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# Status Check of the Mining Hub of India: Examining the Land-Use Pattern Observed in the Forest –Agricultural Ecosystem of Dhanbad

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**ABSTRACT**: *This paper focuses on the ecosystem based hotspot identification and the pattern of land use change in Forest-agricultural Ecosystem using the land use dynamic degree model. Geological Information on the agricultural ecosystem is obtained by the remote sensing images for the identification of land change. Ecosystem wherein both the agricultural and forest ecosystem coexist is known as forest-agricultural ecosystem. Area is based on the agricultural activities and the forest ecosystem. Hotspot is selected based on the intersection of anthropogenic activities like mining with the forest and agricultural ecosystem. With this hotspot identification it brings a clear picture of how to look into a new definition of hotspots, which identifies a region or specific area and how each area could be identified as a hotspot. Geographic Information System images were used to analyze the changes in land over specific time period.*

## I.    INTRODUCTION

Population and challenges in the ecosystem hotspot has been of long-standing interest to ecologists. Over the past years the subject has been researched in various ways, like identification of various areas of biodiversity using different methods, measuring the overlap of human poverty and ecosystem hotspots, spatial patterns and economic contributions of mining and tourism in biodiversity hotspots. With an increase in the population in the Indian hotspot region, population and challenges in the region is unclear. Estimates of Myers. et al(2000)  show  that in 1995 more than 1.1 billion people, nearly 20%  of  world  population, were living within the hotspots, an area  covering  about  12% of Earth's terrestrial surface. Population growth rate in the hotspots (1995-2000) is 1.8% yr$^{-1}$, substantially higher than the population growth rate of the world  as  a  whole (1.3% yr$^{-1}$)  and  above  that  of  the  developing  countries (1.6% yr$^{-1}$) . These  results suggest that substantial human-induced environmental changes are likely to continue in the hotspots and that demographic change remains an important factor in global biodiversity conservation. Biodiversity hotspots face tremendous anthropogenic pressure resulting in forest destruction and species extinction. This is mainly because of the rising human population in the hotspot region.

Dhanbad was one of the chief mining districts for the past 30 years. So gradual changes or impacts were only observed in land use change. During the three sub periods of observation high increase in building zone and increase in scrub/ fallow land were observed  because of the newly formed Jharkhand giving opportunities/new project establishments at all levels of infrastructural development. Few multinational coal exploratory organisations were established in Dhanbad after the city became the part of the new state, attracting high revenue at the price of high degradation.

### 1.1 *Objective of the Study*

To identify the ecosystem hotspots in India, those are under greater threat due to both natural and anthropogenic activities using geological information. The change in the ecosystem hotspot is correlated with the change in the land use pattern change using dynamic degree model. Identification of ecosystem hotspots based on the intersection of specific ecosystem and anthropogenic activities are to be done. Anthropogenic activities in an ecosystem have caused extinction of certain flora and fauna, or they are entering into an endangered category. Thus identification of such areas is important for the future conservation/restoration

program. India rich in its flora and fauna and with a characteristic of increasing population is an appropriate site for the study.

## II.     LITERATURE REVIEW

Population and challenges in the ecosystem hotspot has been of long-standing interest to ecologists. Over the past years the subject has been researched in various ways, like identification of various areas of biodiversity using different methods, measuring the overlap of human poverty and ecosystem hotspots, spatial patterns and economic contributions of mining and tourism in biodiversity hotspots. With an increase in the population in the Indian hotspot region, population and challenges in the region is unclear, hence my study stands relevant.

A landmark paper that deals with biodiversity by Myers (2000), entitled "Biodiversity hotspots for conservation priorities" developed a strategy for prioritizing areas of biodiversity by providing a ranking of hotspots in order to assist planners in the face of insufficient funding. The authors focused their analysis on and defined 'hotspots' as areas having "exceptional concentrations of endemic species and experiencing exceptional loss of habitat". They defined 25 original hotspots, but this list was recently expanded to 34 hotspots and has become the major focus of Conservation International's (CI) work. By focusing on these hotspots, the authors estimate it may be possible to protect 44% of all vascular plant species and 35% of 4 major vertebrate groups in only 1.4% of the earth's surface. This was, and continues to be, an important and timely effort due to the growing evidence of human driven ecosystem degradation and species loss (Vitousek, 1997). While it is an excellent endeavour to help prioritize funding for conservation, their paper does not address the fact that the success of conservation initiatives is largely dependent on the socio-economic conditions of the areas where these hotspots occur.

Paper by Cincotta (2000), entitled "Human population in the biodiversity hotspots" estimated of key demographic variables for each hotspot, and for three extensive tropical forest areas that are less immediately threatened. They estimated that in 1995 more than 1.1 billion people, nearly 20% of world population, were living within the hotspots, an area covering about 12% of Earth's terrestrial surface. They estimated that the population growth rate in the hotspots (1995-2000) is 1.8% yr(-1), substantially higher than the population growth rate of the world as a whole (1.3% yr(-1)) and above that of the developing countries (1.6% yr(-1)). These results suggest that substantial human-induced environmental changes are likely to continue in the hotspots and that demographic change remains an important factor in global biodiversity conservation. The results also underline the potential conservation significance of the continuing worldwide declines in human fertility and of policies and programs that influence human migration.

Dynamics and interactions between mining and tourism were discussed by Huang, Zhou, Ali (2011). This paper examined how mining and tourism industry interact in terms of their economic contributions and spatial patterns in a biodiversity hotspot, Yunnan, China. Studies showed nearly one third of active mines and exploration sites are within areas of intact ecosystems or high conservation value (e.g. Miranda, 2003). The negative impacts associated with mining include land degradation, ecosystem disruption, and negative impacts on the local community (i.e. sexually-transmitted diseases) (The World Bank, 2004). The negative impacts of tourism include land degradation, water pollution, waste and noise brought by tourists, and overwhelming pristine cultures by the modern lifestyle (Butter, 1980). Both mining and tourism have been recognized for their positive roles in alleviating poverty by providing jobs and income to local communities. In this paper two questions were put forward, first, do mining and tourism industries reinforce or impede each other in terms of their economic contributions? Second, what is the spatial pattern of the locations of mining and tourism sites? Do they tend to cluster or avoid each other? Answers to these questions provided important insights on how mining and tourism together may impact the economy and environment in biodiversity hotspots.

In their study they selected Yunnan region in China one of the 34 global biodiversity hotspots. Yunnan hosts the "mountains of southwest China" biodiversity hotspot. Mining and tourism in Yunnan have been growing at a rate of 20-30 percent since 1998.  In this paper they used correlation analyses to measure the relationships between mining activities, tourism visits and local gross domestic productions. They also employed a distance based technique to investigate the nature of any dependency between mining and tourism sites.Results showed that mining activities tend to be in relatively fluent areas while tourism tends to occur in less developed areas when measured by economic indicators. The physical locations of mines and tourism sites are clustered. Conflicts between tourism and mining exist when they occur in the same area as tourism income is impacted by mines nearby.

Hotspot analysis involves either the identification or ranking of political and ecological regions on the basis of their biodiversity. A biodiversity hotspot is a region that has an extraordinary amount of diversity. Perhaps the first hotspot analysis was that conducted by Myers (1988, 1990) when he described the immense endemic plant diversity found in several regions of the world. Since then, hotspot analysis has become more quantitative and comprehensive. "Incorporating socioeconomic factors into the analysis of biodiversity

hotspots" paper by J.A. Veech introduces a new method of hotspot analysis that ranks hotspots on the basis of biodiversity and anthropogenic threats to biodiversity.

Methods of study include data compilation, defining threat on a per-species basis: the species load, using multiple regressions for hotspot analysis. Data on the total number and number of endemic non-fish vertebrate species and vascular plant species in each mega diversity country were obtained from Mittermeier, Myers, and Thomsen. (1997). Socioeconomic data for each country were obtained from their 'Data Profiles' on the World Bank website, specifically population size, population growth rate, rural population density, and debt. Prior to conducting the hotspot analysis, the four socioeconomic variables were standardized to the number of species within a hotspot; these standardized variables are referred to as 'species loads'. Using data from all 17 mega diversity countries, a multiple regression was performed of species richness against the inverse of the area of each country and the species load for population size (Lpop), population growth rate (Lpgr), rural population density (Lrpd), and debt (Ldeb).

The primary goal of the study was to test whether threats to biodiversity can be usefully incorporated into a comprehensive hotspot analysis. More specifically, it tested whether the ranking of hotspots was significantly improved by including socioeconomic variables presumed to represent processes (e.g. habitat destruction) that result in the loss of biodiversity. Using the standardized residuals obtained from multiple regression models, the mega diversity countries were ranked on the basis of the threat per species (i.e. species load variables) and the number of species per unit land area; this was the full regression model. This ranking was then compared with a ranking based only on the number of species per unit land area. The ranking obtained from the full regression model differed substantially from that obtained from the area-only model, as evidenced by the low Spearman rank correlation coefficients comparing the two models. It is reassuring that the ranking of hotspots based on either endemic vertebrate or endemic plants species richness are similar to one another and similar to rankings based on total vertebrate and plant species richness. However, perfect agreement (100%) on the very top ranks should not be expected and was not obtained.

Paper by Venevsky and Venevskaia (2005) suggests quantitative measures which enable two criteria of the global biodiversity hotspots to be applied on a national level for 74 large countries, and show how these measures can be applied to map national biodiversity hotspots. The basic concept in identifying biodiversity hotspot is to elaborate and further develop the national protected area system, to satisfy both national and international conservation goals. They showed how national biodiversity hotspots can be mapped from the species–energy relationship for vascular plants using climate, topographical and land use data when spatial pattern of species richness is not known. This methodology to map national biodiversity hotspots from abiotic factors is applied to Russia as a case study. Three Russian biodiversity hotspots, North Caucasus, South Siberia and Far East were identified. The resulting hotspot maps cover national-scale environmental gradients across Russia and although they are also identified by Russian experts their actual geographical locations were hitherto unspecified. The large-scale national hotspots, identified for Russia, can be used for further fine scale and more detailed conservation planning.

Due to the linkages between socio-economic systems and ecological systems, issues such as development, poverty eradication, and biodiversity conservation need to be addressed not as individual phenomena but rather as complex dynamic systems. Paper by Fisher and Christopher (2007) presents present five key socioeconomic poverty indicators (access to water, undernourishment, potential population pressure, number living below poverty line and debt service) and integrate them with an ecologically based hotspots analysis in order to illustrate magnitude of the overlap between biological conservation and poverty.

Method they used for the research are, 34 hotspots were clipped to a map of the world's countries, these files were combined in order to determine which hotspots overlapped with which country and to select all countries with at least 100,000 ha of overlapping hotspots. This resulted in 125 countries for further analysis. They chose critical socio-economic indicators relating to poverty that show interaction between poverty and conservation threats. They used traditional economic metrics of poverty: national debt service and percentage of people living below the national poverty line. They also included a broader range of poverty indicators (undernourishment, access to clean water and potential population pressure) not based solely on Market-identified poverty. Due to their innate connection with life-supporting ecosystems, they mentioned it as ecological poverty indicators.

The main result of the analysis shows which of the globally important ecoregions for biodiversity are faced with deep and multifaceted poverty. It demonstrates the magnitude of this overlap and points to the possibility of a vicious cycle between poverty and biodiversity loss. This analysis does not imply that poverty is the underlying driver of the ecosystem degradation that leads to biodiversity loss. The analysis here suggests that the overlap between severe, multifaceted poverty and key areas of global biodiversity is great and needs to be acknowledged. Understanding the magnitude of overlap and interactions among poverty, conservation and macroeconomic processes is crucial for identifying illusive, yet possible, win–win solutions. European-aggregated model specification results confirmed that rising temperature negatively affected biodiversity

conditions at an accelerating rate across geo-climatic regions in Europe by 2050. They also found a strong relationship between temperature and the value of EGS (Ecosystem Goods and Services), but the direction of this relationship depended on the type of EGS under consideration. For example, this relationship was estimated to be positive for provisioning and regulating services, but negatively related to cultural services. The regional model specification results suggested that the negative impacts of climate change on biodiversity (i.e. CCIBE) could go against the positive direct climate change impact on forest growth and generate a net negative impact on total value of EGS, such as for the provisioning services in the Mediterranean Europe  .Our estimation results confirm the role of biodiversity as a nature-based policy solution for climate change mitigation, shedding light on the policy actions that generate co-benefits by enhancing ecosystems' capacity to mitigate climate change impacts, while conserving biodiversity and sustaining the flows of EGS for human livelihoods. Especially, nature-based mitigation policies are more cost-effective and better at coping with the ethic and inequality issues associated with distributional impacts of the policy actions, compared to the pure technical solutions to improving energy efficiency and reducing emissions. However, the strength of biodiversity as a nature-based policy option for climate change mitigation depends on both the nature of the EGS and the geographical area under consideration.

## III.     METHODOLOGY

The geographical information of forest ecosystem across India for a particular time series is analyzed. Simultaneously, the degradation of this ecosystem is examined by the anthropogenic activities, which has gradually or steeply increased in these zones at the same time period. Based on this intersection of data, the hot spot is selected and investigated. Satellite remote sensing (RS) and geographic information system (GIS) have been widely applied in identifying and analyzing land use/cover change.GIS provides a flexible environment for displaying, storing and analyzing digital data necessary for change detection. Using GIS (Geographical Information System) tool, the land use data of agriculture and forest ecosystem in the years 2000, 2005, 2010 and 2015 were extracted as the basic data of land use/cover change analysis. Land use/cover change is a major factor for global change because of its interactions with climate, ecosystem processes, biogeochemical cycles; biodiversity, and, even more important, human activities (Vogelmann and Howard, 1998; Xiao et al., 2006), research on land use/cover change has become an important aspect of global change. Geographic information system (GIS) has been widely applied in identifying and analyzing land use/cover change.  GIS can provide multi-temporal data that can be used to quantify the type, amount and location of land use change. GIS also provides a flexible environment for displaying, storing and analyzing digital data necessary for change detection (Wu et al., 2006).

### 3.1 Land use dynamic degree model

The land use change was determined using the land use dynamic degree model that included the single land use dynamic degree model and the synthesis land use dynamic degree model. Region differences in the rate of land use change were determined with the single land use dynamic degree that could be mathematically expressed by the following relationship (Li and He, 2002):

$$S_i = (A_i - UA_i)/A_i/(T_2 - T_1) \times 100\% \qquad (1)$$

Where $S_i$ is the rate of the ith type land use change during the monitoring period $T_1$ to $T_2$; $A_i$ is the area of the ith type land use at the beginning, and $UA_i$ is the area of the ith type land use that remains unchanged during this monitoring. Thus, this model represented the time rate of change for one type of land use that was converted into another type of land use relative to the land use situation at the beginning of the monitoring period. Regional difference in land use characteristics was determined using the synthesis land use dynamic degree model as follows (Liu and Buhe, 2000):

$$S = [\sum(\Delta A_{i-j}/ A_i)] \times (1/t) \times 100\% \qquad (2)$$

S is the land use change rate over time t, $A_i$ is the ith type land use area at the beginning of the monitoring period, and $\Delta A_{i-j}$ is the total area of the ith type land use that is converted into the other types of land use. This model was thus defined as the time rate change of land use that converted into the other types of land use and that at the beginning of monitoring period was part of the land use subject to change. This dynamic degree represented, in a comprehensive manner, the change of land use in a given region.

## IV.     DISCUSSION AND RESULTS

Ecosystem wherein both the agricultural and forest ecosystem coexist is known as forest-agricultural ecosystem. Area is based on the agricultural activities and the forest ecosystem. Hotspot is selected based on the intersection of anthropogenic activities like mining with the forest and agricultural ecosystem. Dhanbad is one of the district of Jharkhand state, known as the coal capital of India. Dhanbad is famous for its coal mining and has some of the largest mines in India. Because of the rising coal mines, how it has been affected and what are the future repercussions leads to the identification of Dhanbad as a hotspot. For most of the rural population

agriculture is their employment and primary income generating activity. Thus the intersection served in the identification of hotspot.

Firstly, temporal changes of land use characteristics were quantitatively analyzed through land use dynamic degree. And then the driving forces of land use changes were analyzed based on natural and artificial factors. From 2000 to 2015, as the result of natural factors and human disturbances, the area of forest-agricultural land shrunk, bringing the conversion from forest and agricultural land to building zone, scrub/fallow land, industrial zone and mining [Figures 1 -4].

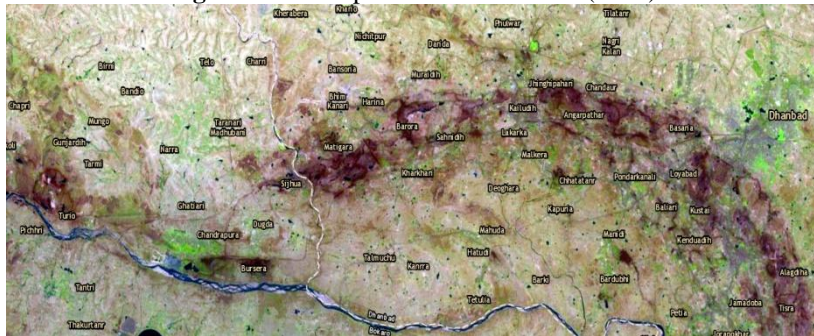**Figure 1** GIS map of Dhanbad district (2000)



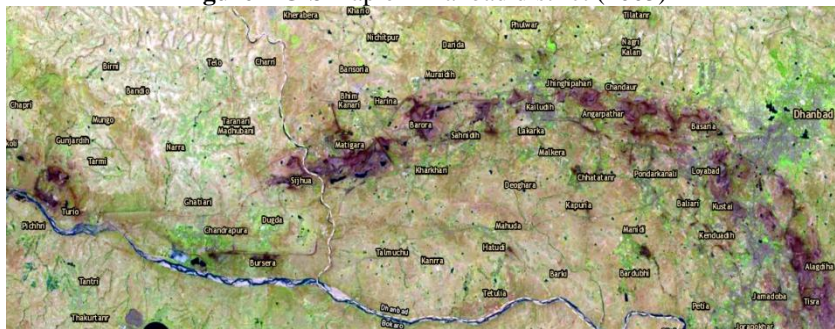**Figure 2** GIS map of Dhanbad district (2005)



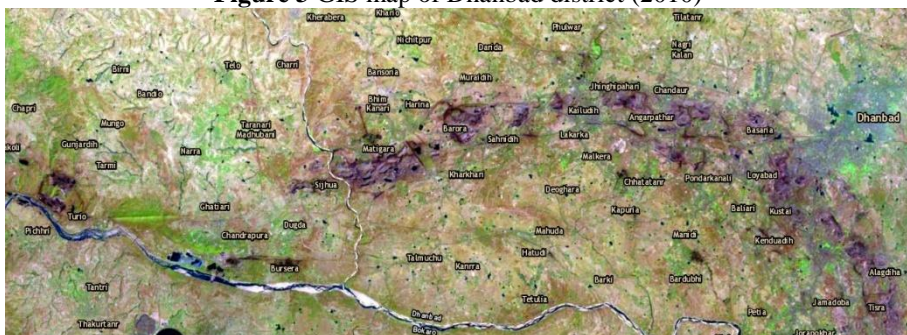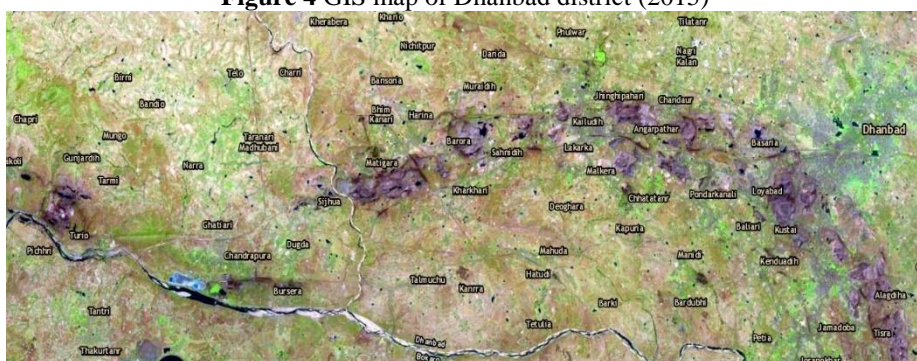**Figure 3** GIS map of Dhanbad district (2010)



**Figure 4** GIS map of Dhanbad district (2015)

The annual conversion rates indicated the rapid land use changes in Dhanbad forest-agricultural ecosystem hotspot. Through the synthesis land use dynamic degree for the three sub-periods, the land use changes during the period 2010-2015. The change in land-use pattern in 2005-2010 increased comparing with that during the period 2000 to 2005. Hence, the management of Dhanbad forest-agricultural ecosystem hotspot must focus on forest land use changes in future, so as to achieve effective conservation of the forest and agricultural land. The study results could provide foundations for target protection in Dhanbad forest-agricultural ecosystem hotspot.

### 4.1 Quantity analysis of land use changes

The land use change for the three sub-periods was shown in Table 1 with an increase of irrigation land during the second period(2005-2010) and decrease in the third period Table 1  also shows an increase of forest land in the second (2005-2010) and third (2010-2015) compared to first period (2000-2005). The areas for building zone and industrial zone increased during the sub- periods. The areas of forest decreased during the sub periods.

**Table 1:** Dhanbad profile from GIS mapping (hectares)

| Type of ecosystem | 2000 | 2005 | 2010 | 2015 |
|---|---|---|---|---|
| Water Body | 8179 | 7943 | 7816 | 7649 |
| Building Zone | 9813 | 12843 | 16303 | 19975 |
| Irrigation land | 145672 | 137161 | 129229 | 119765 |
| Scrub / Fallow land | 15968 | 21827 | 26659 | 32878 |
| Industrial zone | 536 | 583 | 661 | 724 |
| Mining | 6073 | 6287 | 6436 | 6812 |
| Forest | 19483 | 19081 | 18622 | 17923 |
| Total | 205726 | 205726 | 205726 | 205726 |

### 4.2 Land use dynamic degree analysis

The single land use dynamic degree for each land use types that is the annual conversion rates of land use types were calculated for the three periods. Among the various land use types, irrigation land annual conversion rate was the highest during the three periods. Losses of irrigation land were mainly converted to building zone, scrub/fallow land and industrial zone (Table 2, 3 and 4). Losses of forest land were mainly converted to building zone, scrub/fallow land, industrial zone and mining (Table 2, 3, and 4).

**Table 2:** Dhanbad Annual average change (hectares/year)

| Type of ecosystem | 2000-2005 | 2005-2010 | 2010-2015 |
|---|---|---|---|
| Water Body | -47.2 | -25.4 | -33.4 |
| Building Zone | 606 | 692 | 734.4 |
| Irrigation land | -1702.2 | -1586.4 | -1892.8 |
| Scrub / Fallow land | 1171.8 | 966.4 | 1243.8 |
| Industrial zone | 9.4 | 15.6 | 12.6 |
| Mining | 42.8 | 29.8 | 75.2 |
| Forest | -80.4 | -91.8 | -139.8 |

**Table 3:** Land Conversion Matrix: Dhanbad 2000-2005

| Type of ecosystem | Water Body | Building Zone | Irrigation Land | Scrub/Fallow land | Industrial zone | Mining | Forest | Total |
|---|---|---|---|---|---|---|---|---|
| Water Body | 7943 | 236 | 0 | 0 | 0 | 0 | 0 | **8179** |
| Building Zone | 0 | 9813 | 0 | 0 | 0 | 0 | 0 | **9813** |
| Irrigation land | 0 | 2391 | 137161 | 5859 | 47 | 214 | 0 | **145672** |
| Scrub / Fallow land | 0 | 0 | 0 | 15968 | 0 | 0 | 0 | **15968** |
| Industrial zone | 0 | 0 | 0 | 0 | 536 | 0 | 0 | **536** |
| Mining | 0 | 0 | 0 | 0 | 0 | 6073 | 0 | **6073** |
| Forest | 0 | 403 | 0 | 0 | 0 | 0 | 19081 | **19483** |
| **Total** | **7943** | **12843** | **137161** | **21827** | **583** | **6287** | **19081** | |

**Table 4:** Land Conversion Matrix: Dhanbad 2005-2010

| Type of ecosystem | Water Body | Building Zone | Irrigation Land | Scrub/Fallow land | Industrial zone | Mining | Forest | Total |
|---|---|---|---|---|---|---|---|---|
| Water Body | 7816 | 127 | 0 | 0 | 0 | 0 | 0 | **7943** |
| Building Zone | 0 | 12843 | 0 | 0 | 0 | 0 | 0 | **12843** |
| Irrigation land | 0 | 3333 | 129229 | 4521 | 78 | 0 | 0 | **137161** |
| Scrub / Fallow land | 0 | 0 | 0 | 21827 | 0 | 0 | 0 | **21827** |
| Industrial zone | 0 | 0 | 0 | 0 | 583 | 0 | 0 | **583** |
| Mining | 0 | 0 | 0 | 0 | 0 | 6287 | 0 | **6287** |
| Forest | 0 | 0 | 0 | 311 | 0 | 148 | 18622 | **19081** |
| **Total** | **7816** | **16303** | **129229** | **26659** | **661** | **6435** | **18622** | |

Though the areas of other land use types (building zone, scrub/fallow land and industrial zone) increased during the study periods, their annual conversion rates indicated the rapid land use changes in (Table 5).

**Table 5:** Land Conversion Matrix: Dhanbad 2010-2015

| Type of ecosystem | Water Body | Building Zone | Irrigation Land | Scrub/Fallow land | Industrial zone | Mining | Forest | Total |
|---|---|---|---|---|---|---|---|---|
| Water Body | 7649 | 167 | 0 | 0 | 0 | 0 | 0 | **7816** |
| Building Zone | 0 | 16303 | 0 | 0 | 0 | 0 | 0 | **16303** |
| Irrigation land | 0 | 3505 | 119765 | 5959 | 0 | 0 | 0 | **129229** |
| Scrub / Fallow land | 0 | 0 | 0 | 26659 | 0 | 0 | 0 | **26659** |
| Industrial zone | 0 | 0 | 0 | 0 | 661 | 0 | 0 | **661** |
| Mining | 0 | 0 | 0 | 0 | 0 | 6435 | 0 | **6435** |
| Forest | 0 | 0 | 0 | 260 | 63 | 376 | 17983 | **18622** |
| **Total** | **7649** | **19975** | **119765** | **32878** | **724** | **6811** | **17983** | |

### 4.3. Driving Factors of Land-Use Change

The synthesis land use dynamic degree of Dhanbad forest-agricultural ecosystem hotspot for the period 2000 to 2005 was -13.82%, for 2005-2010 was -11% and for 2010-2015 was -9.58% (Table 6). Comparing with the overall land use change during the earlier stage, the land use change for the later stage had increased.

**Table 4.6:** Land use dynamic degree of each land use types for the three periods: Dhanbad (in %)

| | Type of ecosystem | 2000-2005 | 2005-2010 | 2010-2015 |
|---|---|---|---|---|
| Single Land Use Dynamic Degree model | Water Body | 0.5770 | 0.3197 | 0.4273 |
| | Building Zone | -6.1754 | -5.3881 | -4.5046 |
| | Irrigation land | 1.16851 | 1.1565 | 1.4646 |
| | Scrub / Fallow land | -7.3384 | -4.4275 | -4.6655 |
| | Industrial zone | -1.7537 | -2.6758 | -1.9062 |
| | Mining | -0.7047 | -0.4739 | -1.1684 |
| | Forest | 0.4126 | 0.4811 | 0.7507 |
| Synthesis land use dynamic degree | | **-13.82** | **-11** | **-9.58** |

*4.4 Service Declines, Degradation, and Increasing Vulnerability*

Our work highlights the substantial impact of land-cover change on ecosystem services, resulting in declines in ecosystem service levels. These declines mirror biodiversity losses in the region. The significance of these declines relates to the overarching role regulating services play in soil conservation and nutrient cycling, and in turn, the services of primary production and water. It is the latter services that underpin the agricultural economy. These results also point to the substantial impacts of the extensive areas of degraded land. Degraded areas, overlap with the hotspots of the carbon, forage, erosion, and tourism services. Overgrazing of these areas, together with clearing of other areas to grow livestock feed to supplement the forage production service, have been major drivers of change in ecosystem services.

The declines in what are mostly regulating and supporting services, together with the documented biodiversity losses, raise concerns about long-term decreases in the region's productivity and resilience, and thus increases in its vulnerability to shocks such as floods, drought, or market shifts. The examined regions are facing decreased ecosystem service levels, threatened biodiversity, high unemployment levels, and narrowing future options. The situation mirrors semiarid regions around the world, which house the most vulnerable people, ecosystems, and ecosystem services. Understanding the drivers of changes in land cover and subsequently in ecosystem services is essential in the design of interventions.

## V.    POLICY IMPLICATIONS

Land-cover change has been identified as one of the most important drivers of change in ecosystems and their services. However, information on the consequences of land cover change for ecosystem services and human well-being at local scales is largely absent. Where information does exist, the traditional methods used to collate and communicate this information represent a significant obstacle to sustainable ecosystem management. Embedding science in a social process and solving problems together with stakeholders are necessary elements in ensuring that new knowledge results in desired actions, behavior changes, and decisions. We have attempted to address this identified information gap, as well as the way information is gathered, by quantifying the local-scale consequences of land-cover change for ecosystem services of the highly degraded ecosystems of Indian subcontinent of major ecosystems.The declines in what are mostly regulating and supporting services, together with the documented biodiversity losses, raise concerns about long-term decreases in the region's productivity and resilience, and thus increases in its vulnerability to shocks such as floods, drought, or market shifts. The examined regions are facing decreased ecosystem service levels, threatened biodiversity, high unemployment levels, and narrowing future options. The situation mirrors semiarid regions around the world, which house the most vulnerable people, ecosystems, and ecosystem services. Understanding the drivers of changes in land cover and subsequently in ecosystem services is essential in the design of interventions.

The political, social, economic, and technological changes associated with the ecosystems were key drivers of change in the examined ecosystem. The history of land-use decisions and their impacts point to the need to manage systems in ways that recognize their natural constraints and vulnerabilities, as well as the need to create future economies and livelihoods that foster sustainable use of services along with the promotion of human well-being. Sustainable land-use practices rely on the consideration of, and protection of, ecosystems and their services. Such practices focus on maintaining the resilience of ecosystems, and on building agility into production strategies, enabling responses to market trends and fluctuations.

## VI.    CONCLUSION

Our work highlights the substantial impact of land-cover change on ecosystem services, resulting in declines in ecosystem service levels. These declines mirror biodiversity losses in the region. The decline in the water-flow regulating service and the decline in areas responsible for erosion controls are particular concerns to the region's future sustainability. The significance of these declines relates to the overarching role regulating services play in soil conservation and nutrient cycling, and in turn, the services of primary production and water. It is the latter services that underpin the agricultural economy. These results also point to the substantial impacts of the extensive areas of degraded land. Degraded areas, overlap with the hotspots of the carbon, forage, erosion, and tourism services. Overgrazing of these areas, together with clearing of other areas to grow livestock feed to supplement the forage production service, have been major drivers of change in ecosystem services. The declines in what are mostly regulating and supporting services, together with the documented biodiversity losses, raise concerns about long-term decreases in the region's productivity and resilience, and thus increases in its vulnerability to shocks such as floods, drought, or market shifts. The examined regions are facing decreased ecosystem service levels, threatened biodiversity, high unemployment levels, and narrowing future options. The situation mirrors semiarid regions around the world, which house the most vulnerable people, ecosystems, and ecosystem services. Understanding the drivers of changes in land cover and subsequently in ecosystem services is essential in the design of interventions Creating a sustainable ecosystem will require improvements in the current condition of its ecosystems and their services. This, in turn, will require large-scale conservation and

restoration activities targeted at areas of importance to water-flow regulation and erosion control. This realization is not new and, the government formulated policies to deal with drought and erosion.

## ACKNOWLEDGMENT

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