in agricultural trend, still the continuing increase in population promote the continuing intensification of agriculture to meet the numerous pressures of food security, sustainable income-generating livelihood, and global competitiveness will just continually pose serious consequences and create an adverse state of the environment (METI, 2015; Tiongco *et al.*, 2015). As one of the country's food basket shows an example of how agriculture and perennial industrial plantation influence the changes in the environment (Dingal, 2007). The disturbance and changes of forest in Allah valley landscape show the practical applications of disturbance mapping using remote sensing and GIS in determining the rate of changes.

Percentage of Land Cover

To further understand the changes, looking at the percentages each feature occupies in 1989, 2002 and 2015 (Fig. 6) had been done. It showed that on the year 1989 forest had 45% cover in the whole Allah watershed area, followed by agricultural land with 36%, grassland 10%, perennial plantation 4%, built-up 2% and for water and bare land had respectively 2% had 1%. In 2002 agriculture had the highest percentage cover about 41% of the total valley landscape areas, followed by forest with 39%, grassland 10%, perennial plantation 4%, built-up 3%, water 2% and bare land 1%. Then by the year, 2015 forest is 1% higher compared to agricultural land about 31%, while agricultural land had become 30%, then grassland 19%, perennial plantation 11%, built-up 7%, water 2% and bare land had below 1% cover that makes it appear 0%.

The extracted information of percentage cover it really showed that during 1989 the whole Allah valley landscape forest vegetation cover still holds the majority percentage during that year base on the generated result of the information. Thirteen years after 1989 on the other year in 2002 agricultural areas holds the majority cover and forest followed second, which showed a significant takeover of agricultural areas. Then another thirteen years followed from 2002 during 2015 agricultural areas was just second to forest areas. Even thou in 2015 forests were the highest among all features, but if we compare if from 1989 the rate of decrease was huge and showed that forest areas in Allah valley landscape had undergone disturbances from forest resources extraction and the brought about effect of food security and economic advancement in the area driven by need for more agricultural land, built area and plantation expansion.

The percentage cover result showed the strong agro-industry (agricultural crop and industrial plantation cultivation) sector within Allah valley landscapes. Especially that the two provinces (Sultan Kudarat and South Cotabato) that encompass the whole Allah valley are known to be agricultural areas wherein rice, corn and even high valued crops like asparagus are grown extensively due to the presence of source for water irrigation and the rich fertile valley soil which prompt extensive agricultural cultivation. The two provinces of Allah valley landscape famously considered to possess the strength of having a suitable environment for agricultural production and known to be as the food basket of Southern Mindanao (RDC XII, 2011). The rich agricultural areas are found in between mountain ranges notably in the Daguma and Roxas-Matulas mountain ranges. The two mountain ranges serve as a buffer against typhoons and strong winds, protecting agricultural products and properties in the Allah valley (DAR, 2006). Further part of the SOCCSKSARGEN region in Mindanao of which South Cotabato and Sultan Kudarat were part, considered as the largest producer of corn, coconuts, copra, pineapples, asparagus and rice in Southern Mindanao.

Also, SOCCSKSARGEN region was among the top leaders in the country in rice and corn production (RDC XII, 2011). With all those mention provisions that enable agricultural prosperity in the Allah watershed, tend to show that agricultural activity in the valley landscape dominates the whole coverage area and would still continue due to the need for food security to support for the continually growing population.

The next seen feature that holds larger coverage and third in ranking from agricultural and forest areas was the grassland area. Extensive areas of grasslands in Mindanao are found particularly in the provinces of South Cotabato, North Cotabato and Bukidnon (Moog, 2006). Some of the grassland areas of Mindanao especially in Allah valley were the remains of massive logging activities in the past. Based on Fig. 1 and 2, in support of the statement of Moog (2006) most of the classified grassland areas in Allah valley landscapes where found in South Cotabato province. Province of South Cotabato holds the majority of the area of the valley landscape. The presence of large tract of grassland only indicates extensive rangeland pastoralism in the area. According to Moog (2006), South Cotabato belongs to the provinces with the highest commercial cattle population in the Philippines. The presence of large track of grassland in Allah valley landscape, therefore, support livestock raising particularly on cattle production in the area.

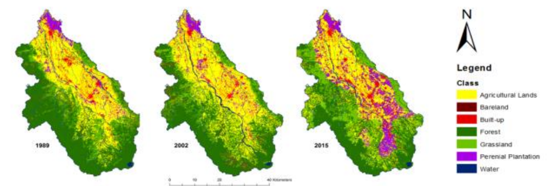
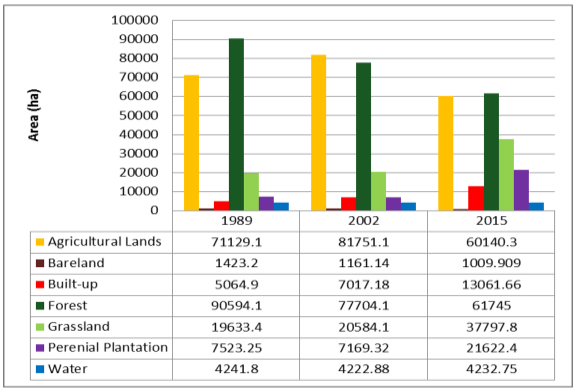


Fig. 2. Allah Valley land-use and land cover change time series.

Fig.3. Image classification accuracy assessment (confusion matrix).

Another feature that had an interesting trend (Fig. 4) was the presence perennial plantations. In this study, perennial plantations were those plantation areas of high-value agricultural crops (banana, coconut, and pineapple) and industrial forest plantation (rubber, oil palm and timber plantation) that were perennial in nature unlike the usual crops such as rice and corn which were short-term crops. In the result of percentage cover perennial plantation from 2002 to 2015 double up its areas planted from 4%, it blew up to 11% in 2015. The trend only shows that the continued increase of perennial plantation from 1989 to 2015 only gives the idea that establishing and planting different perennial plantation in Allah watershed was a renowned boosting sector of the economy in the area. This was for the fact that provinces of Sultan Kudarat and South Cotabato were full of commercial and international processing industries (DOLE, SUMIFRU and etc.).



	1989	2002	2015
Agricultural Lands	71129.1	81751.1	60140.3
Bareland	1423.2	1161.14	1009.909
Built-up	5064.9	7017.18	13061.66
Forest	90594.1	77704.1	61745
Grassland	19633.4	20584.1	37797.8
Perenial Plantation	7523.25	7169.32	21622.4
Water	4241.8	4222.88	4232.75

Fig. 4. Allah valley class feature area information on land use and land cover (LULC).

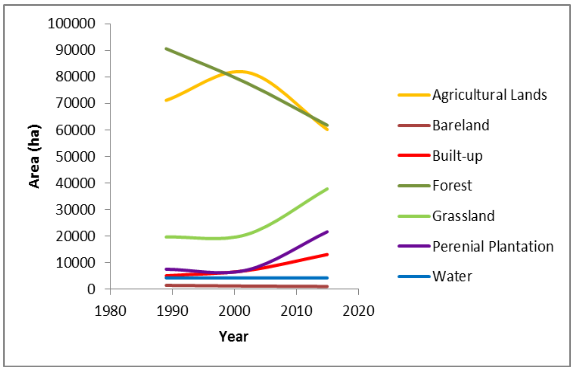


Fig. 5. Allah valley class feature time series trend on land use and land cover (LULC).

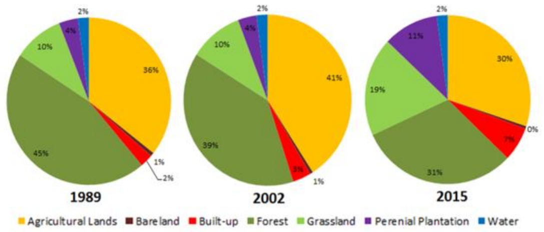


Fig. 6. Allah valley time series land-use and land cover percentages.

Land Cover Change

In reference to the most obvious seen trend among land cover (Table 2), the forest had the most distinct decrease cover change. In which from 1989 to 2002 the forest area of Allah watershed had lost 12,890ha of cover and from 2002 to 2015 and additional cover loss of 15,959.1ha making the total loss of forest cover form 1989 to 2015 summing up of about 28,849.1ha. The decrease in forest can be related to the increase in agricultural land (1989-2002) and grassland area (2002-2015) in which agricultural area had an additional increase of 10,622 ha and grassland had 17,213.7ha increase respectively. But during 2002 to 2015 sudden decrease in the agricultural land can be observed of which this could be related due to the increase in perennial plantation during the year 2002 to 2015 that had blown increases by 14,453.08ha of additional plantation areas.

Another very important driver in the occurrence of land-use and land cover change was the sustained increase of built-up areas in the Allah valley landscape of it can be observed that by 1989 to 2002 increase was just about 1,952.28ha, but during 2002 to 2015 blown up an increase of 6,044.48ha can be observed from built-up areas. Obviously escalated population increase everywhere would also lead to built-up area increase that also increased the demand for timber resources and need of land for cultivation which resultantly led to deforestation and forest degradation in the Allah Valley landscape.

With all the land use and land cover changes happening in Allah valley landscape, it can be observed that changes happen in all parts of the area (Fig. 2). The forested mountain ranges of Allah valley landscape in the western, eastern and southern portion of the area, forest degradation, and depletion can be observed. Forested areas were evidently replaced with grassland and converted to agricultural land. While on the central part, sprawling of built-up areas and expansion of perennial plantation can be observed. With all these extracted information on advancement built-up areas, expansion of agricultural and industrial plantation of the region really brought up dynamic changes in Allah Valley landscape from the year 1989 to 2002 and 2002 to 2015.

Table 2. Allah Valley land-use and land cover changes.

Year	Agricultural Land (ha)		Cover Change Area (ha)	
1989	71,129.1			
		+ 10,622		
2002	81,751.1			- 10,988.8
			- 21,610.8	
2015	60,140.3			
Year	Built-up (ha)		Cover Change Area (ha)	
1989	5,064.9			
		+ 1,952.28		
2002	7,017.18			+ 7,996.76
			+ 6,044.48	
2015	13,061.66			
Year	Forest (ha)		Cover Change Area (ha)	
1989	90,594.1			
		- 12,890		
2002	77,704.1			- 28,849.1
			- 15,959.1	
2015	61,745			
Year	Grassland (ha)		Cover Change Area (ha)	
1989	19,633.4			
		+ 950.7		
2002	20,584.1			+ 18,164.4
			+ 17,213.7	
2015	37,797.8			

Year	Agricultural Land (ha)		Cover Change Area (ha)	
Year	Perennial Plant'n (ha)		Cover Change Area (ha)	
1989	7,523.25			
		- 353.93		
2002	7,169.32			+ 14,099.15
			+ 14,453.08	
2015	21,622.4			
Year	Bareland (ha)		Cover Change Area (ha)	
1989	1,423.2			
		- 262.06		
2002	1,161.14			- 413.291
			- 151.231	
2015	1,009.909			
Year	Water (ha)		Cover Change Area (ha)	
1989	4,241.8	- 18.92		
				- 9.05
2002	4,222.88			
			+ 9.87	
2015	4,232.75			

Conclusion

The land-use and land cover change (LULC) detection in Allah valley landscape of the year 1989, 2002 and 2015 had shown promising important information, despite the coarse data resolution (30m) used (Landsat images) on understanding the past changes of major land classification features that can be found in the valley. This study shows through the use of remote sensing (image classification) and GIS (feature extraction) application done on Allah valley landscape, land use and land cover (LULC) information for the year 1989, 2002 and 2015 had been able to assess the trends and quantify changes of major LULC feature in the study. The nature and magnitude of LULC changes of the year 1989, 2002 and 2015 had been identified, thru the classified images. This study concludes that the use of multi-temporal Landsat images to identify LULC changes produces information that can be used for present LULC management.

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