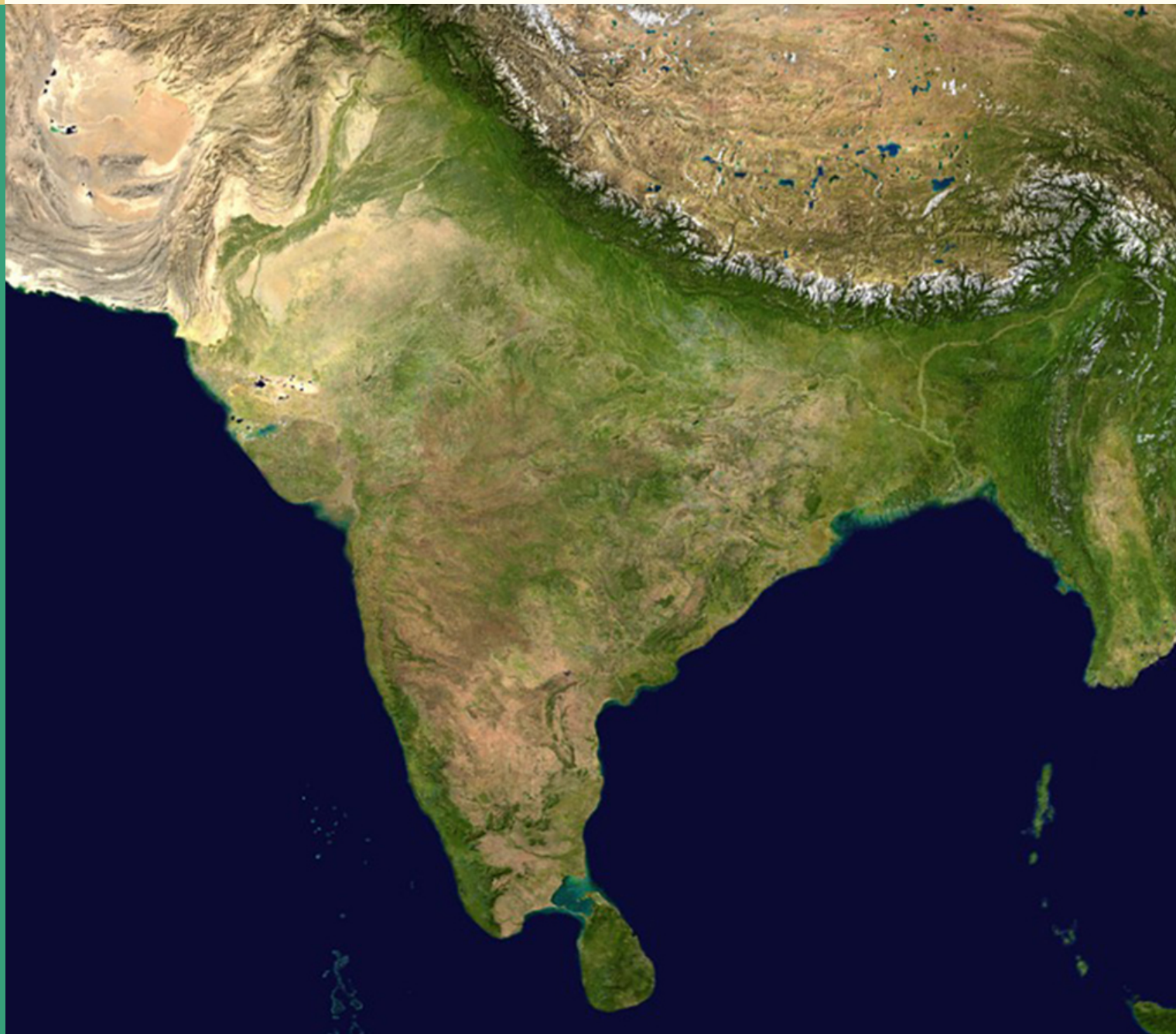
2021 - 2039

LAND UTILISATION IN INDIAN STATES: A QUANTITATIVE MODELLING

DATA REPORT

The Economics Society, SRCC



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INTRODUCTION

Land is one of the most important resources of a country. It is not only economically crucial but is essential for mere existence. A crucial problem that a large country like India faces is the ineffective utilisation of land. Any strip of land which does not provide economic utility in the form of food, shelter etc. can be termed as a wasteland. As India advances to become a global superpower, there is a necessity to understand ineffective land utilisation in the country and even forecast the same for the future. As societies become more resource-dependent, even non-waste lands degrade and become underutilised and fallow lands.

Hence, this report is an endeavour to study land use in Indian states, specifically focusing on various wasteland classes, and understand their possible transformation in the future. This report forecasts land use distribution to the subsequent decades by utilising scientific methods, thereby serving as a means for policy-makers to intervene to ensure the best utilisation of the rare resource - land.

Land is one of the most important non-renewable resources as it is the center of all production systems. During the course of time, the country's land area has suffered from many types of degradation - both man-made and natural. India has only 2.4% of the world's geographical area but supports over 16% of the world's population. It has only 0.5 % of the world's grazing area but has more than 18% of the world's cattle population. These pressures are leading to drastic changes in the proportion of land utilisation namely for agricultural activities, urbanisation and industrial development.

The various types of agricultural practices that rely heavily on water, chemical fertilisers and pesticides cause issues like waterlogging and makes the water salty in many parts of the country.

The constant expansion of the irrigation system without proper steps to treat the catchment areas have worsened the situation. While mining and industrial activities devour forests in eastern India, global climate crises are reducing snow cover in the Himalayas. The various events, though discrete and independent, create repercussions in land use patterns. Such events directly impact the productivity of soil, vulnerability to rainfall variations, the amount of drinking water available and the capacity of fodder and fuelwood, ultimately impacting the country's growth potential.

Due to the influence of land utilisation in every aspect of human life, accurately predicting the changes in land usage becomes a matter of paramount importance.

Estimates of degraded land vary to a great extent and the degree of land degradation has not yet been determined accurately in India. Given all the above-mentioned importance of land use planning, we believe that wastelands can be used for human development through corrective actions.

As mankind conquers the orbit space, a large amount of data is generated with regards to land usage patterns. Geospatial models used to predict changes over time also become far more complex and somewhat more accurate.

In this report, a model developed using the concept of Markov Chains is used to model the changes in land distribution in the states of India up till the year 2039. A Markov chain in the case of land use follows the assumption that all future states of land use are based on states obtained in the current state. Thus, by calculating the probability of transition between different land categories and assuming them to be constant we can effectively predict future distributions of wastelands in India from current data.

THE MARKOV CHAIN MODEL

The Markov Chain models are in essence, a prediction structure that discusses the probabilistic motions of a specific element in a system consisting of various states.
When put to use on land and other applications, the chain tends to emphasise that a system, at a given time, can exist in any one of a finite set of states. The changes between the states of the system, from time to time are maintained in the form of a transition matrix that records the expected probability of movement from one state to another. The nuances of a system as a finite Markov Chain require specific types of properties to hold. These include:

- A definite and countable number of states that are mutually exclusive and collectively exhaustive. Essentially meaning that the rows of the probability matrix add up to one.
- Over the periods, the probabilities of the transition matrix must be the same.
- Probabilities have no memory and hence, the land distribution of tomorrow depends only on today.
- Time periods must be uniform in the length of duration.

In practice, one or all these conditions may not be met.

The simple premise of the Markov Chain model is that land use at some point in the future ***(t+1)*** can be determined as a function of the present use of land ***(t),*** mathematically it can be written as

$$X_{t+1} = f(X_t)$$

Where ***Xt+1*** represents the land use at time ***t+1*** and ***Xt*** represents land use at time ***t.***

The concept of the Markov Chain model as applied to land-use changes considers a vector ***nt*** with dimension ***mX1*** (where m represents the number of states, in this case, land use classes). Elucidating the division of use and representing the transitions, an **mXm** matrix of transition probabilities (P) that controls the probability of transition between each pair of land is used. Where

$$P_{ij} = P(x_t = j \mid x_{t-1} = i),$$

i.e. the ***ijth*** entry representing the probability of an item being in state ***j*** in time ***t,*** given it was in state ***i*** in time ***t-1***. Finally, the model can then be written as a difference equation in matrix form

$$n_t = P \cdot n_{t-1} = (P^t) \cdot n_0$$

The wasteland distribution in period ***t+1*** is simply the matrix product of the Markov transition probability matrix ***(P)*** and the land distribution vector in period ***t.***

METHODOLOGY

DATA COLLECTION

The data used for modelling was taken from the Wasteland Atlas of India 2019, published by the Department of Land Resources, Ministry of Rural Development, Government of India. The land use distribution of various wasteland classes in each state for the period 2007-2008 and 2015-16 and the transitions within were obtained. The data was also cross-checked from the Bhuvan portal, the national Geoportal that is developed and hosted by ISRO for Geo-Spatial Data, Services and Tools for Analysis.

For the purpose of our study, 12 different land classes were identified. They are the possible wasteland classes as identified by the DoLR and the 12th class being Non-Waste Lands. They are deemed to-be sufficient, given the objective of this study; to track possible usability of such lands and the changes in land use. The 12 land classes are as follows:

Gullied & Ravenous Land: Gully is a tapered channel, created due to excessive flow of water at high-speed in response to clearing and too much land use. A network of gullies form a ravine and refer to heavily eroded land stretches. Ravines can be medium and deep depending upon their depths.

Scrubland: These types of lands have minimal plant cover and are susceptible to deterioration caused by erosion. They are found in topographically high locations apart from hilly regions. On the basis of the type of vegetation found here, scrubs can be dense scrub or open scrub.

Waterlogged Marshy Land: These are low lying lands where the water table is near the surface and stands still on the surface making the soil unstable. On the basis of the duration of waterlogging, there are 2 classes : permanently waterlogged and seasonally waterlogged.

Land affected by salinity: Areas with high concentration of soluble salts (saline) or high exchangeable sodium in the soil are classified here. Salinity is caused due to capillary movement of water, during extreme weather conditions leaving salt encrustation on the surface. These lands have presence of carbonates and bicarbonates of sodium, making agriculture impossible.

Areas of shifting cultivation: Shifting cultivation is an ancient technique of growing crops on forested/vegetated mountain areas by then burning the vegetation. The land where this is taking place is called the current land and the land on which this was performed and left for more than a year but less than five years is called abandoned land. The practice is detrimental to environmental as it leaves economical forest lands as non-arable fallows.

Underutilised land: This land class covers forest land that is being put to inefficient usage. Forest lands that have degraded to less than 20% vegetation cover and agricultural lands made by clearing forests fall under this category. They are generally found as pockets within larger areas, which can be identified as a forest as per the Forest Act of 1927.

Degraded Pastures & Croplands: These lands are those, which are either under permanent pastures or meadows, but have degraded due to lack of proper soil and water conservation and drainage development measures. These lands, if appropriated, can be brought under built-area.

Sand (coastal / desert / riverine): In these types of lands, there is accumulation of sand in coastal or inland areas. They tend to differ in size and shapes with contiguous linear patterns. Mostly found in deserts and alongside shores.
Coastal sand are the sands that get collected along the seacoast due to the action of seawater. They are not used for activities other than recreation. Desert sand is confined to dry and arid environments where there is hardly any rainfall. The heights depend on the amount of sand that has been transported through soil aeolian processes. This land cannot be put to any economic use, but rise in desert can point towards environmental catastrophe.

Mining and Industrial Wasteland:
These are the areas where industrial raw materials, quarried debris after extraction of minerals, effluents or waste materials from industrial processes etc are deposited. Poisonous elements may leach out through these wastes, possessing a threat to human life. Such lands can also inhibit plant growth.

Barren Rocky Lands: These are rocks of different types of lithology often barren and void of soil and vegetative cover. They are found amidst hill-forests as openings or on plateaus and plains. The category also includes steep sloping areas devoid of vegetation cover that were classified separately in the earlier exercise.

Glacial & Snowy Lands: These types of lands are covered by snow and are found in the Himalayan regions. The mountain peaks and slopes and high relief areas where glacial lands are found. They, undoubtedly, hold important value in the hydrology and climate of the plains.

Non-Waste Land: This study considers any land that is not waste, as a non-wasteland. This functionally includes all land that is put to an economic use or provides a utility (forests, agricultural land and built area).

STRUCTURING OF DATA

The transition of land from one class to another class was collated as a Transition Matrix. The matrix was such that the rows represented the land use distribution in 2007 and the columns represented the same in 2015. Each of the individual cells showed the total area that transformed through the respective classes during the period between 2007 and 2015.
This was the basis for calculating Markov's Transition Probability matrix. The maximum likelihood estimator for each of these probabilities was calculated as:

$$\hat{p}_{ij} = \frac{n_{ij}}{\sum_{j=i}^{n} n_{ij}}$$

where **pij** is the probability of transition between **i** and **j** and **nij** denotes the number of transitions from i to j in the transition matrix. Since these are probabilities, it was also tested to observe that

$$\sum_{i=i}^{n} \hat{p}_{ij} = 1 \; \forall \, j \; \leq n$$

Scientific Method:

To test the validity of the Markov process in this case, it is necessary to prove that the distribution of land classes in each period are not independent of each other. Hence, a null hypothesis that the "Land use is actually independent over periods" was developed.

The validity of the same was then tested using the Chi-square test of independence.

The expected transition matrix, when land use is independent, was developed as

$$\hat{m}_{ij} = P_{+i} \cdot P_{j+}$$

where P+i and Pj+ represent the marginal PMFs of the respective class i and j.
To test the hypothesis, the test statistic (T) was to be calculated with

$$T = \sum_{i=1}^{n} \sum_{j=1}^{n} \frac{(\hat{m}_{ij} - n_{ij})^2}{\hat{m}_{ij}}$$

The test statistic so obtained was compared to Chi-Square distribution with degree of freedom depending on the number of lands uses classes in each state. The null hypothesis was rejected when

$$c < T : c = \chi^2_{n^2}(k\ 0.05)$$

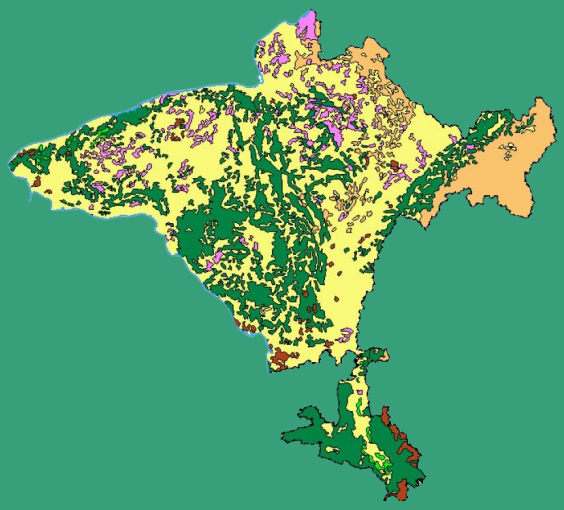
at a significance level of 95%. The rejection of the null hypothesis signalled the applicability of Markov processes in our model.

Thereafter, the calculated Markov Transition Probability Matrix was multiplied with the land use vector for the period 2015-2016, to obtain the land use vector in the years 2023-2024. This process was repeated for three successive periods to obtain the land use distribution for years, 2023-2024, 2031-2032 and 2039-2040. The projections received for each period were summed and cross checked to be equal to the state's Total Geographic Area (TGA)

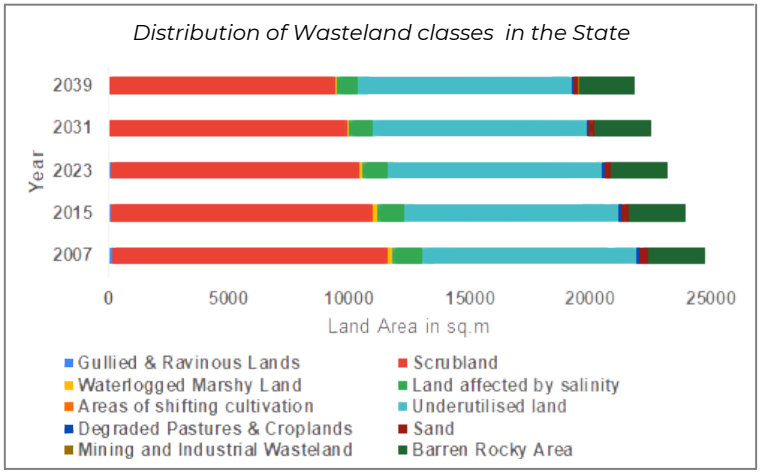
The estimations and projections which were arrived at, were utilised to make valid observations on land use in each state. The observations made, when read in light of the scenario in each state, becomes a valid document for land use planning and land development.

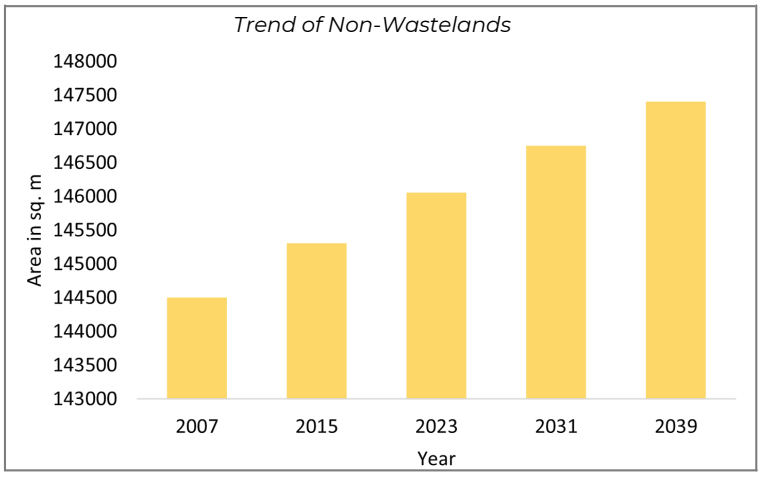
STATE

LAND PROFILES



ANDHRA PRADESH



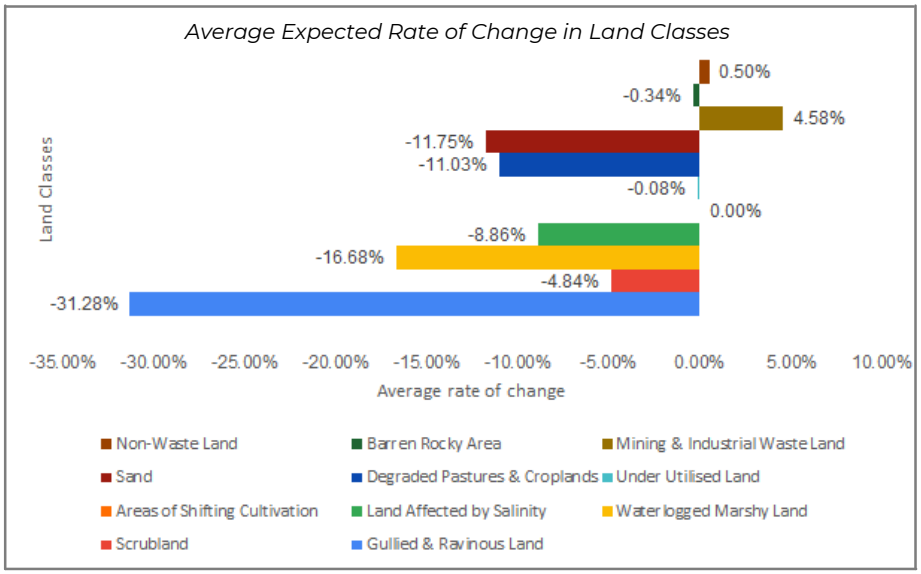


Observations

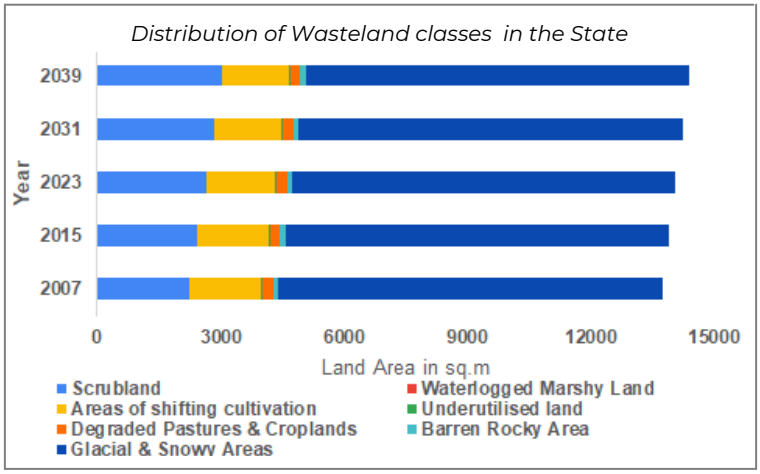
- In the course of the next few years, it is expected that there will be a minor increase in the area under non-waste land, which is an indicator of economic prosperity and efficient utilization.
- By analyzing the calculated trend, it can be observed that the wasteland in the state mainly comprises of Scrublands and Underutilized Land. While a small reduction in Scrublands is predicted over the years, the underutilized land remains constant.
- Although Waterlogged and Marshy Land represents a very small portion of the total wastelands in the state, it is expected to almost completely dissapear over the next few years. This can be a crucial problem in the state, since this land class plays an important role in sustaining local hydology.

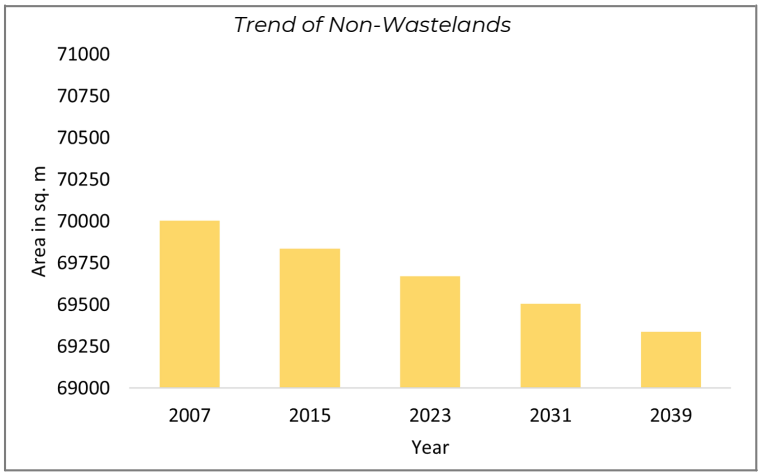
Recommendations

- The state must focus on coverting the large areas of Underutilized Land into an optimally functioning resource. This can be achieved by investment in agriculture technology, afforstation, or other land improvement techniques.
- If the state is able to effectively utilize its land reserves, it will enter a period of great economic prosperity.



ARUNACHAL PRADESH



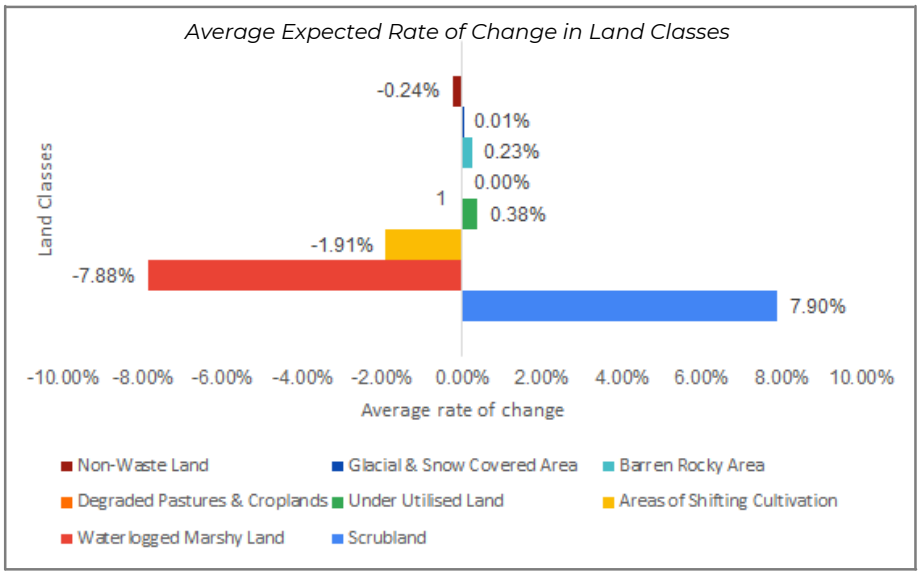


Observations

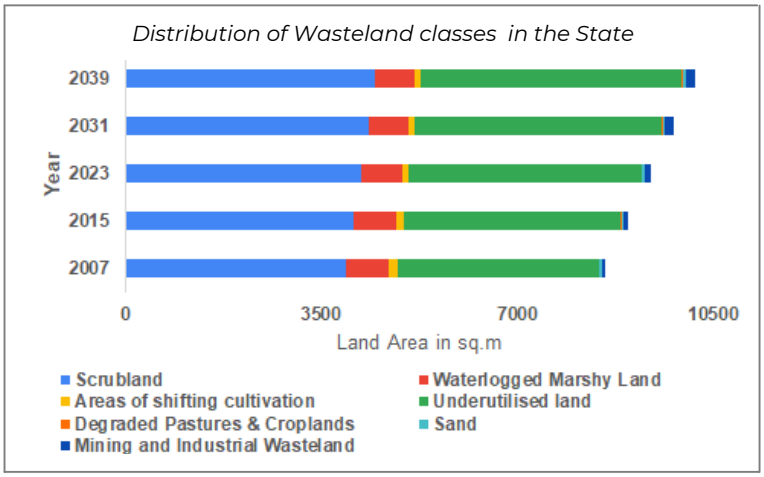
- No significant changes in land distribution are expected for the state up to 2039. Although there is a positive trend in Wasteland growth, the actual growth is meager.
- About 10% of the state's land resources are Glacial and Snowy areas and cannot be put to economic use. They also preserve biological diversity and provide perennial sources of water. The growth rate of this land category is also fairly stagnant
- Transition of the area under shifting cultivation to Scrubland is also observed, indicating recovery from the harmful impact of shifting cultivation.

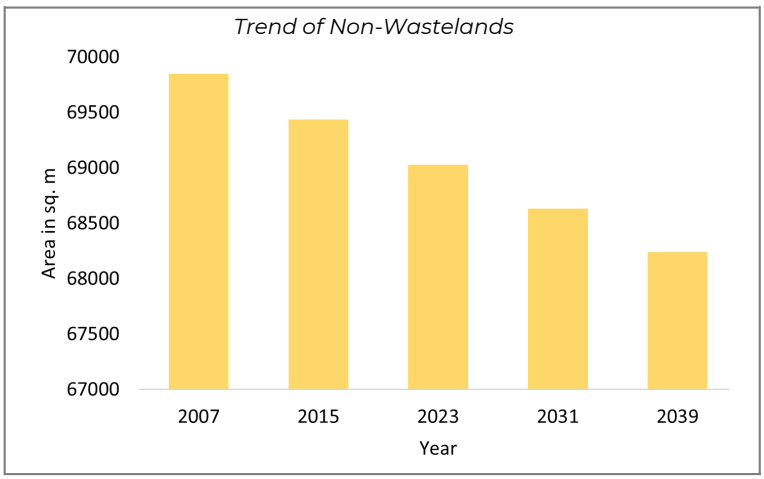
Recommendations

- The Snowy and Glaciel land that lie in the region need to be preserved from the impact of climate change in order to protect the pristine ecosystem of the state.
- The scrublands that are spread across the state can be developed into pasturelands for grazing.



ASSAM



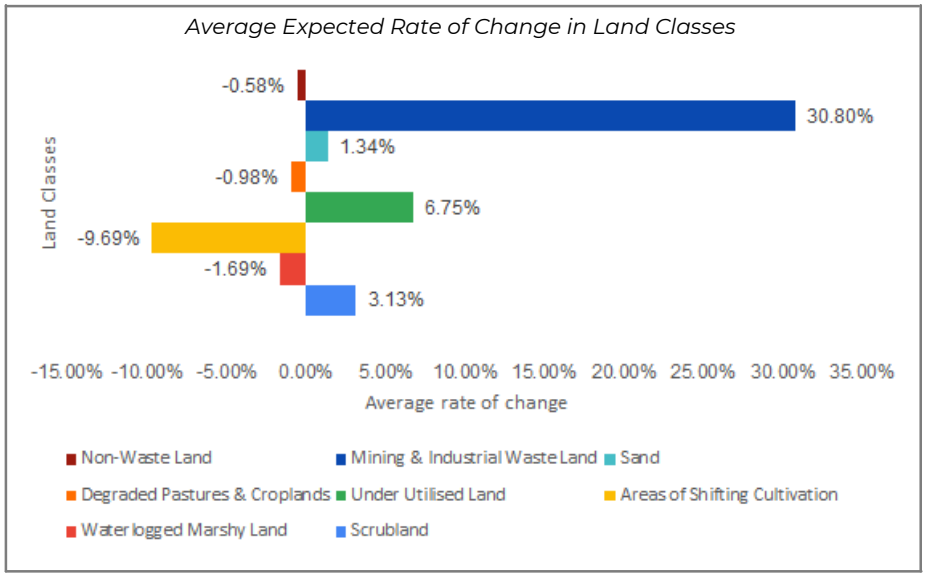


Observations

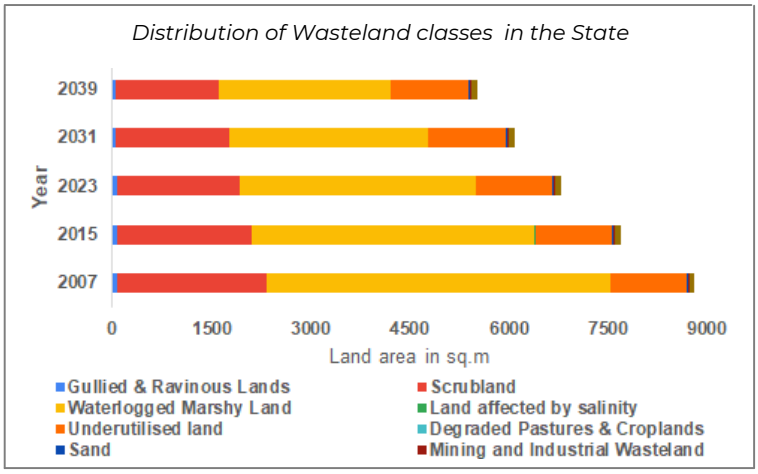
- Going by current estimates, a marginal increase in the Wasteland area is projected for the state of Assam. Although, the current land utilization in the state is fairly good, and Waste Land accounts for only about 10% of the total land area.
- By analyzing the transition matrix we also observe a transition in areas of Shifting Cultivation into Scrublands. This is a positive indicator, considering the negative impacts of shifting cultivation. These scrublands can further be developed as grazing grounds or dense forests.
- There is also a stark increase projected in Underutilized land. It is expected to increase by nearly 30% by 2039. Additionally, mining and industrial wasteland are also projected to become 3 times their original size.

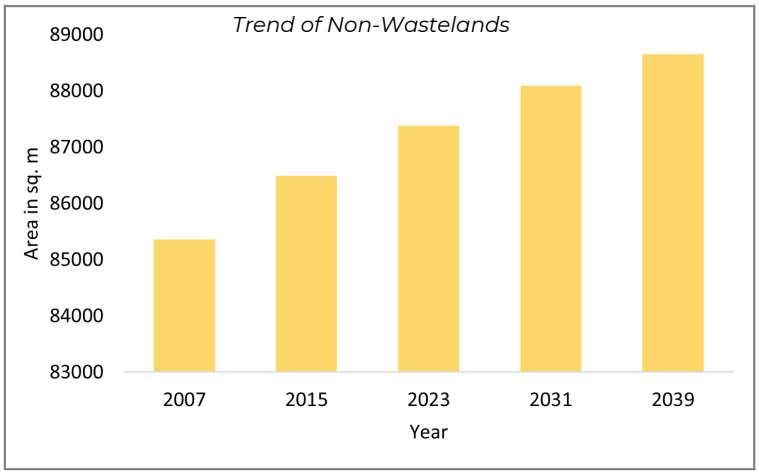
Recommendations

- Given that Land is an economic resource, there is need to effectively employ the state's underutilized land.
- Mining and industrial activities can generate a lot of environmental externalities. Thus, it is imperative that increase in such wasteland be monitored to protect ambient environment.



BIHAR



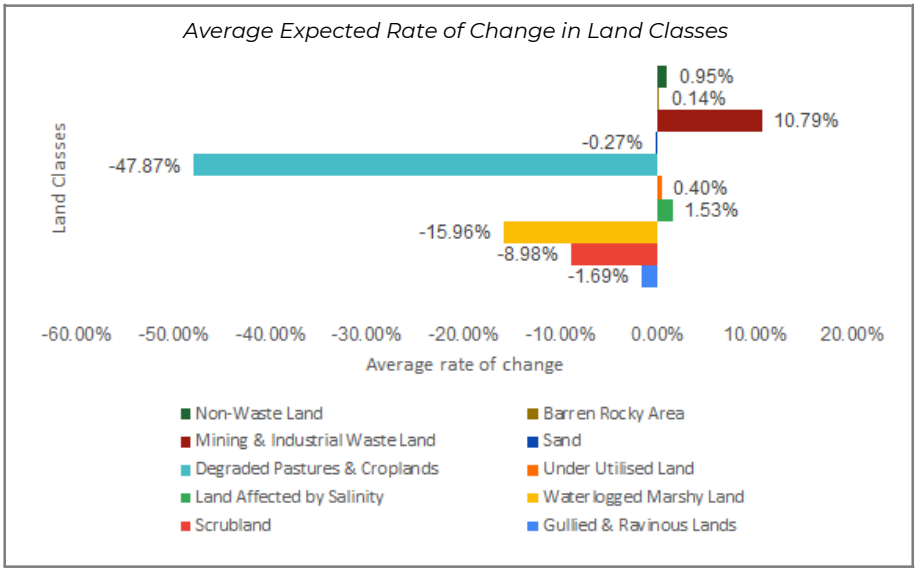


Observations

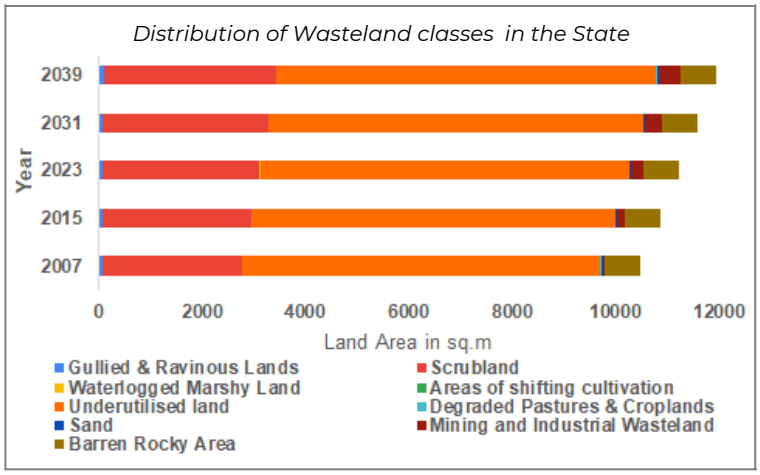
- Current data projects favourable trends for the state of Bihar. It is expected that the Wasteland area will decrease by nearly 30% by 2039. This implies great economic opportunities for the state if the acquired resources are optimally utilized.
- The most significant transition to be observed is from Waterlogged and Marshy Lands to Non-Waste Lands. Although it presents a great economic opportunity, this must not be left unchecked and the biodiversity provided by the marshes should be preserved.
- Most of the degraded pasturelands and croplands are also expected to transition into areas of economic utility, thus emphasising the state's focus on effective utilization of land.

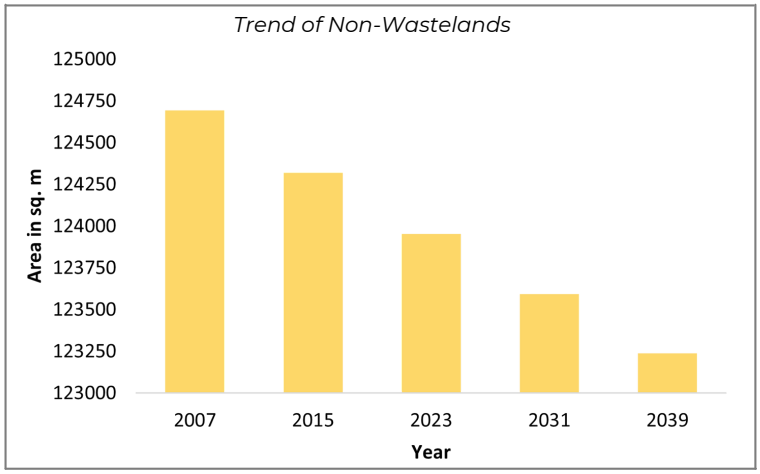
Recommendations

- The current trends present a favourable scenario for Bihar. Effective planning needs to be done in order to make full use of these land resources.
- Industrial activity and upskilling of local labour force should be emphasised. The abundant labour present will play a huge role in accelerating economic growth.



CHHATTISGARH



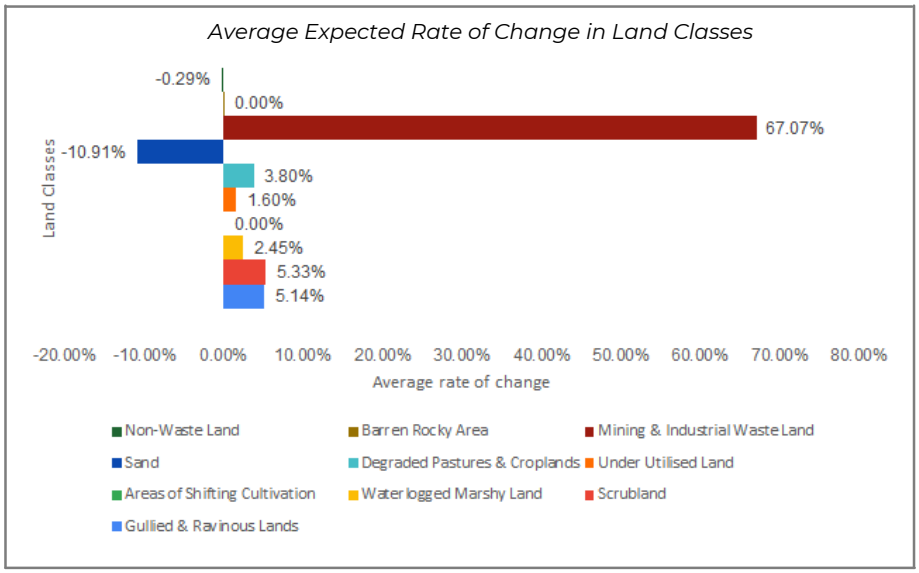


Observations

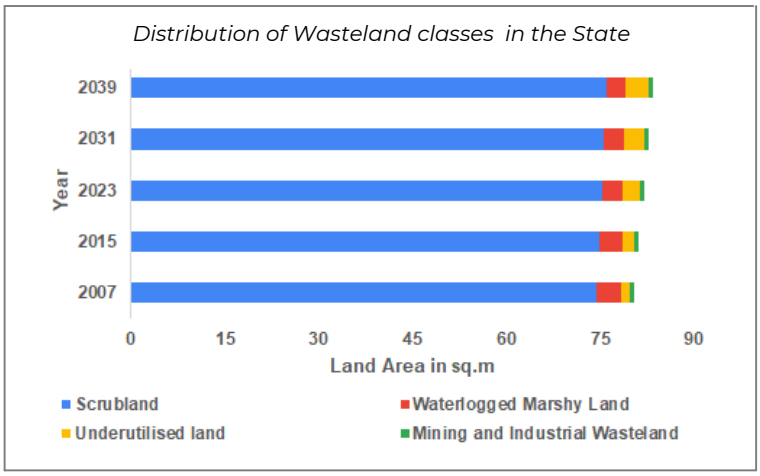
- According to current projections, it is estimated that Wasteland Area in Chattisgarh will continue to increase, and by 2039, there will be an increase of approximately 13%.
- Another thing that can be observed is the steep increase in Mining and Industrial Wasteland. It is projected that they will become 8 times their original size by 2039. Given the predominance of mining in such areas, the projection is not surprising.
- Underutilized land accounts for about 50% of the total land resources of the state, although the projected growth rate for this category is very meagre.
- Moreover, Scrublands in the state are estimated to increase by roughly 23%, since a significant portion of Non-Wasteland is being degraded. It could spell trouble for developmental activities in the state.

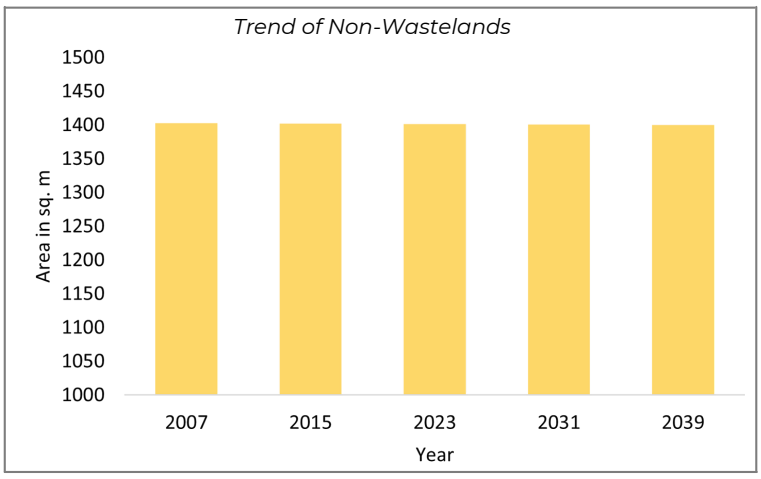
Recommendations

- Given the large area of Underutilized land, the primary focus should be on afforestation and land improvement techniques.
- Given the need for mineral resources and employment opportunities, mining activities cannot be curtailed in a strict manner, thus effective steps must be taken to ensure that degradation from mining is minimised.



DELHI





Observations

- Current projections estimate a fairly stagnant distribution of land resources across different categories. No major transitions or increase is predicted till 2039. This can be due to the fact that the majority of the land resources are already optimally utilized for various industrial and residential purposes. Only about 5% of the total land area is Wasteland in Delhi.

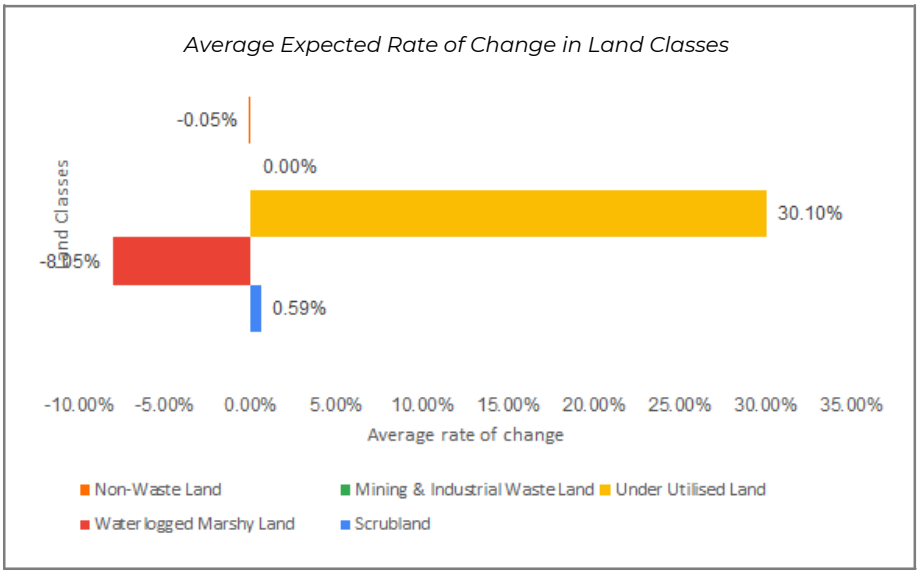
- Scrublands dominate the wastelands in the state, accounting for about 90% of the total wasteland in Delhi by 2039. These can be converted into dense forests to provide Delhi with the much needed green cover and improve air quality in the territory.

- In addition to this, underutilized land is also expected to increase significantly by 2039. Given the paucity of land in the capital, this can be a source of large concern.

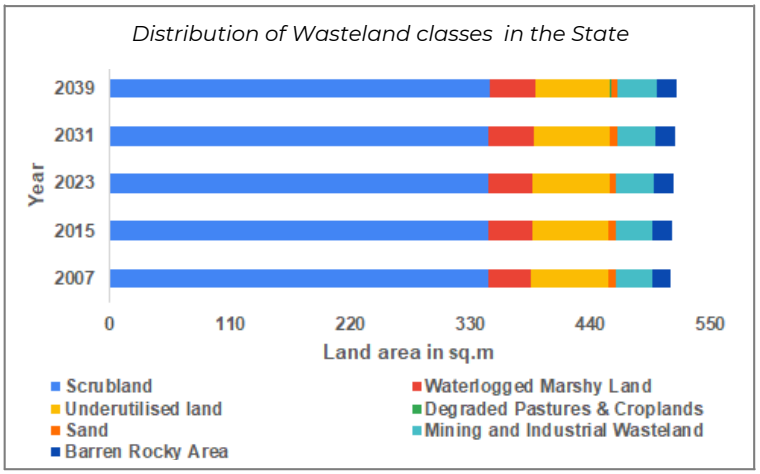
Recommendations

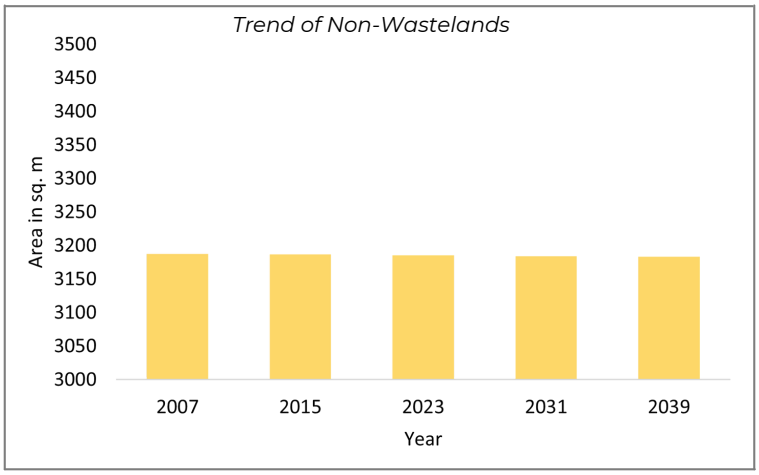
- Given the acute problem of Air Pollution in the region, paramount importance should be given to the task of increasing the green cover, which will consequently improve air quality.

- Necessary policies must be implemented to keep the growing area of Underutilized Land under check.



GOA



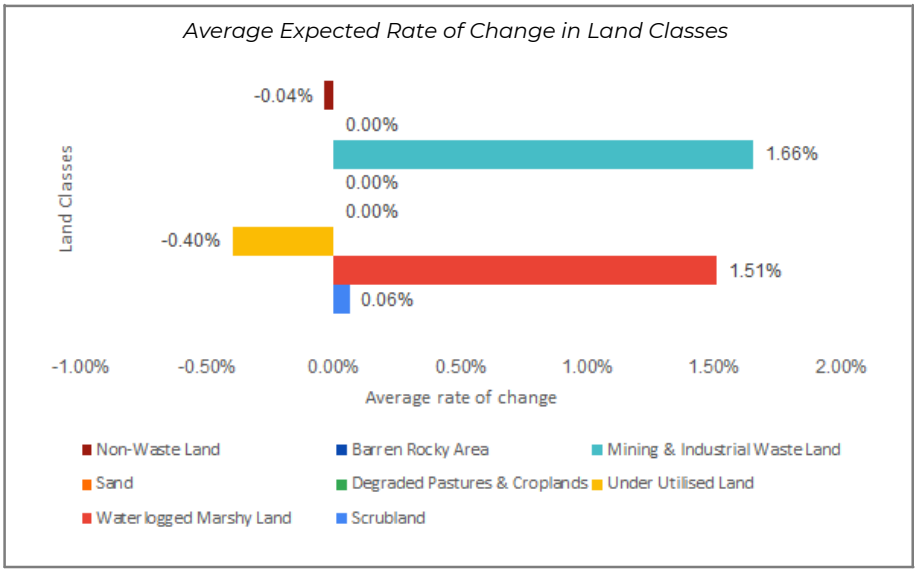


Observations

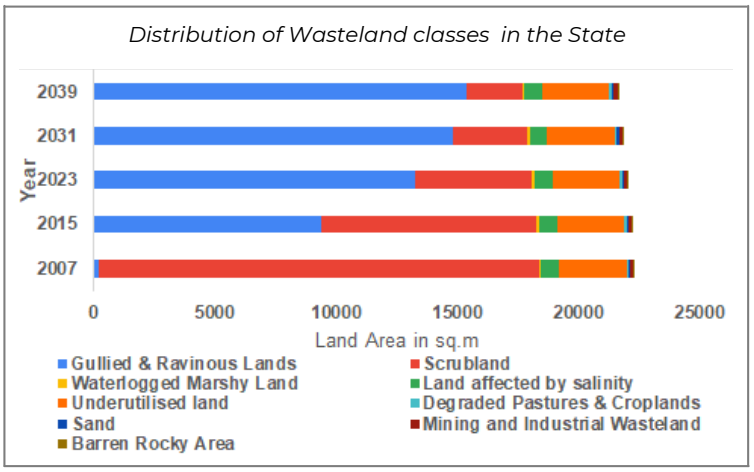
- The overall usage of lands in the state is predicted to largely remain constant. This may be because the state is not heavily dependent on land as a resource, especially in its interiors.
- Most of the wastelands in the state are comprised of Scrublands. These lands can be converted back into dense forests, given the need for afforestation in the state's hilly interiors regions.
- Mining and Industrial Wastelands, though smaller in proportion, are predicted to increase rapidly in the state. This relates to the recent controversies in the state, with regard to coal mining.
- The rise in waterlogged marshy lands in the state will be beneficial for the unique habitat it supports.

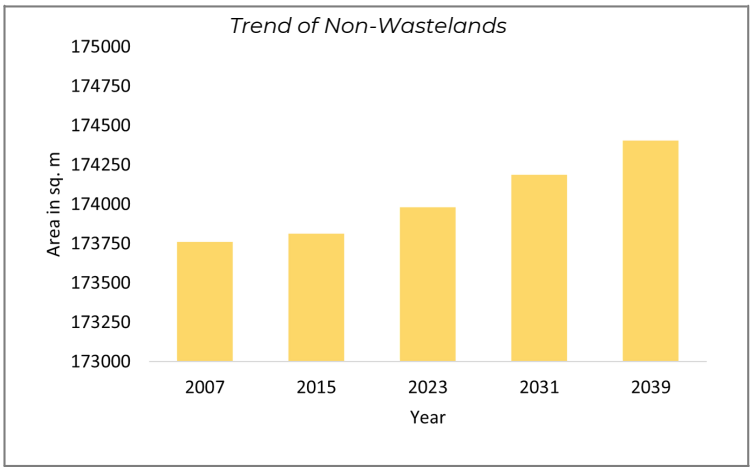
Recommendations

- Underutilized lands are expected to decrease in the state, and to be converted into forests. This trend will be a prospective trend in forest conservation & afforestation.
- Since the state has the largest potential in tourism sector, efforts must be taken to appropriate lands to benefit this sector.



GUJARAT



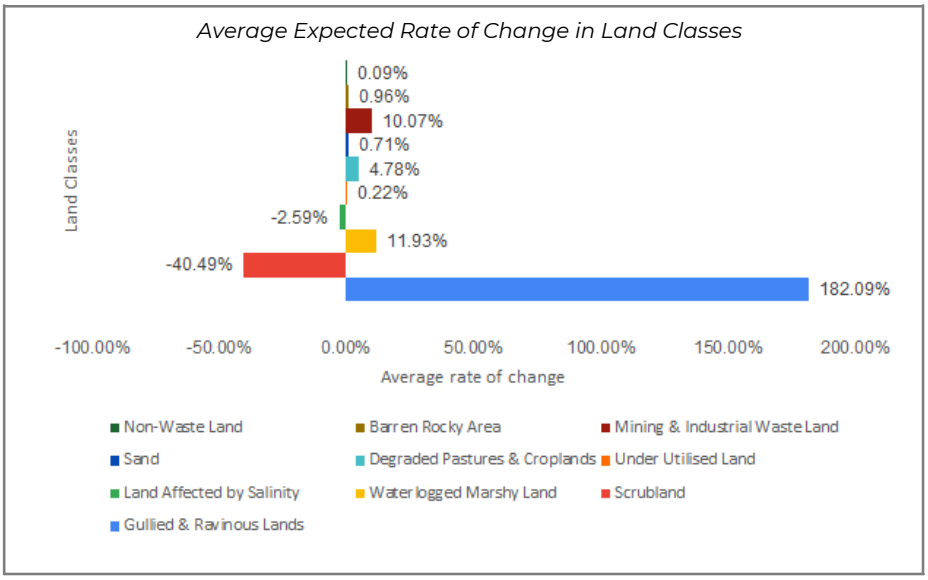


Observations

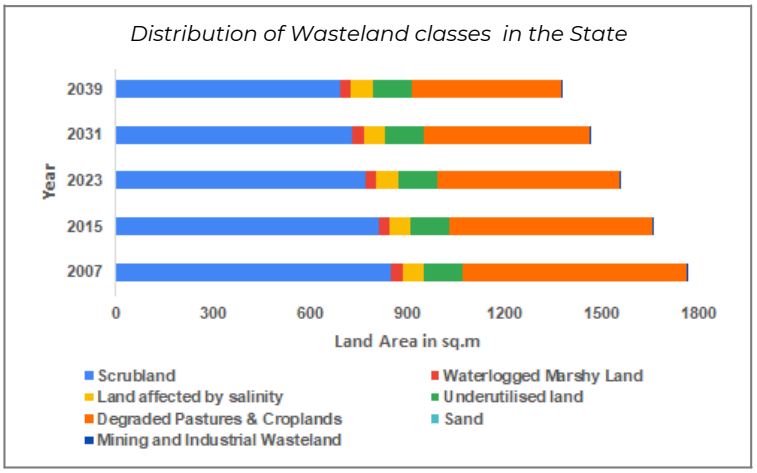
- Over the years, wastelands are expected not to decrease in the state. More land is expected to be brought under economic use only at a very slow rate.
- The most startling observation here is the predicted spontaneous increase in Gullied and Ravinous Lands. It is expected that this land class would increase by over 68 times.
- The increase in Gullies and Ravines is, however, commensurate by an equal decline in Scrublands.
- As observed from the transition matrix, it is predicted that over the period, Scrublands would lose their plant cover degrading the land into Gullies. This can prove to be a threat to the biodiversity supported by scrublands.

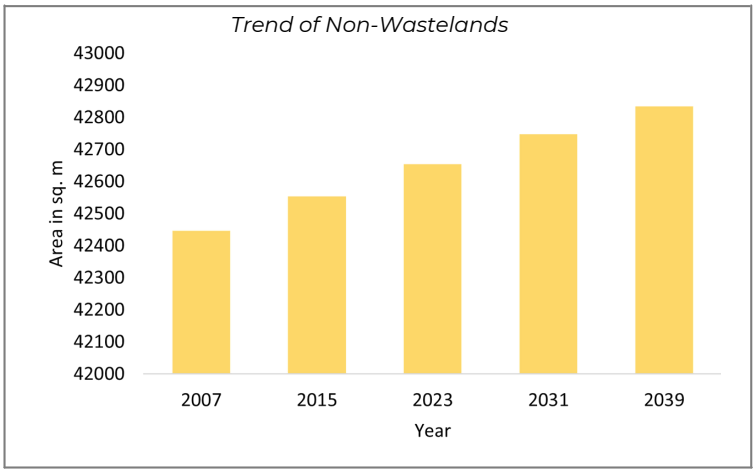
Recommendations

- The stagnation of non-wastelands will be a problem for a development-driven state like Gujarat. Ravinous lands can be refurbished to set up industry. This should be given priority, since a spurt in this land class is expected in the state.
- Underutilised lands can be put to better use, as resourceful forests through afforestation.



HARYANA



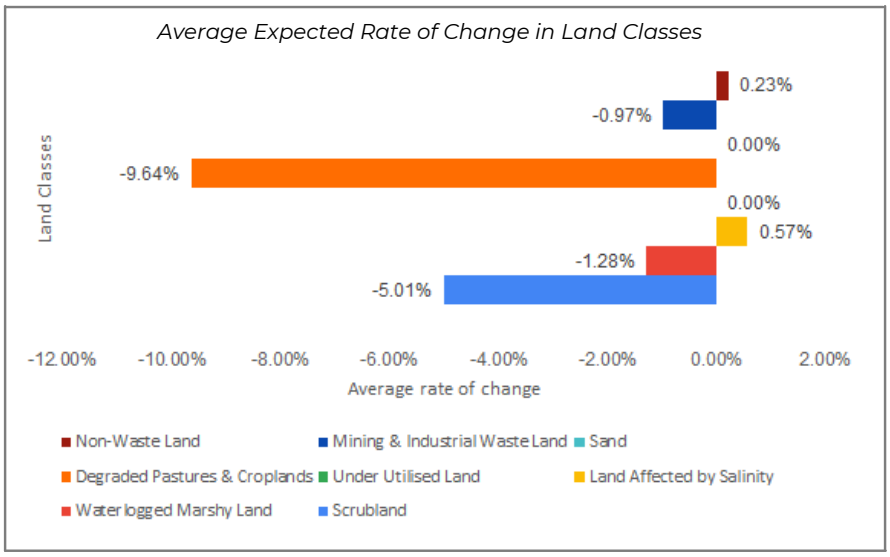


Observations

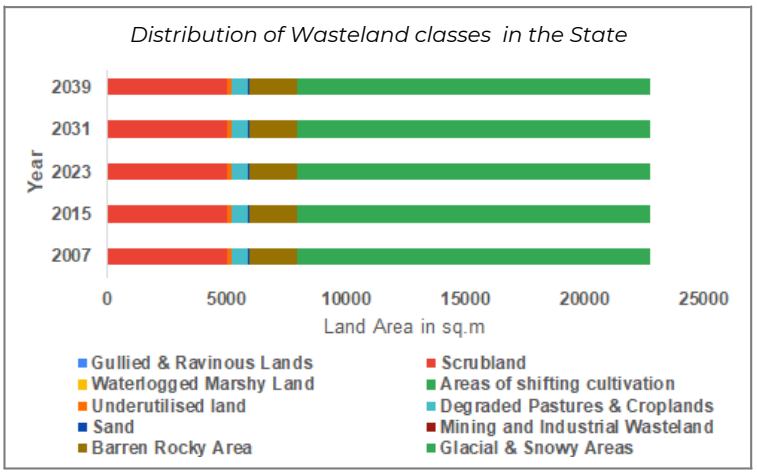
- A degreasing trend in wastelands is expected over the period. However, the transition of wastelands into non-wastelands is noted to be weakly significant.
- A decrease in degraded pastures and farmlands is noted to be the highest in this state. The transition matrix also validates that these lands are increasingly being converted to agricultural lands.
- The decrease in scrublands is also expected here. Even these lands are expected to be converted to grazing pastures or arable-land overtime.
- Though very limited in area, waterlogged marshy lands found here are also expected to further decrease. This can be a threat to the biodiversity supported by the swampy-marsh ecosystem.

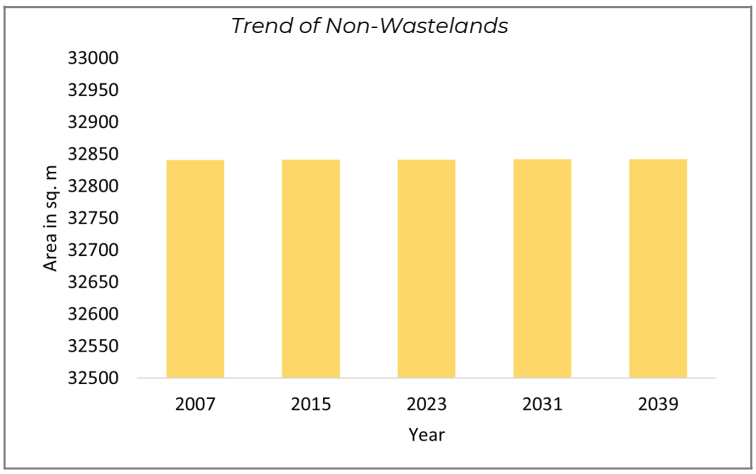
Recommendations

- The decrease in wastelands is expected to be due to the transition of wastelands to agricultural lands.
- Expansion of agriculture is necessary in a state with an expanding population, but it can prove to be counterproductive if they tend to be chemical and water intensive. Therefore, sustainable and environment friendly agriculture is to be ensured here.



HIMACHAL PRADESH



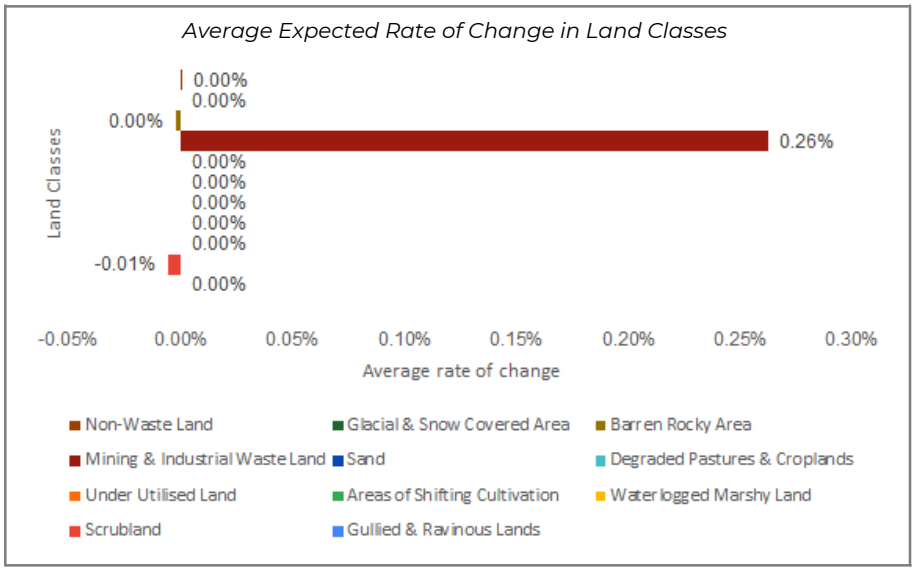


Observations

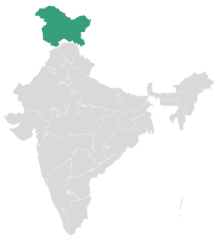
- The land use distribution in the state is expected to be almost very stagnant. No significant transitions of land classes from one type to another are predicted in the state.
- Over 45% of the land area in this state is wasteland and the same is expected to remain stagnant over the period. This can be due to the reason that much of these lands are protected regions due to their ecological and environmental significance (For e.g. Glaciers and alpine meadows that cover about 1/5th of the state, cannot be put to economic use).
- The only transition observed here is the conversion of Scrublands to Mining Wastelands. Though minor and insignificant in the current modelling, it can prove to be a serious environmental menace, if left unabated now.

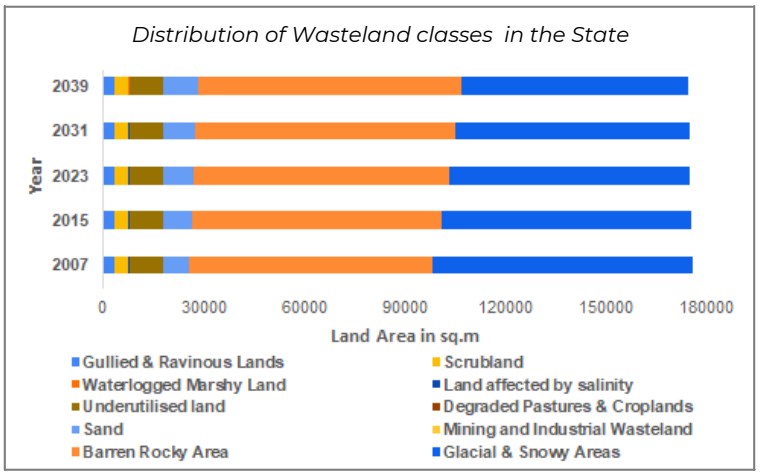
Recommendations

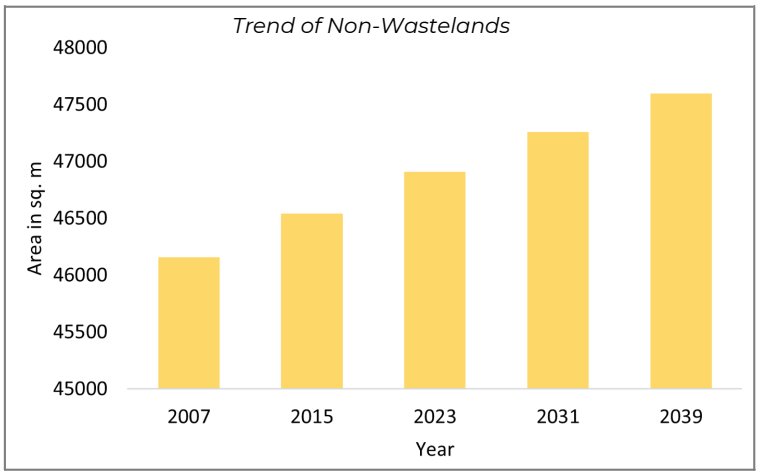
- The stagnancy expected in the state, is beneficial. Climate change is sure to impact the pristine terrestrial ecosystem of the state. Efforts would need to be taken to protect them.
- Other developmental activities in the Non-wastelands also should be intended to preserve the state's ecosystem.



JAMMU AND KASHMIR





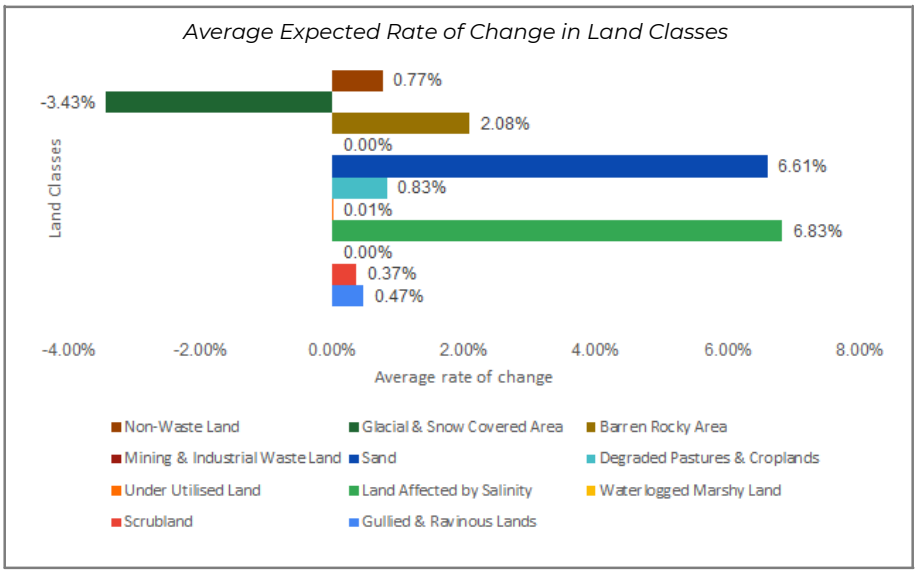


Observations

- A marginal increase in Non-wastelands is expected here. The largely uninhabited nature of the state can be a reason for the slow land development here.
- While a fall in snow and glacial cover is predicted, a complementary increase in Barren Rocky Area is also expected. Glaciers are also expected to be converted into waterbodies. These observations, undoubtedly, refer to melting of glacial caps exposing the mountainous rocks beneath.
- The rise in Desertic sand cover is also a valid observation made in the region. The protection of these cold deserts are vital as they are unique to this region.
- The increase predicted in Gullies and Ravines is due to improper watershed management.

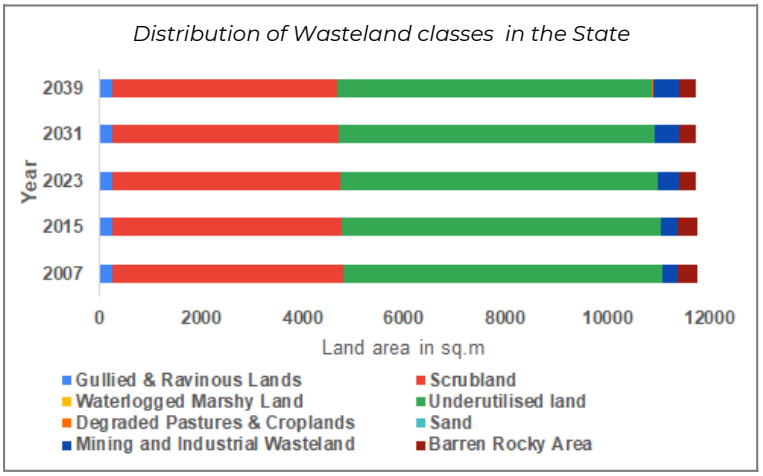
Recommendations

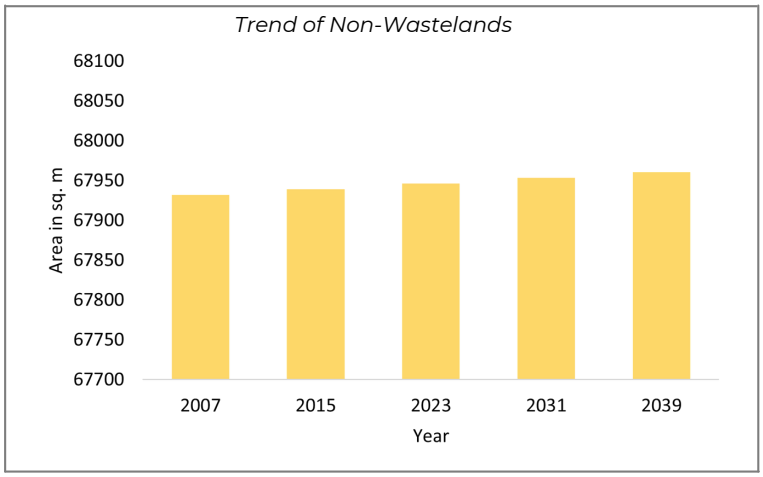
- Land development in the region has always been a crucial matter, owing to its backwardness and its strategic importance. The recent land development activities, however, provide better hopes.
- Additional efforts are also needed to be put to protect the pristine ecosystems unique to the state.



NB: Similar to the Wastelands Atlas of India, this analysis also studies the present-day union territories of Jammu & Kashmir and Ladakh together. And the land under study includes those regions that are not under Indian control.

JHARKHAND



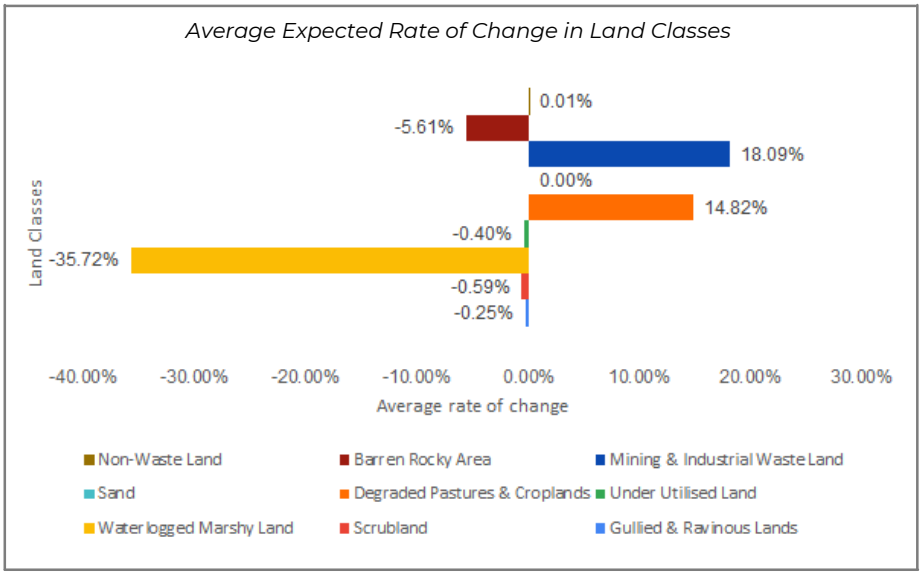


Observations

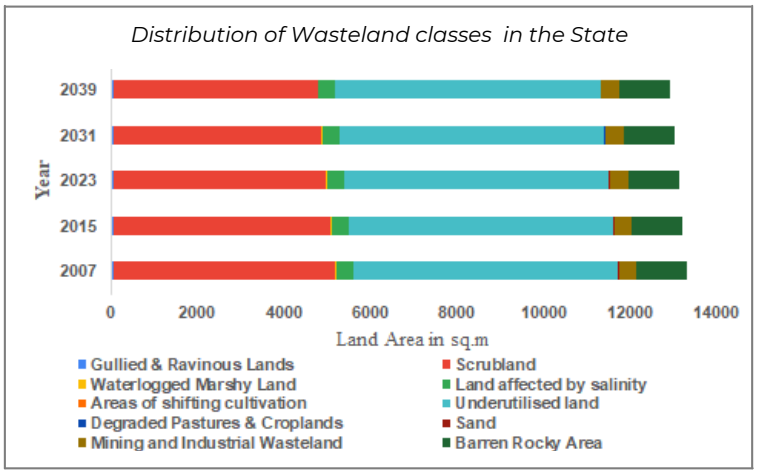
- Transition of wasteland classes into better economic utilities is expected to be negligible in the state. The development of lands is also largely stagnant here.
- A vital observation made here is the rise in Mining and Industrial Wastelands. Given the immense mineral resources found in the state, mining is bound to be a major activity here. However, the modelling suggests that mining will lead to significant environmental degradation in the state.
- A rapid decrease in Waterlogged Marshy lands is also predicted. The transition matrix directs at the covering up of these lands for industrial purposes. Given the importance of these lands to local hydrology, this trend will need to be curbed.

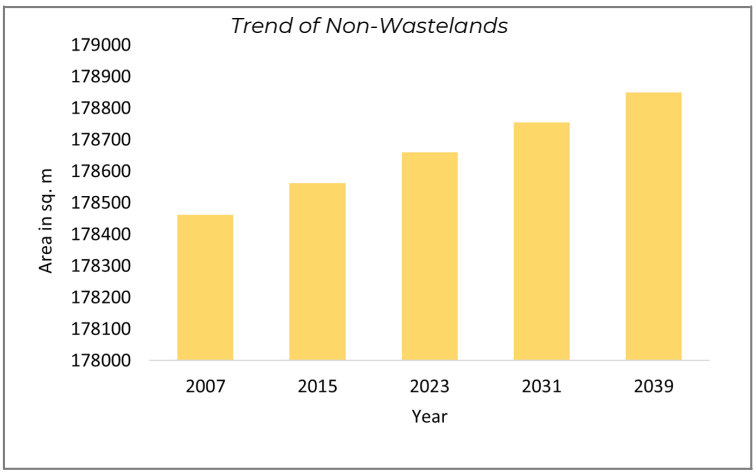
Recommendations

- Mining is seen to increase majorly in the state over the period. Though this will be beneficial for the state, environmental degradation, as suggested by our study shall remain to be a key problem.
- Hence, actions to ensure safe extraction of minerals will have to be focused at by the government.



KARNATAKA



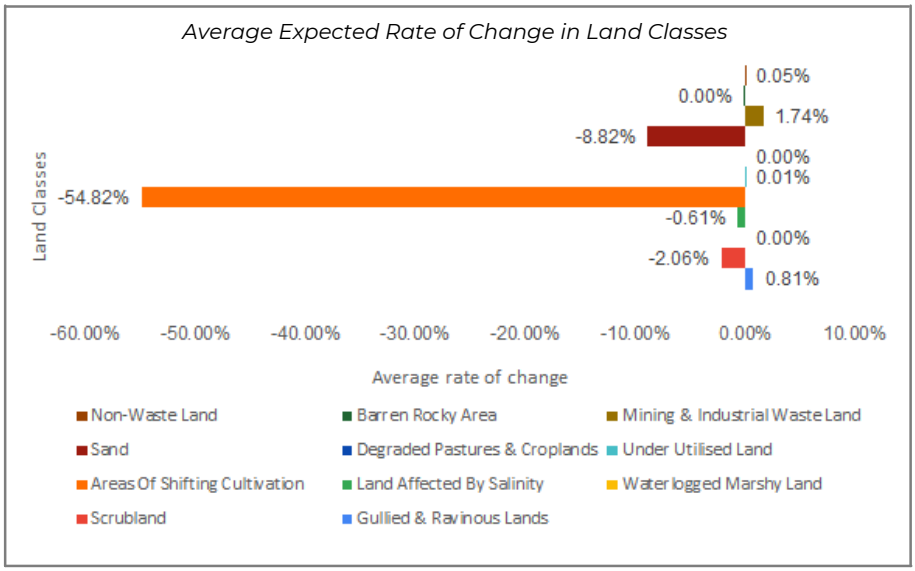


Observations

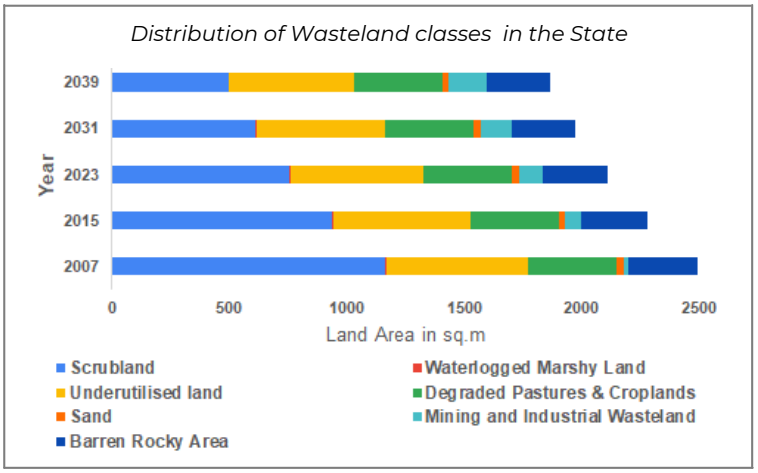
- Over the period, more regions are expected to be converted into Non-Wastelands. The rate of transition is however meagre and is seen only as an increase in agricultural land.
- Areas where shifting cultivation is practiced covers a significant area of the state. The study, however, predicts a decline in this practice over time. This will be beneficial for the forest conservation measures in the state.
- A major fall is expected in lands covered by sand. This is expected to be due exploitative and illegal dredging of riverine sands in the state. This practice shall affect the riverine systems and can lead to water scarcity in the state.

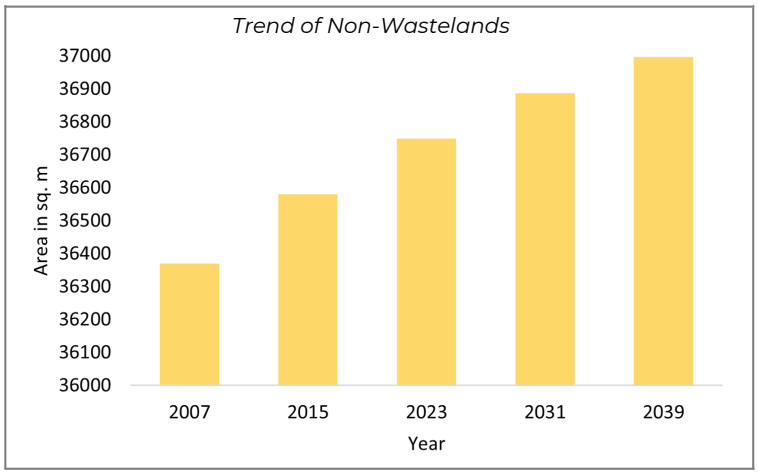
Recommendations

- Underutilised land remains to be a significant portion of 'wastelands in the state. They can be converted to arable lands, industrial areas or to commercial forests.
- Hence, the state must focus in this regard as this land class can be put to better use effortlessly.



KERALA



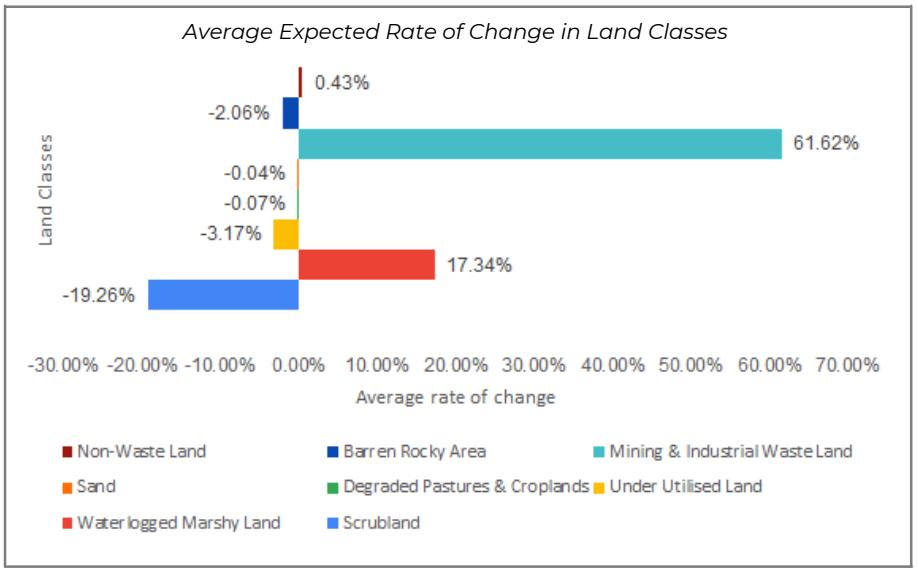


Observations

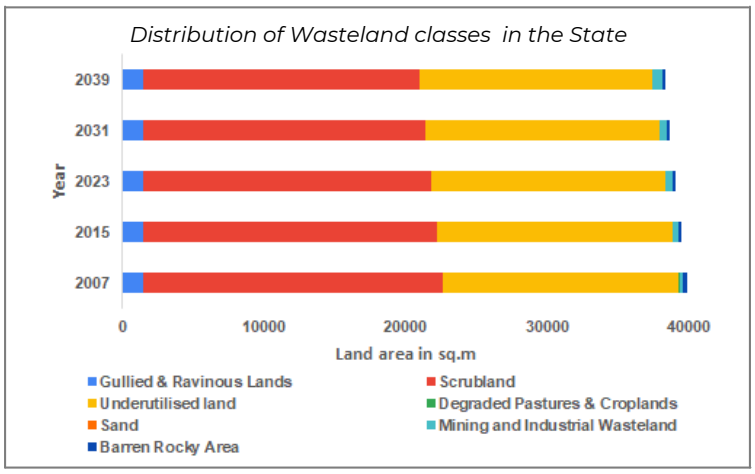
- Over the years, wastelands are expected to fall significantly. This means that, there has been and there will be measures taken to ensure better use of lands.
- A positive change in wasteland is seen in the increase of mining and industrial wastelands. This may be due to the growth of secondary sector in the state.
- A gradual decrease in scrublands is expected in the coming years.
- As can be observed from the graphs, the barren and rocky lands and parts are going to stay almost constant. This forecast can be used to start working on these lands and converting them into areas with vegetations or for industrial purposes.

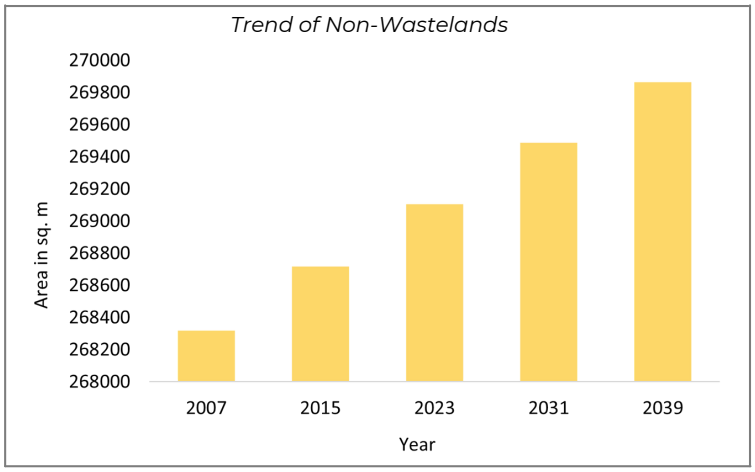
Recommendations

- Underutilised land also remains constant over the years. Measures should be taken to fully utilise these lands and make the most of what they can offer.
- As Kerala is one of the most densely populated states in the country, targeted efforts will have to be taken to ensure effective conversion of lands to economic use.



MADHYA PRADESH



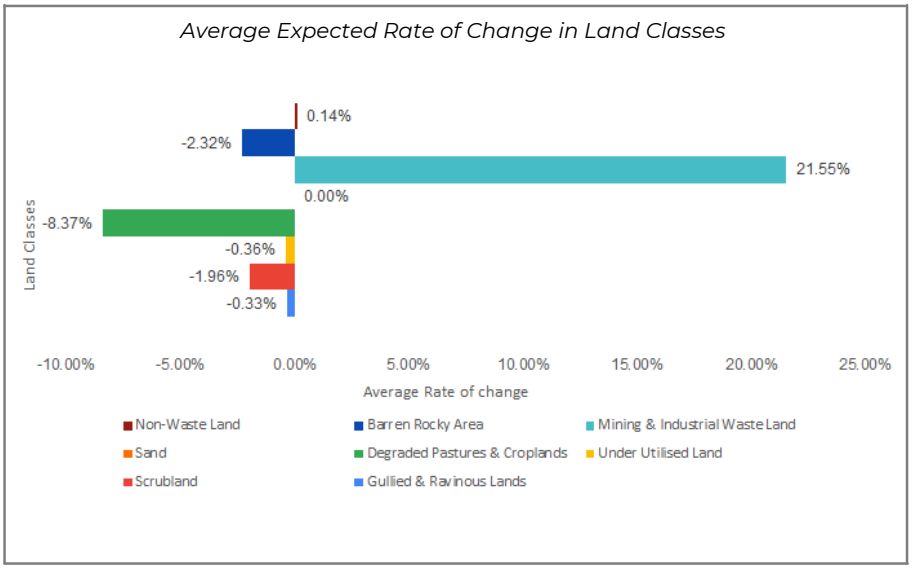


Observations

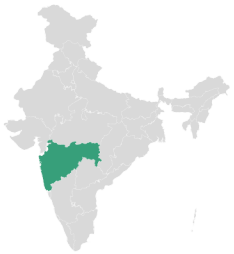
- Through the graphs, it can be concluded that the amount and percentage of non-wastelands are going to grow substantially till 2039. This means that steps should be taken to upkeep this projected growth.
- A large percentage of the land in this state is scrublands. The percentage seems to remain constant over the period. This can contribute to loss of lands available for pasture and agriculture. Since, these lands are spread over large areas, the risk of fires spreading also increases.
- As can be observed the proportions of most types of lands remain constant throughout. For example, gullied and ravinous lands along with underutilised lands show little to no change in the future.

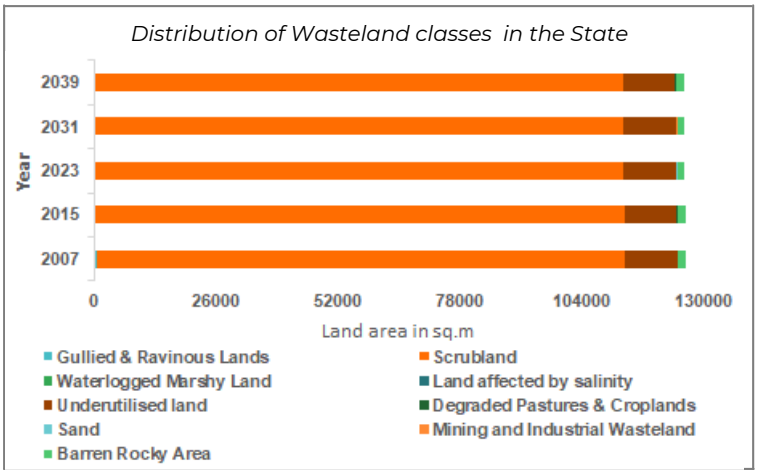
Recommendations

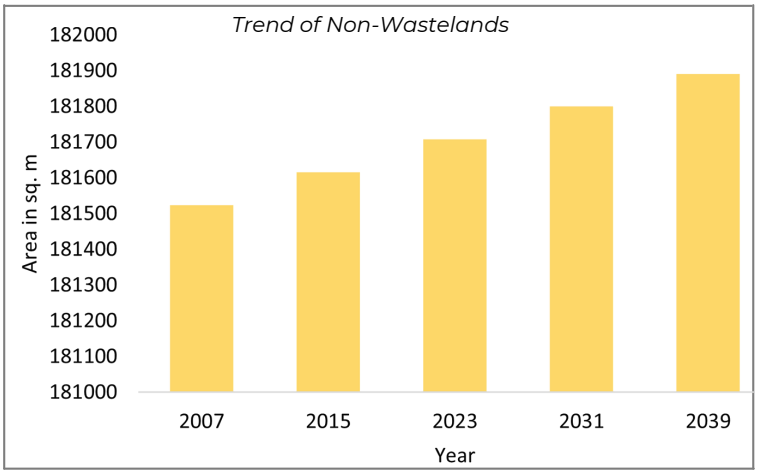
- A very rapid increase in the proportion of mining and industrial lands is expected. Steps have to be taken that no illegal methods are used for mining in the state.
- Mining of riverine sands is also a key issue in the state as it is choking the Narmada river. The same is reflected by the negative growth rate of Sands here.



MAHARASHTRA





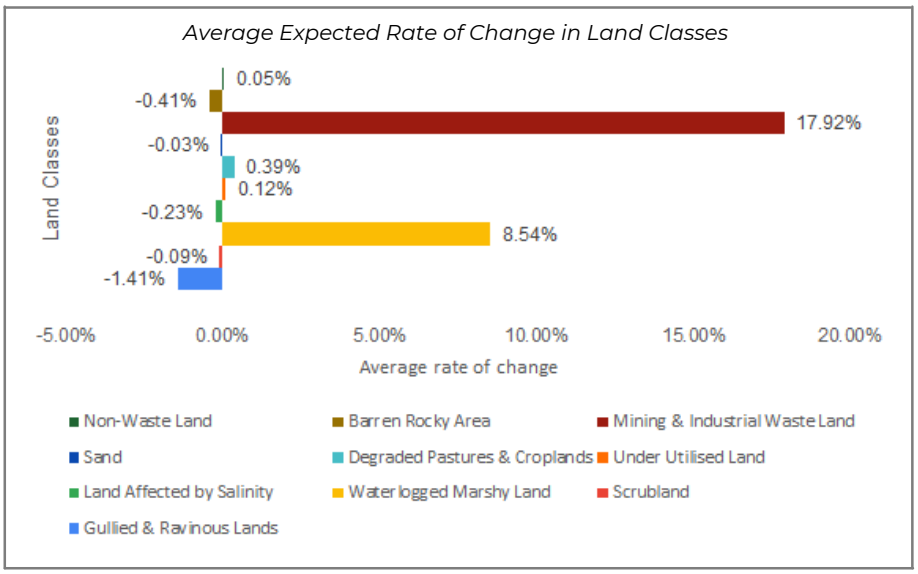


Observations

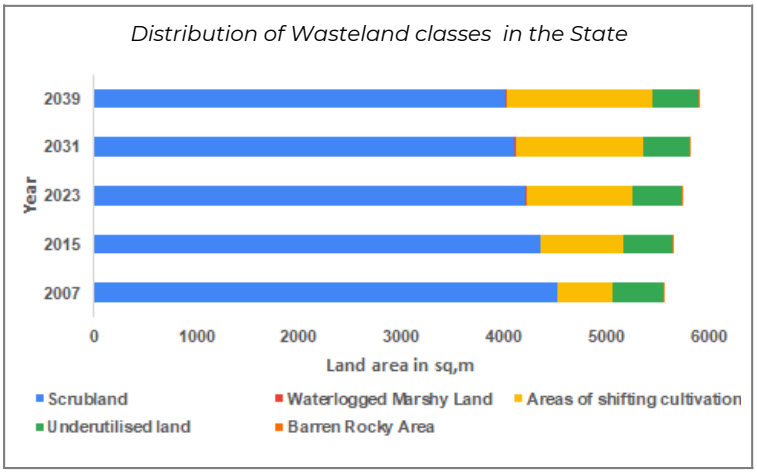
- A change in land use patters in the state is not expected. The rate of conversion of wastelands into economic usage is very negligible.
- Scrublands constitute the largest proportion of wastelands in the state. They can be effectively re-appropriated into arable lands, grazing fields or forests.
- The percentage and proportion of underutilised land would remain constant in the period. Hence, measures should be taken to better utilise these lands to benefit the state's growing population.
- A rise in Waterlogged Marshy lands is predicted. Though this shall benefit in better watershed management, excessive waterlogging can affect agriculture.

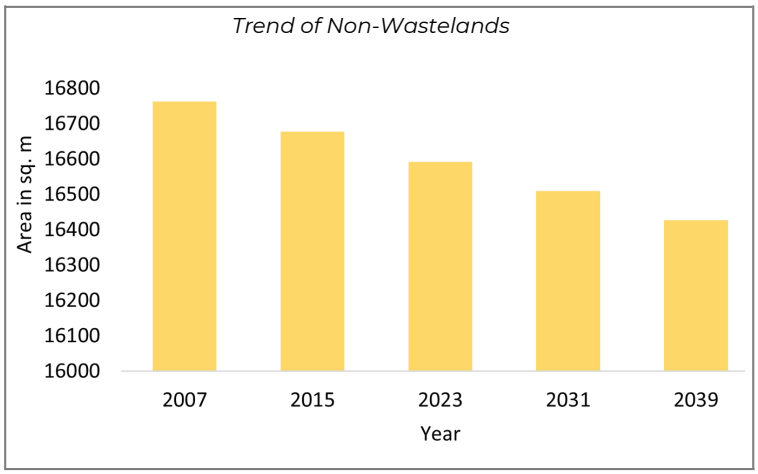
Recommendations

- The state has a very high proportion of scrublands which is going to remain same overtime. Scrublands decrease availability and access to land for agriculture.
- Fires in such lands spread very rapidly because they are spread over large areas. Hence, appropriating them into farmlands or grazing planes must be considered.



MANIPUR



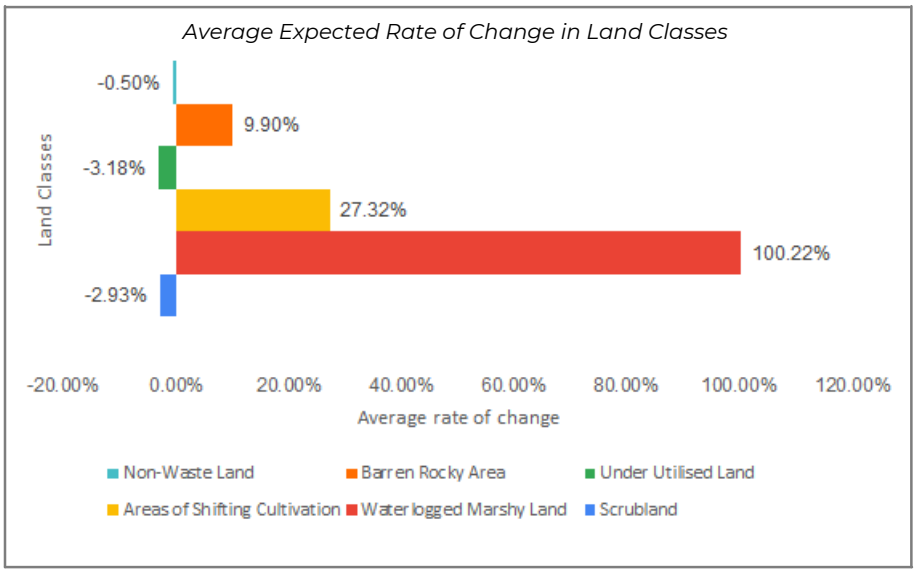


Observations

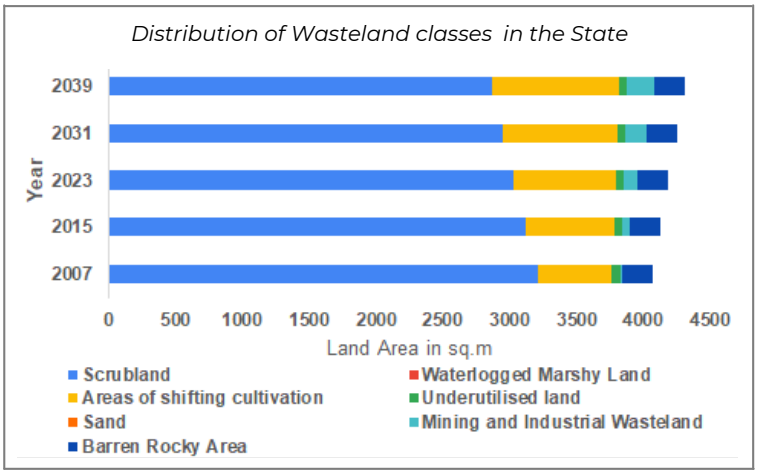
- The startling outcome that can be seen from the graphs is that the percentage of non-wastelands in Manipur is expected to continuously decrease from the current year till 2039.
- It can be seen from the graphs that the amount of land involved in shifting cultivation is going to increase constantly till 2039. This form of agriculture has many environmental hazards and eventually deprives land used in this practice of soil and nutrients.
- A degradation of Manipur's famous mashes and waterbodies is not noted. However, it may become a threat to human settlements, given its rapid rate of growth.

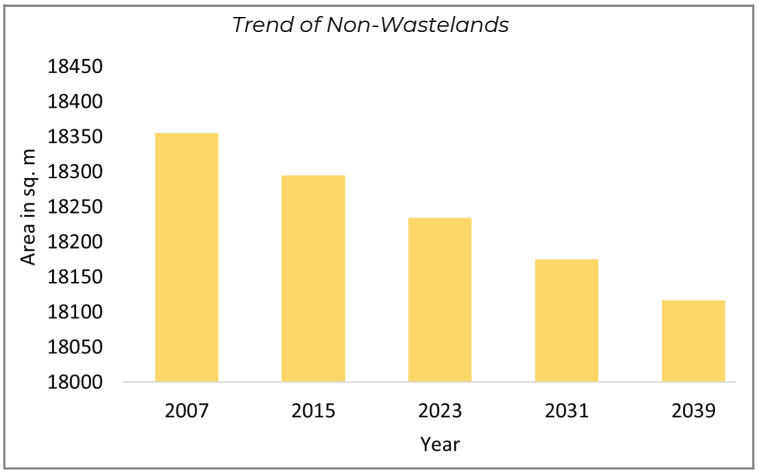
Recommendations

- Scrublands show a decreasing trend while area under shifting cultivation show a rising trend. This could mean a degradation of vegetation for slash-and-burn.
- Steps should be taken to eliminate this type of agricultural practice as this hilly state will continue to get polluted.



MEGHALAYA



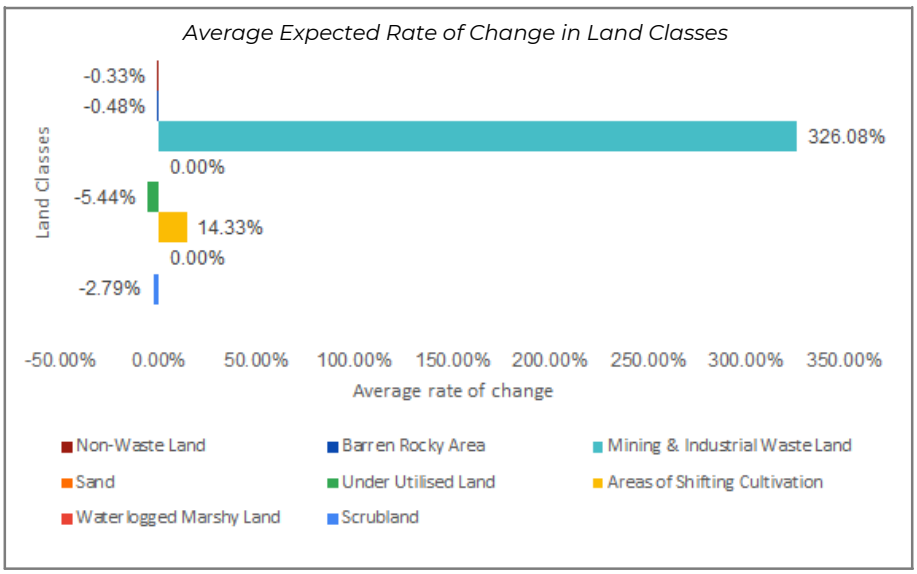


Observations

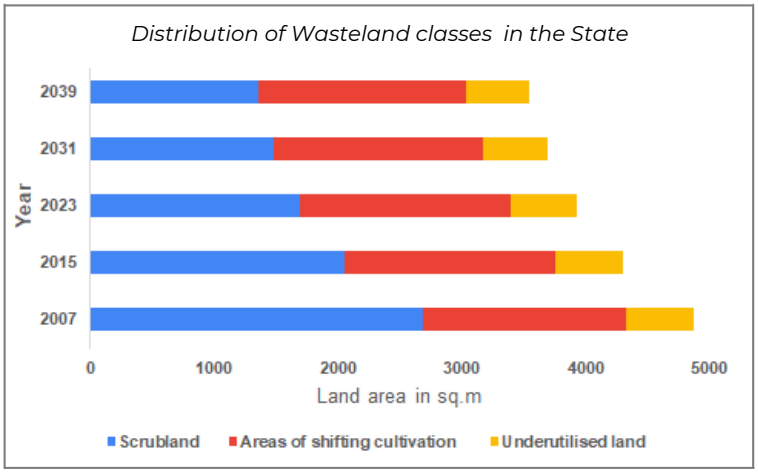
- According to the projection, it can be interpreted that wastelands in Meghalaya are going to increase over time.
- The state has very large parts of land covered in scrubs and this appears to remain constant in the future as well. Measures need to be taken from now on to better utilise these lands and mitigate lands from becoming scrublands to increase the efficiency of these lands.
- A slight increase in the portions of lands used in shifting cultivation can be seen through these graphs. Steps need to be taken to decrease the percentage of people implementing such type of farming as this negatively contributes to the land quality by depriving the soil of nutrients.

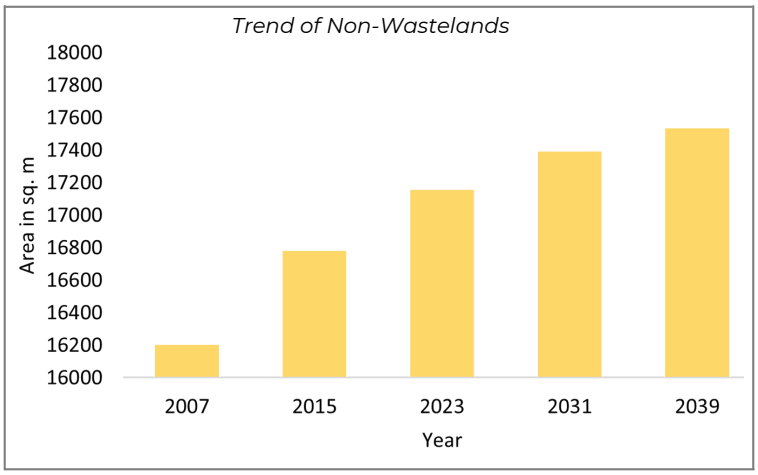
Recommendations

- There appears to be a rapid increase in mining and industrial wastelands. Unscientific mining practices prevalent in the state can be a reason for this. Steps should be taken to control this practice to prevent further degradation of lands
- The focus needs to put on codifying mining activities in the state.



MIZORAM



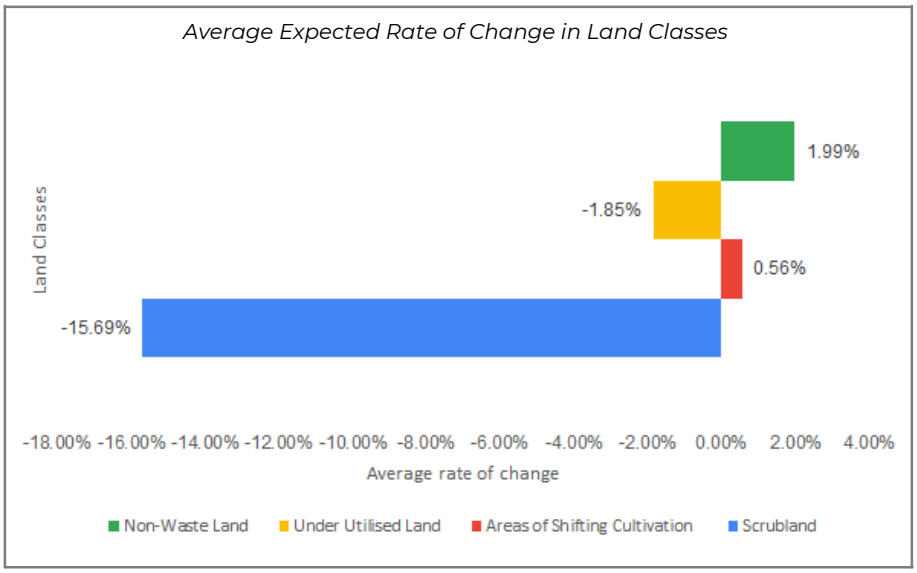


Observations

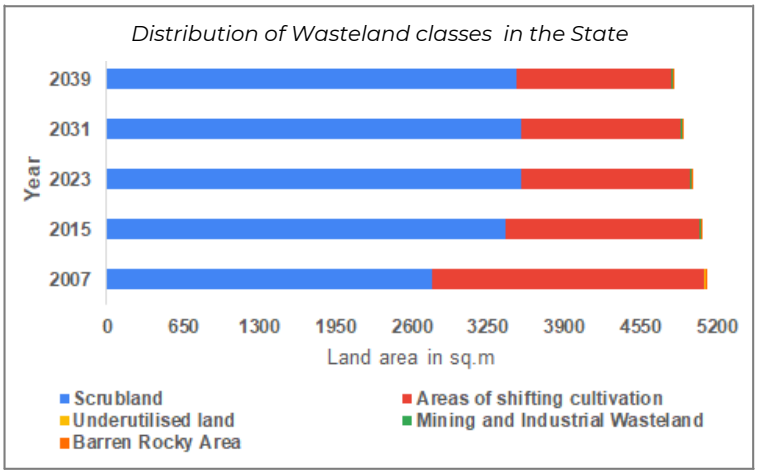
- From the graphs, it can be seen that there is going to be a considerable increase in the area of land that are non-wastelands. The measures taken in the state are hence, understood to be effective.
- There appears to be a significant decrease in the proportion of scrublands, which is a major type of land in this state. However, it is seen from the transition matrix that much of these lands are getting converted into Dense Forests. This is a significant achievement in the state, as protection of forests is of utmost importance in this ecologically diverse state.
- Large areas of land in this state are used in shifting cultivation and there appears to be no major trend of decrease in the proportion of land used for this purpose. This can become make the whole state worse-off in the end.

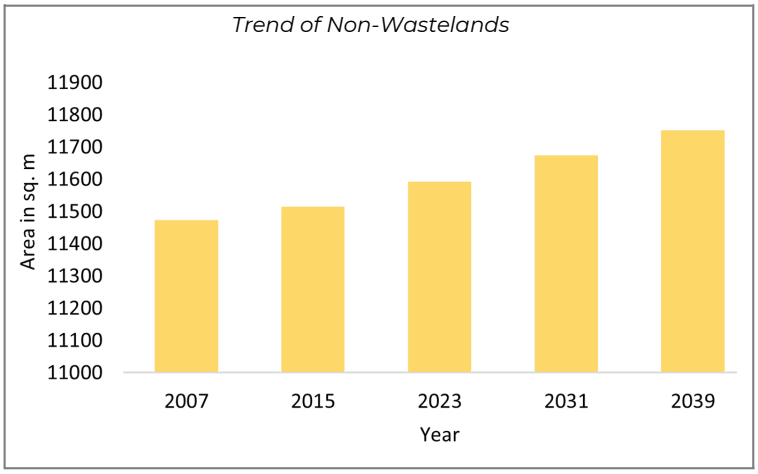
Recommendations

- It is observed that more scrublands are being cleared for shifting cultivation. While some other lands are converted into forests.
- Measures will have to be taken to curb Jhum in the state, as this leads to more air pollution, loss of floral diversity and degradation of soil.



NAGALAND



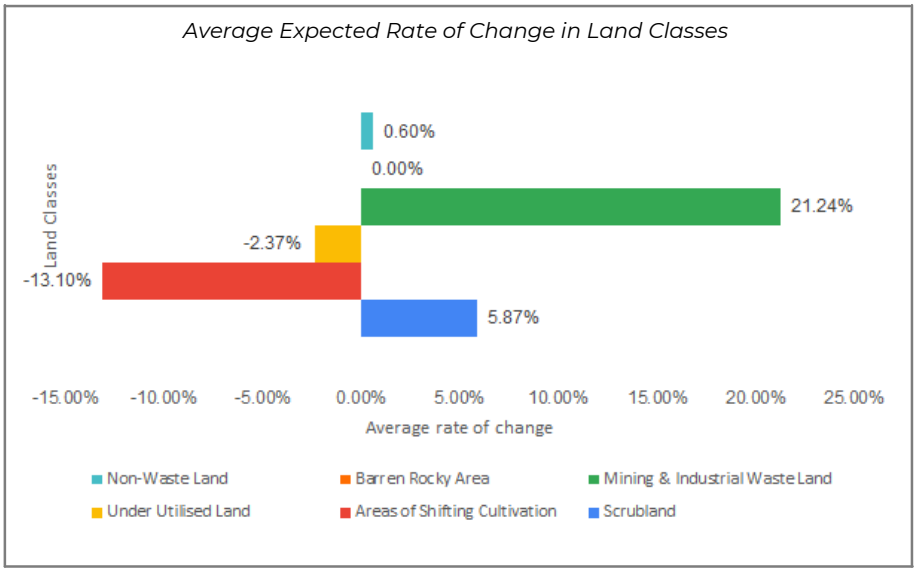


Observations

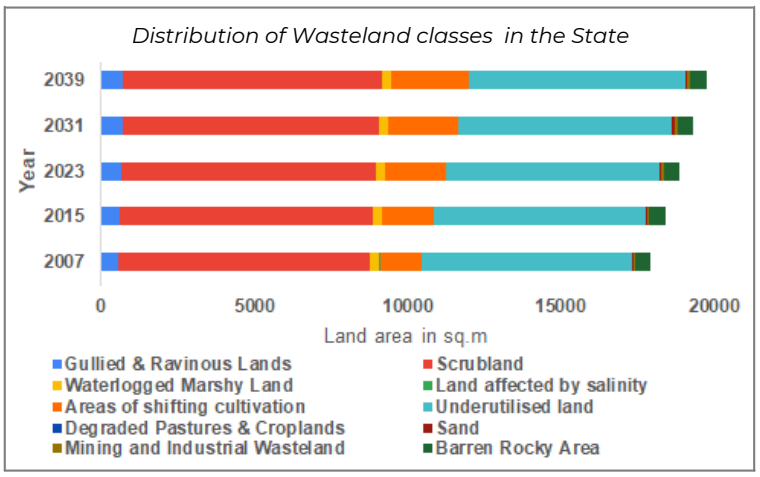
- Wastelands in the state are expected to decrease over the period. This is an important observation for the state, though the rate is observed to be much slower.
- Area under shifting cultivation and underutilised lands are expected to decrease over time. As observed from the transition matrix, abandoned jhums are expected to get transformed back into forests. This is a relavant observation as it contradicts the predictions made in other similar states. The practices in forest management followed here can also be replicated in other states.
- Mining and Industrial wastelands are observed to increase in the state. Given that the state has ample scope for petroleum mining, this prediction is bound to be true. Hence, exploitation of these resources, will need to be executed carefully.

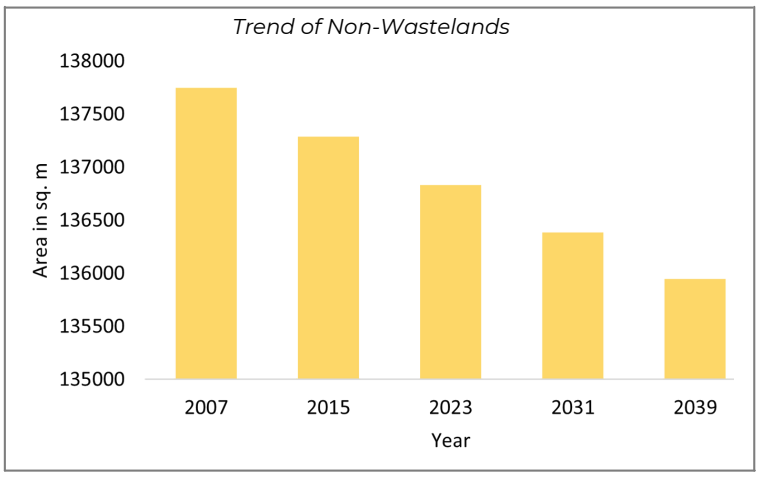
Recommendations

- It is observed that more scrublands are being cleared for shifting cultivation. This may be counterproductive with the preceding observations.
- Measures will have to be taken to curb this practice as this leads to more air pollution, loss of floral diversity and degradation of soil.



ODISHA



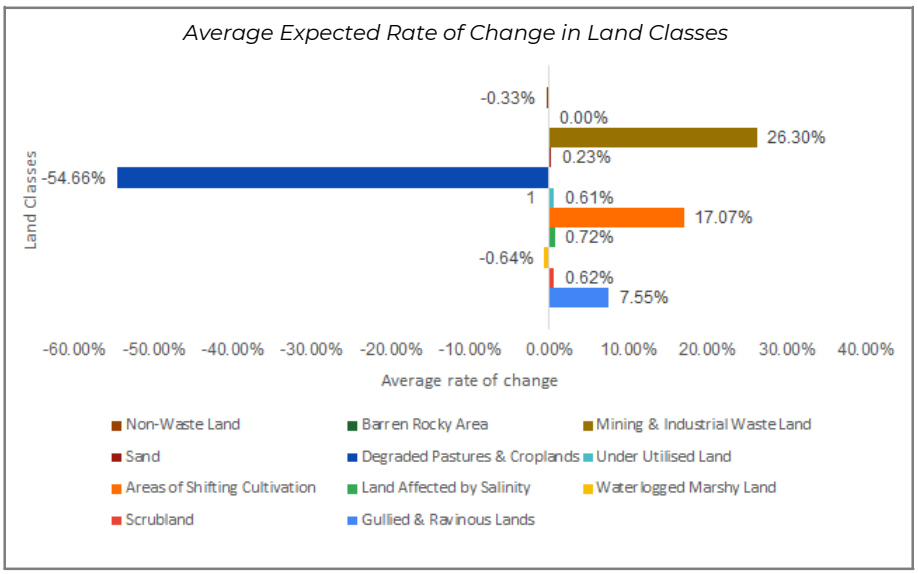


Observations

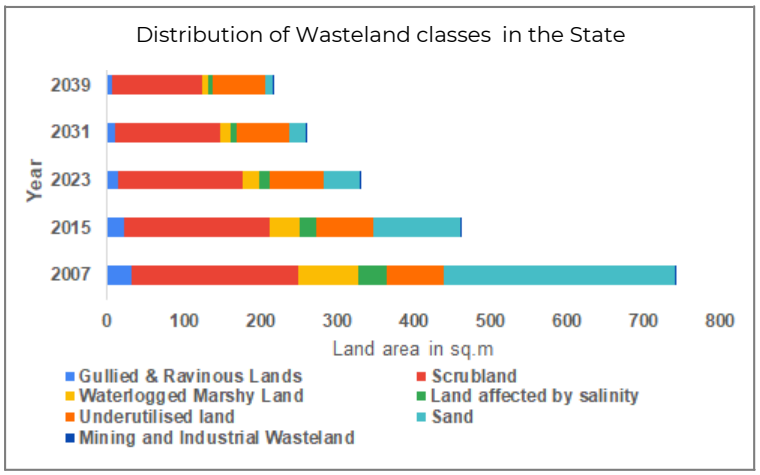
- According to the graphs, it can be seen that the proportions of wastelands are going to increase continuously and substantially over the period till 2039.
- There appears to be a prediction of an almost negligible increase in ravinous and gullied land and underutilised lands.
- Mining and industrial wastelands is expected to increase in the state over this period. This can have serious ramifications, as mining is a major sector in the state.
- The rapid decrease in degraded pastures and croplands is seen due to their conversion into built areas.
- Erosion of soil by water is observed to become a major problem in the state over the period.

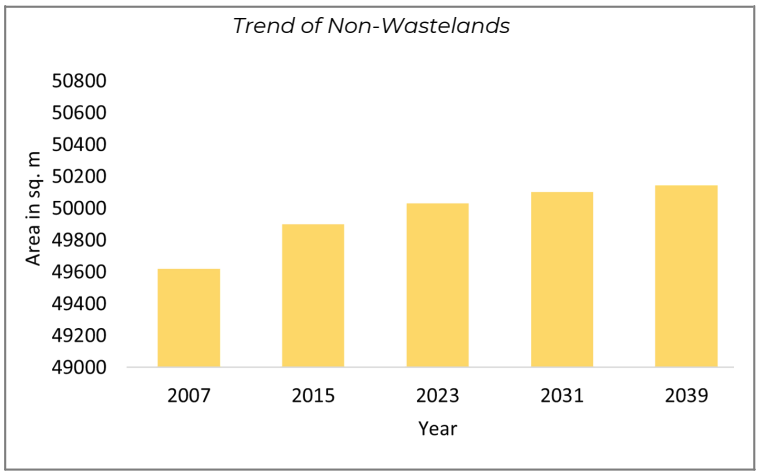
Recommendations

- From the graph, a slight but continuous increase in the proportion of land used for shifting cultivation can be noticed. This along with increase in mining can cause an environmental crisis in the state.
- Steps must be taken from now to prevent this and ensure better techniques of agriculture in the state.



PUNJAB



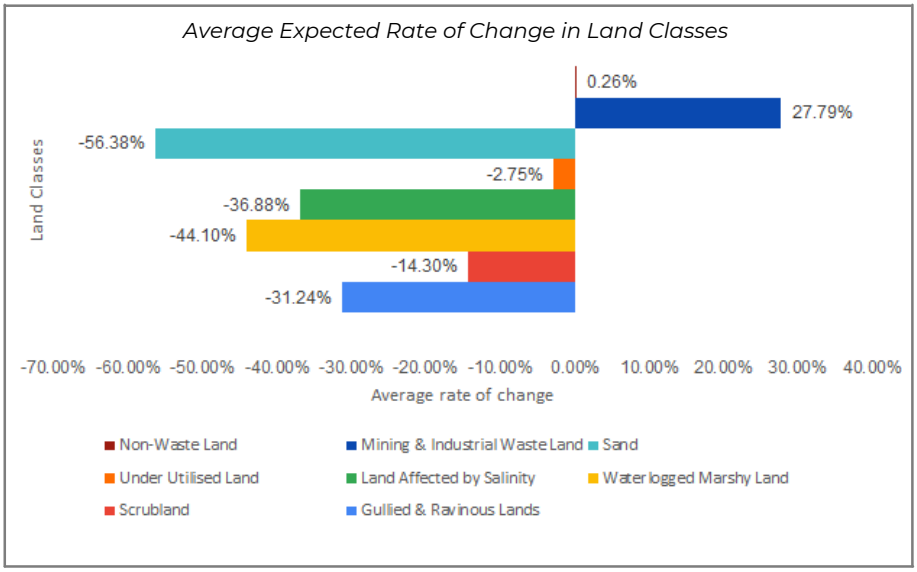


Observations

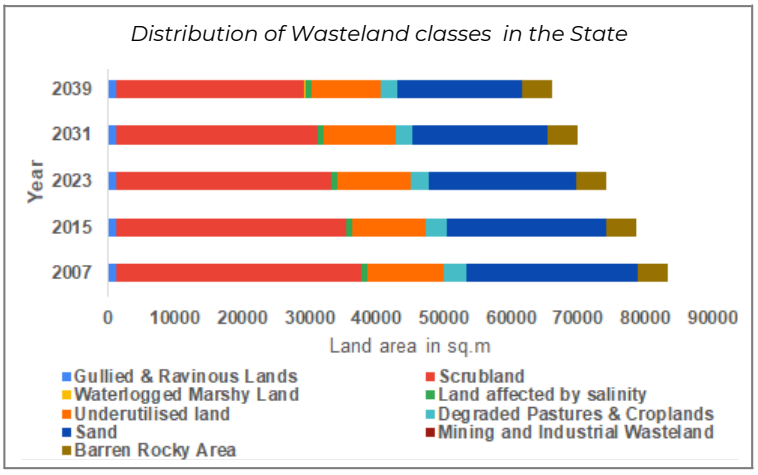
- The state of Punjab is expected to show a drastic fall in wastelands over the period. This would mean that the state will see more land being brought under economic use.
- The state shows significant fall in areas covered by sand. However, sandy areas are expected to decrease at a decreasing rate.
- A similar fall is observed in almost all other wasteland classes, such as underutilised lands, waterlogged marshy lands, gullied lands etc. And from the transition matrix, it is observed that these areas are being converted into croplands.
- The increase in mining and industrial wastelands is to be considered significant, as industrial wastes tend to release toxins which can adversely impact agriculture.

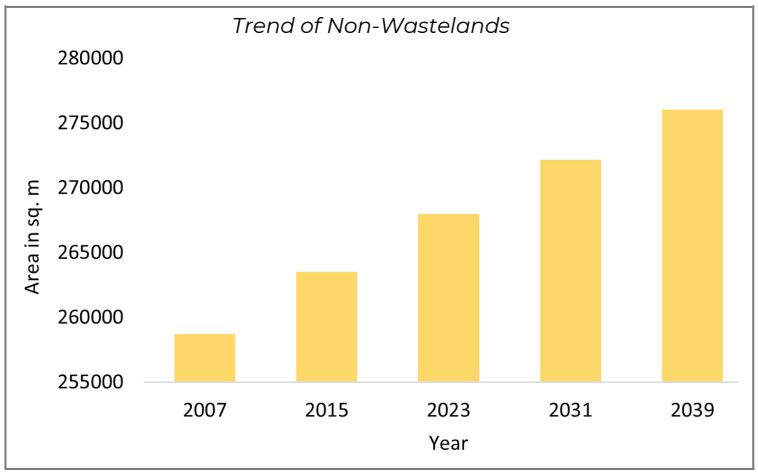
Recommendations

- The positive change in Non-wastelands in seen as a direct effect of the expansion of agriculture.
- While agriculture here will be beneficial for the populace, efforts will have to be taken in ensuring the sustainability of the same.
- Water or chemical intensive agricultural practices should not be promoted in the state.



RAJASTHAN



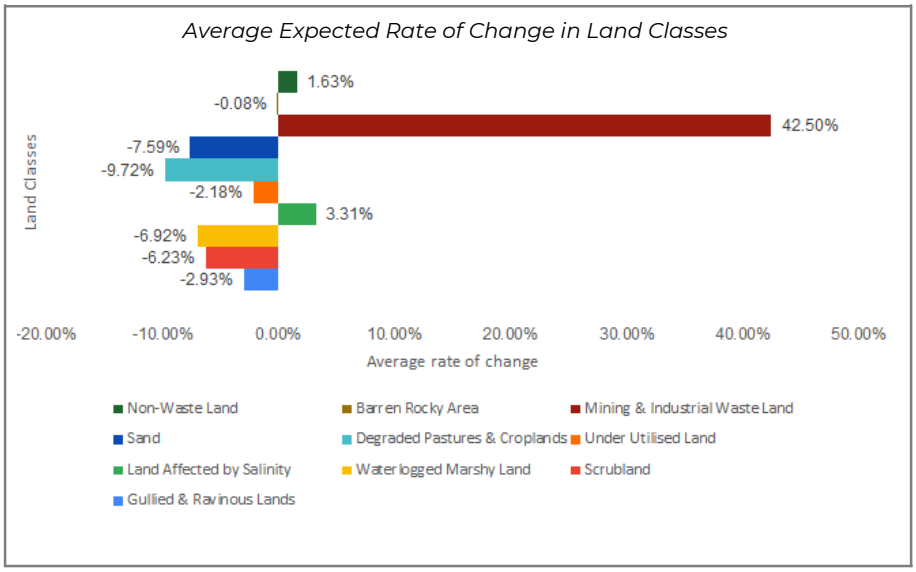


Observations

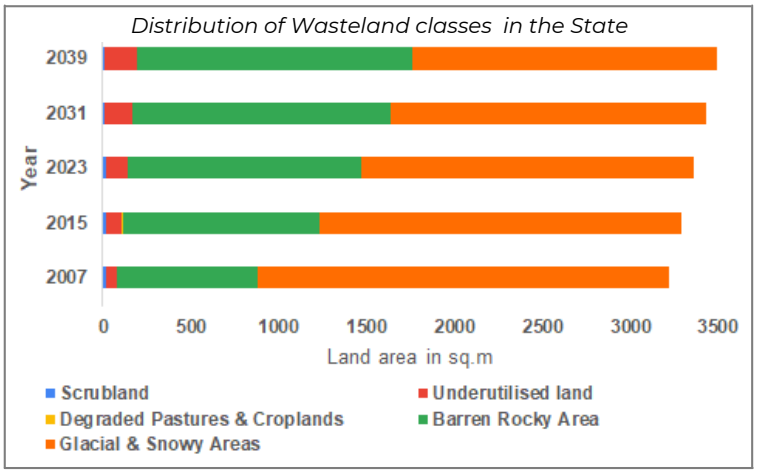
- It is expected that more lands will be brought into useful activities over the period. The state shows a sufficiently large rate of change for non-wastelands.
- The sands of Rajasthan will show a declining trend, though they shall continue to be a major land class of the state. Trends of agriculture in the desert are observed in the state, with the more sandy areas being brought under the plough.
- Mining and industrial wastelands are projected to increase in the state. Mining of sandstone, marble, granite etc is hence noted to be a catalyst of land degradation in the state.
- All other land classes in the state are noted to be transfromed into croplands and built areas.

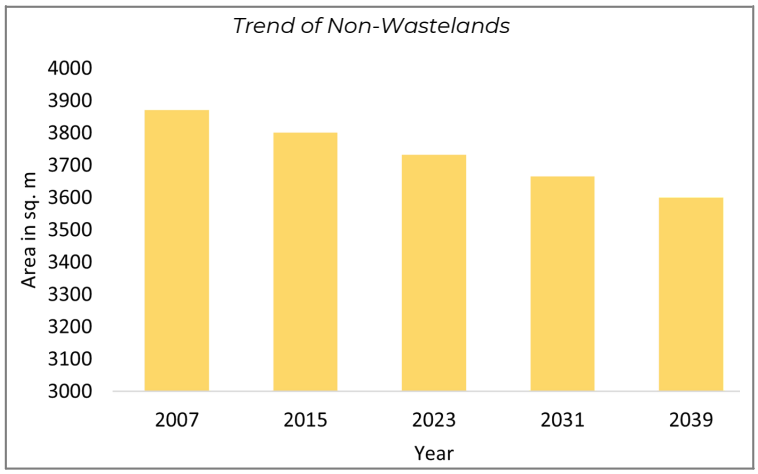
Recommendations

- As an effect of many modern-day irrigation projects, agriculture is expected to increase in the state.
- However, degradation of scrubs and pastures due to overgrazing and extensive mining are noted to be the key problems in the state. Steps shall be taken to abate them.



SIKKIM



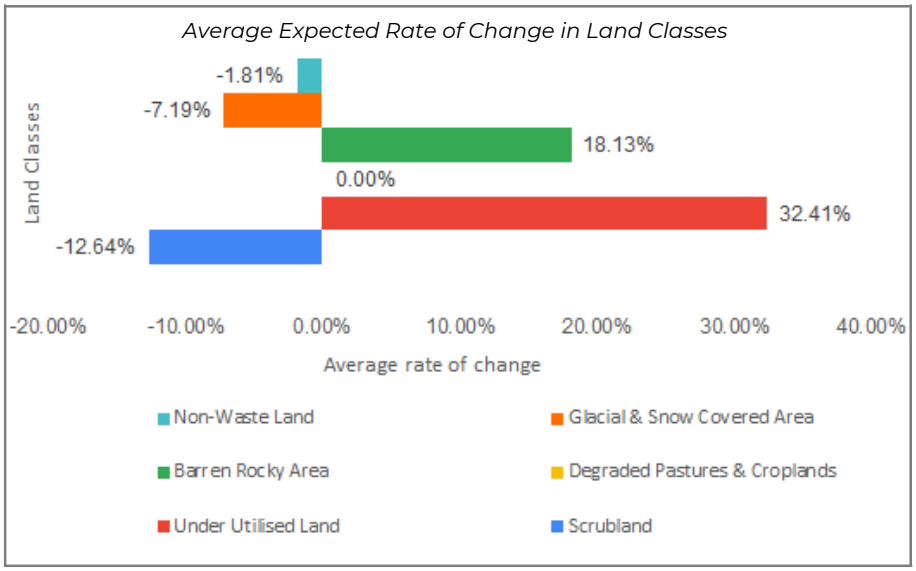


Observations

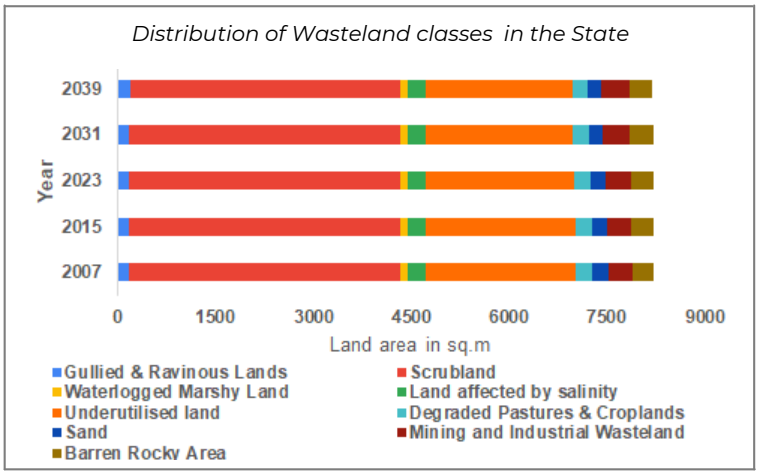
- An overall increase in the wasteland is expected in the state. The rate of decrease in the non-wasteland class is observed to be sufficiently large.
- While a fall in lands covered by Snow and Glaciers is predicted, an increase in Barren Rocky Area is also expected. This observation necessarily refers to the melting of glacial caps exposing the mountainous rocks beneath.
- Though less in proportion, it is seen that more non-wastelands shall get converted into underutilised lands over the period. This may be due to the increased amount of deforestation in the state.
- An interesting observation made is that scrublands may get converted into snow in the state. This is expected to be due to the widespread destruction of the alpine pastures found in the state.

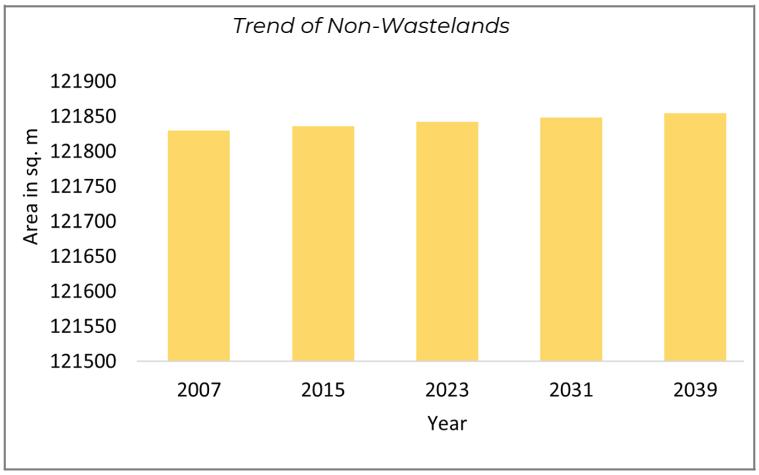
Recommendations

- The increase in wastelands can be an issue, given the infrastructural growth expected in the state over the years.
- The decrease in glacial and snow covered lands and alpine grasslands will be a serious threat to the state's pristine environment. Steps will have to be taken to prevent this.



TAMIL NADU



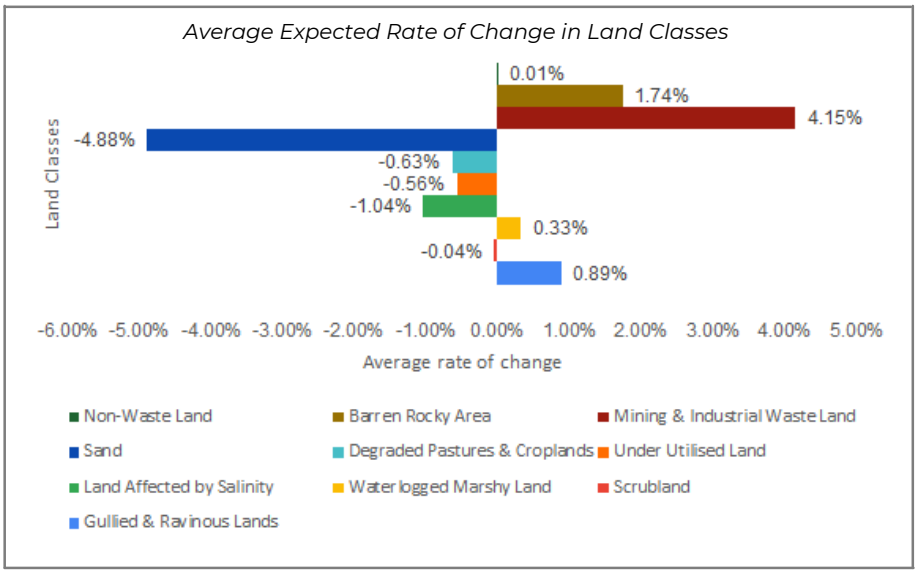


Observations

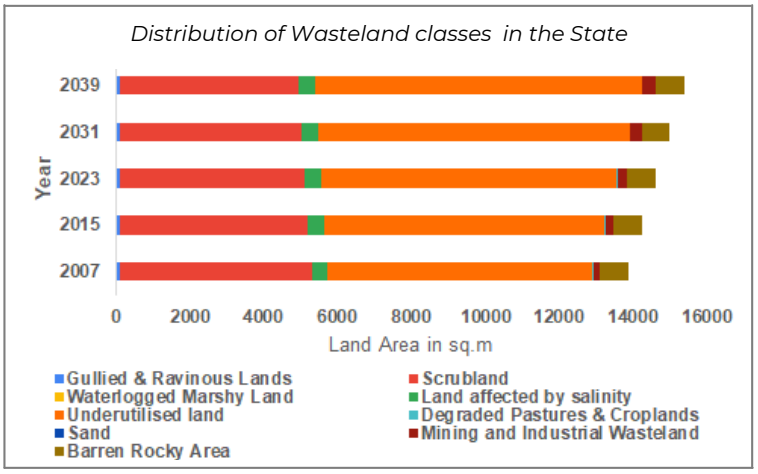
- The transition of wasteland classes into non-wastelands is expected to be very meagre in the state. The distribution of land classes is also expected to be passably constant.
- Underutilised lands cover a major proportion of wastelands in the state. This can be effectively converted into built areas or into plantation crops with ease.
- A major decrease in areas covered by Sand is expected in the state. From the transition matrix, it is observed that sands are transformed into scrublands. It is additionally understood that this is due to the destruction of coastal sand dunes, which are unique to the state.
- The predicted rise in gullies will be due to poor soil management in the state. Focus needs to be laid on that too.

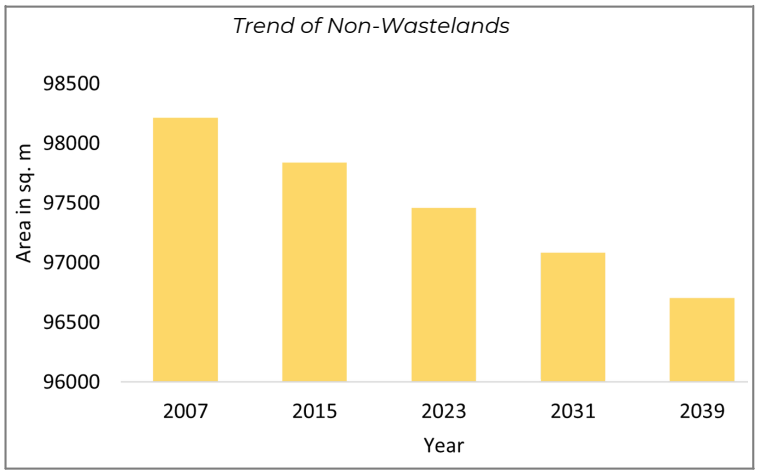
Recommendations

- While a few land classes show a decreasing trend, the overall conversion of wastelands into economical uses is very marginal, as observed. Steps will need to be taken to convert more lands into agricultural lands.
- Degradation of unique ecosystems in the state will need to be prevented at the earliest.



TELENGANA



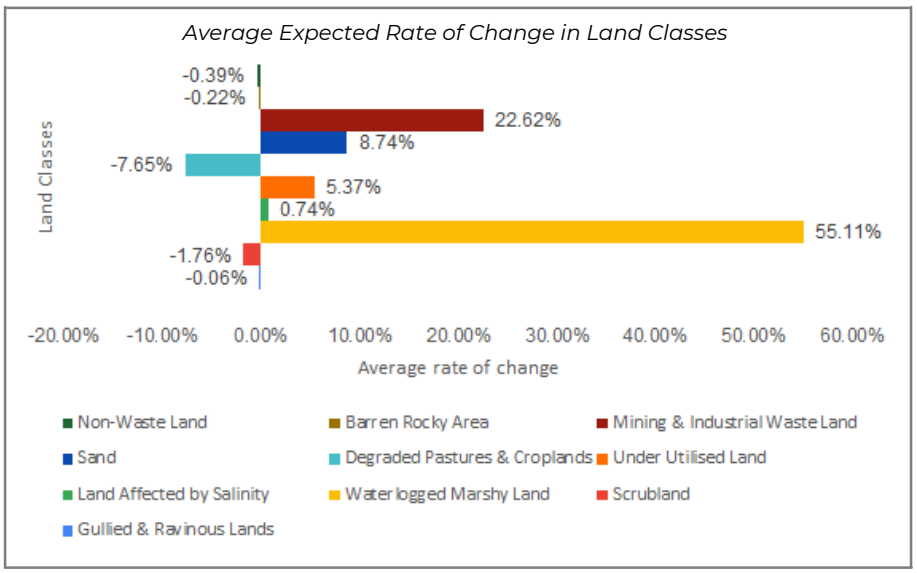


Observations

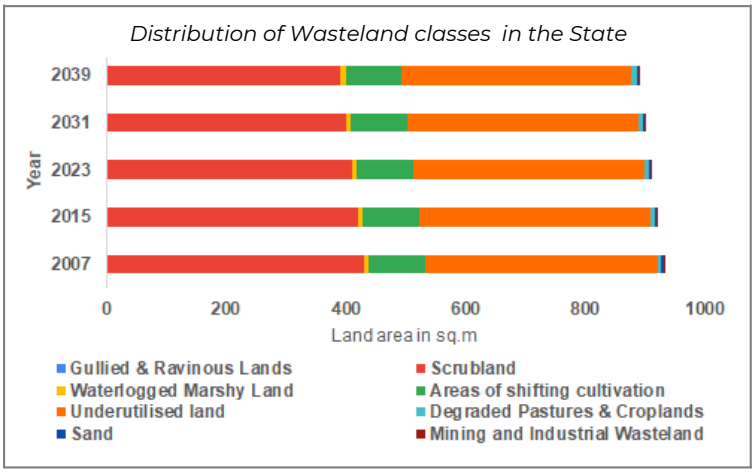
- An increasing trend in wastelands is observed in the state. However, the rate of transition is predicted to be very meagre.
- An overall increase is expected in underutilised lands. This can cause constraints on the state's developmental prospects and forest reserves.
- A rapid rise is projected in waterlogged marshy lands, though it is minute in proportion to total land area. Land affected by salinity is seen to be transformed into this class. This will be a threat in the future to the state, where a large population is dependent on agriculture.
- The decreasing trend for scrublands is seen to be caused by overgrazing and conversion into fallow lands.

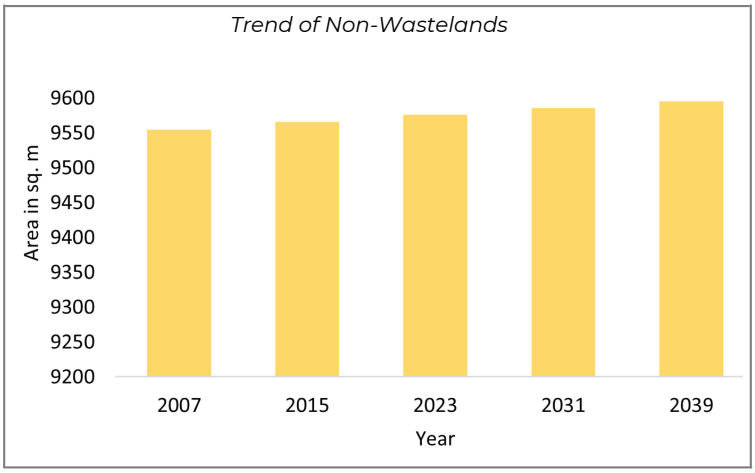
Recommendations

- The rapid rate of increase in Mining lands can become a threat to the state's environment if not controlled well.
- The state has the potential land resources to be converted into agricultural and industrial lands. However, their utilisation is seen to be very inappropriate.



TRIPURA



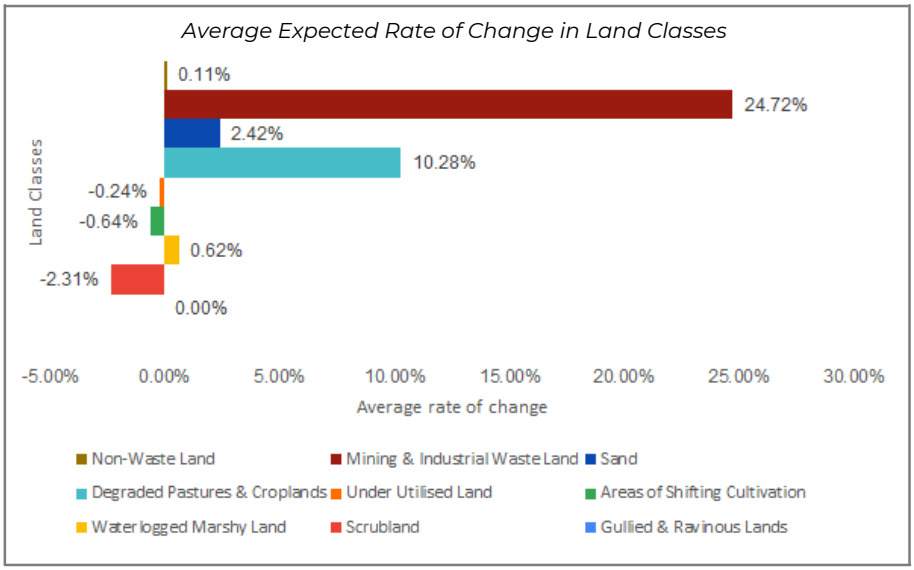


Observations

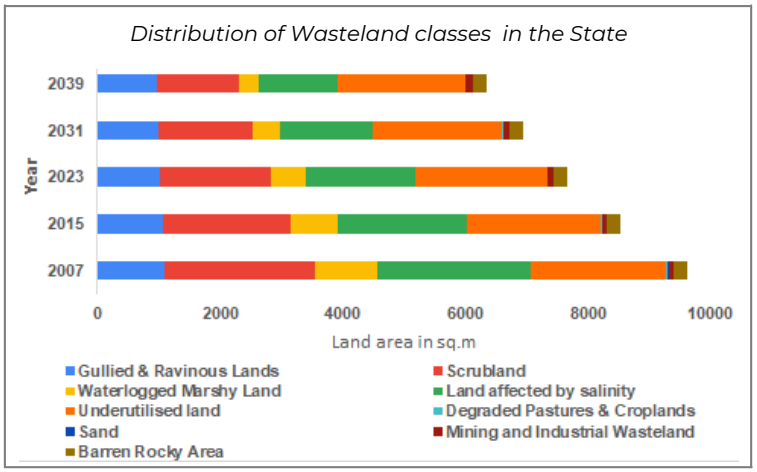
- Dissimilar to other states in the region, Tripura is expected to have an increasing trend in its non-wastelands over the years. A large portion of the lands is expected to be converted into built areas, signalling better growth prospects in the state.
- A large proportion of the state is expected to be under the class of Underutilised lands or scrublands. Both the classes show a declining trend, but at a negligible rate of change.
- Degraded pastures and farmlands in the state are predicted to increase in the state. Degradation of land due to excessive agriculture and/or overgrazing can be understood to be the reason for this.

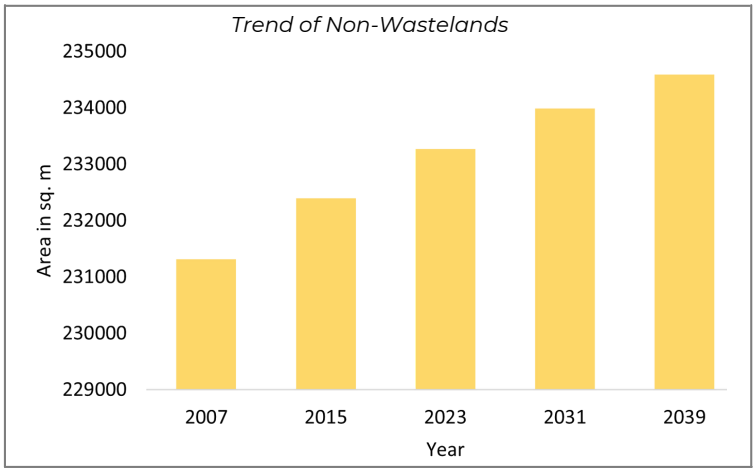
Recommendations

- The exploitation of state's natural gas reserves is expected to rise over the period till 2039. This complements the rise in mining and industrial wastelands, projected in this study. And this is expected to happen at the cost of the state's forests.
- Hence steps must be taken to prevent such terrestrial degradations in the state.



UTTAR PRADESH



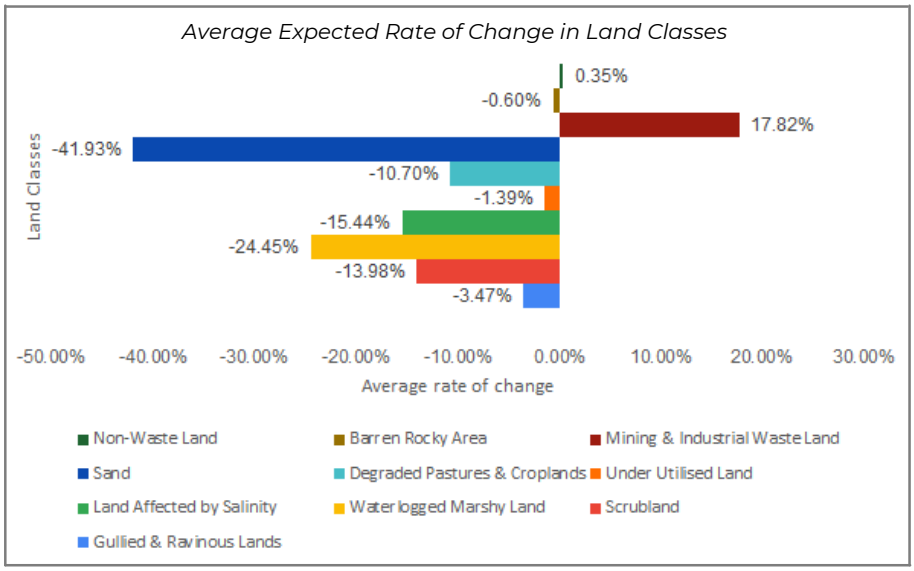


Observations

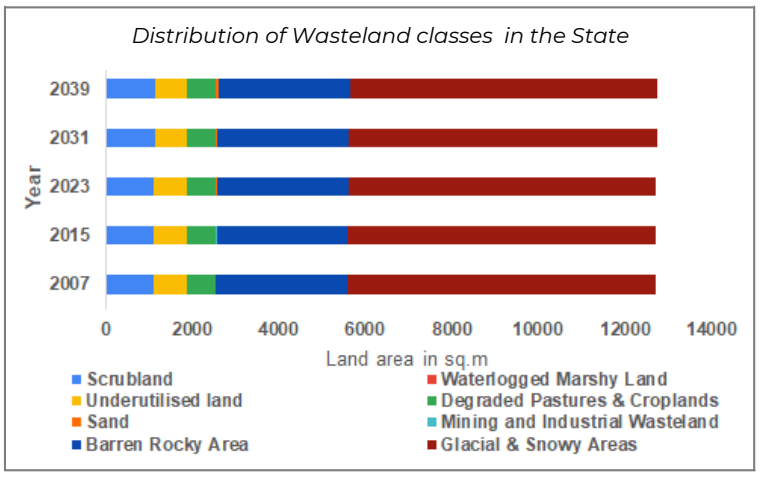
- The state is expected to have better utilisation of lands over the next few decades. As observed, more land is projected to be brought under economic utility in the state.
- The proportion of scrublands in the state is expected to have a decreasing trend. More lands under this class are predicted to be transformed into arable lands.
- The sand cover in the state is expected to fall at an alarming rate. Steps will have to be taken to prevent illegal sand mining in the state, as it shall lead to a diminution of rivers.
- Most waste-land classes are expected to decrease in the state. This shall be beneficial, given the high population in the state. But may transpire at the cost of the environment.

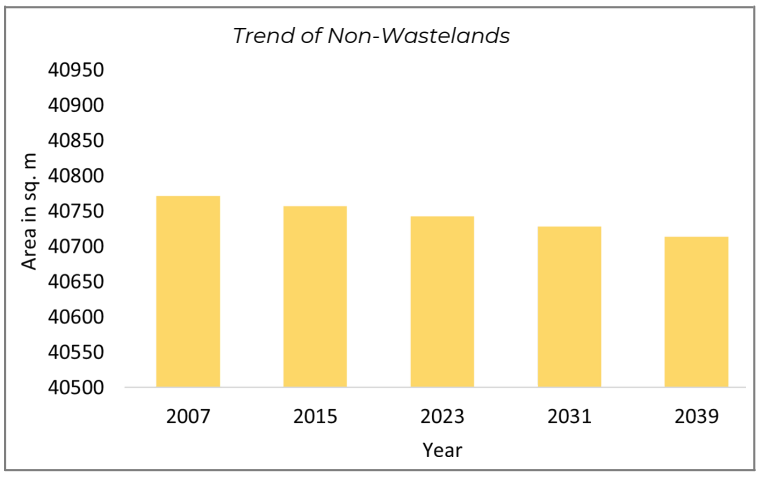
Recommendations

- A trivial observation seen here is the conversion of land affected by salinity into non-wastelands, specifically croplands. Reproducing the efforts taken in this regard, shall provide a major boost to land conservation measures not just in the state, but also in the country.



UTTARAKHAND



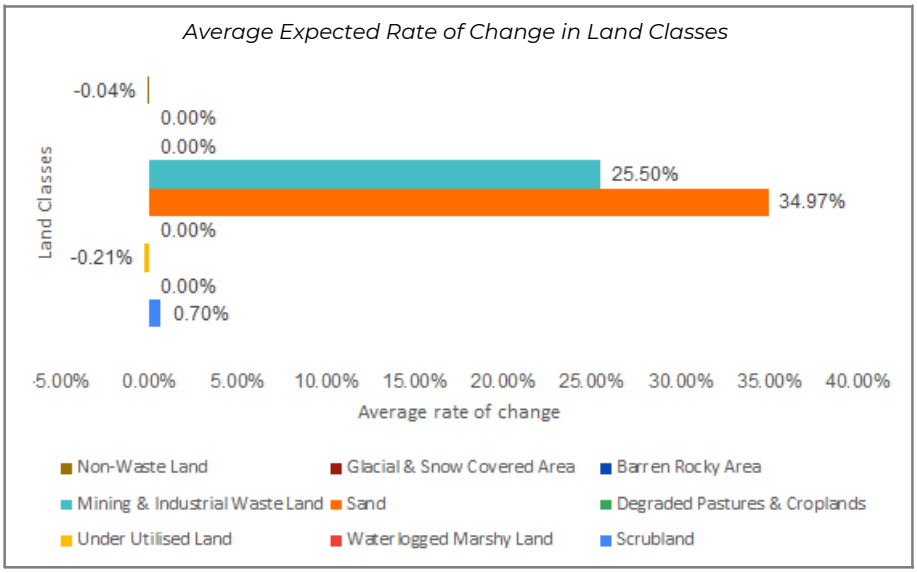


Observations

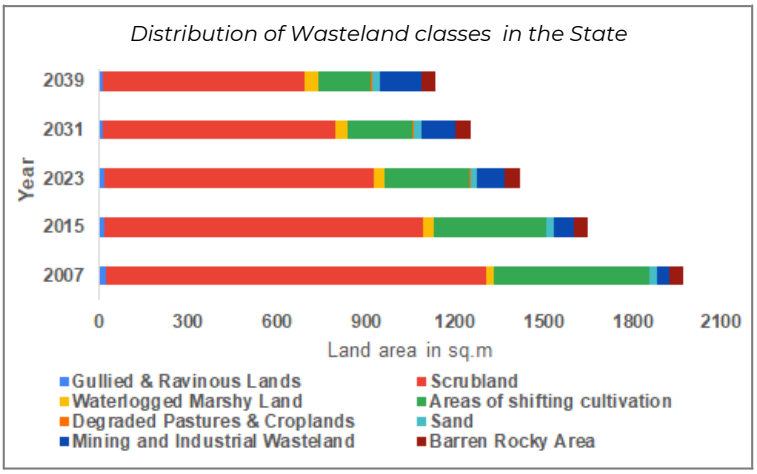
- The state shows an approximately stagnant land use distribution. Though at a very very slow rate, wastelands are expected to increase in the state.
- Glacial and snow-covered areas and barren rocky areas constitute a major proportion of the wastelands. And the state's snow cover is predicted to remain stagnant over the period.
- As sighted from the transition matrix, more wastelands are expected to be brought under built area. This can impact the state's vulnerable mountainous terrain, as validated by the numerous natural disasters observed here in the recent past.
- The rapid rise in sandy areas expected in the state may be an indication of rising soil erosion due to surface run-off by water.

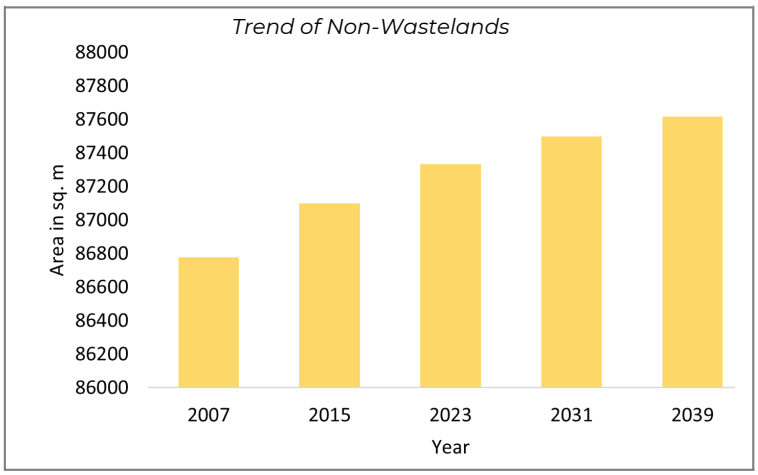
Recommendations

- The major focus in the state should be to execute environmental friendly land development, thereby protecting its vulnerable hilly terrain and preventing any disasters.
- The expected stagnancy in land distribution is a boon for the state, to ensure effective land utilisation that will be resilient to future calamities.



WEST BENGAL



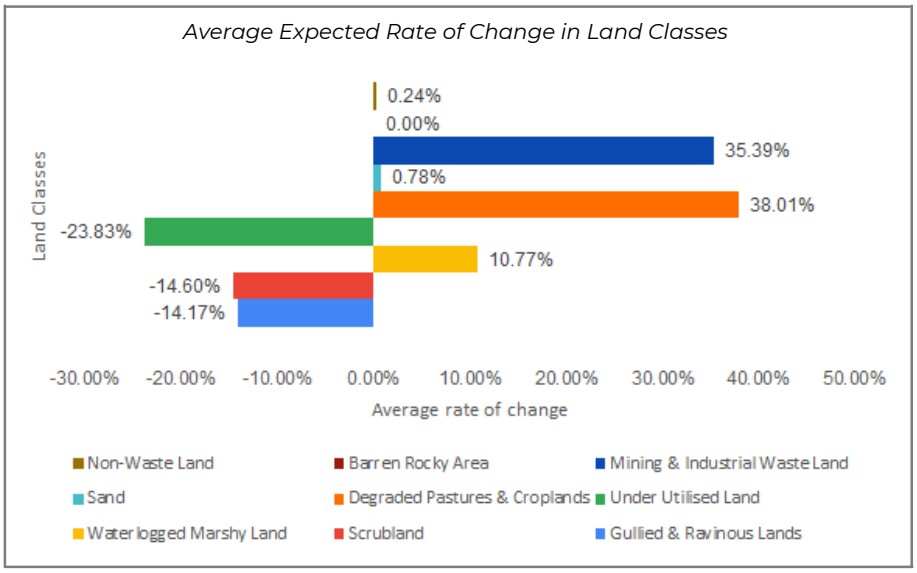


Observations

- The state shows a significant fall in wastelands over the years. The rise in non-wastelands will be beneficial for the state, given its high population.
- The state shows a significant fall in scrublands, and the land is expected to be utilised for economic purposes including construction of industries and for plantation agriculture.
- Shifting cultivation is also expected to decrease in the state, thereby helping the conservation of forests.
- Mining and Industrial wastelands are projected to drastically increase in the state. Since mining is a major activity in the state, this can be a major cause of pollution.
- Waterlogged marshy lands do not show a major class transformation.

Recommendations

- The fall in wasteland classes in the state is expected chiefly due to the usage of lands for primary and secondary activities. This can be promoted further to ensure effective land utilisation.
- The protection of unique ecosystems, such as the deltaic marshes, needs to be ensured.



CONCLUSION

In a country with a dense population like India, it is imperative that the limited land resource we possess be utilized to their optimum. Thus, there is a need for extensive planning and the authorities need to have an estimate of the condition and distribution of land in the coming years. Many states show a trend of scrublands being converted into arable lands while many other show a rise in practice of shifting cultivation. The impact of human activities on the environment is the most vital observation projected. This impact ranges from the significant melting of glaciers to rise in mining and industrial wastelands.

This report makes use of the Markov Chain model to forecast land use patterns in the country. This model has proven effective in describing the short-medium term process of land-use change.

The detailed data provided by the Department Of Land Resources allows for higher accuracy and depth of analysis for the report. Looking at the velocity at which data is being generated today, future studies may incorporate shorter transition intervals to make the model more accurate.

The main strength of the Markov chain model is the simplicity with which it can describe complex and long-term processes of land conversion by using transitional probabilities, making it an indispensable sketch planning tool. The simplicity of this model is also one of its greatest weaknesses. Being a projection model, Markov Chains do not take into account the effect that different policy variables, like regulations and development projects, might have on future trends

Economic forces are often masked by the application of the transition probabilities. Although, some of these factors can possibly be introduced into the model. One way to accomplish this is by defining the transitional probabilities as functions of other variables, thus making it possible to more precisely estimate influences of such.

Such a model can possibly be used to account for the influence of Land Development Projects on land-use changes within the framework.
Another issue that arises due to the usage of transition data from a single period is that it can lead to forecasting of short term and discontinuous trends. For example, climate change is a fast-approaching crisis. Hence, the decrease in Glaciers can be at a faster pace, than predicted through this calculation.

Land Use in a specified location can be influenced not only by its own previous state but also by the land uses in its neighbourhood.

However, it is difficult to account for such neighbourhood effects in the MC framework. Other models, like the Cellular Automata model, can incorporate this by modelling use as a function of the state of cells in a defined neighbourhood. If the Markov model can be modified to represent such effects, it will tremendously improve the output.

The MC framework can be further improved by dividing the land use into different classes based on the intensity of use. The methods employed in this report are fairly basic and there is a need for more detailed analysis and elaborate frameworks to properly model land-use changes across the country.

We aspire that the findings of this report can guide planning and decision-making processes in the country and help research endeavours across a range of ideas relevant to the domain of land development and conservation of land as an economic resource.

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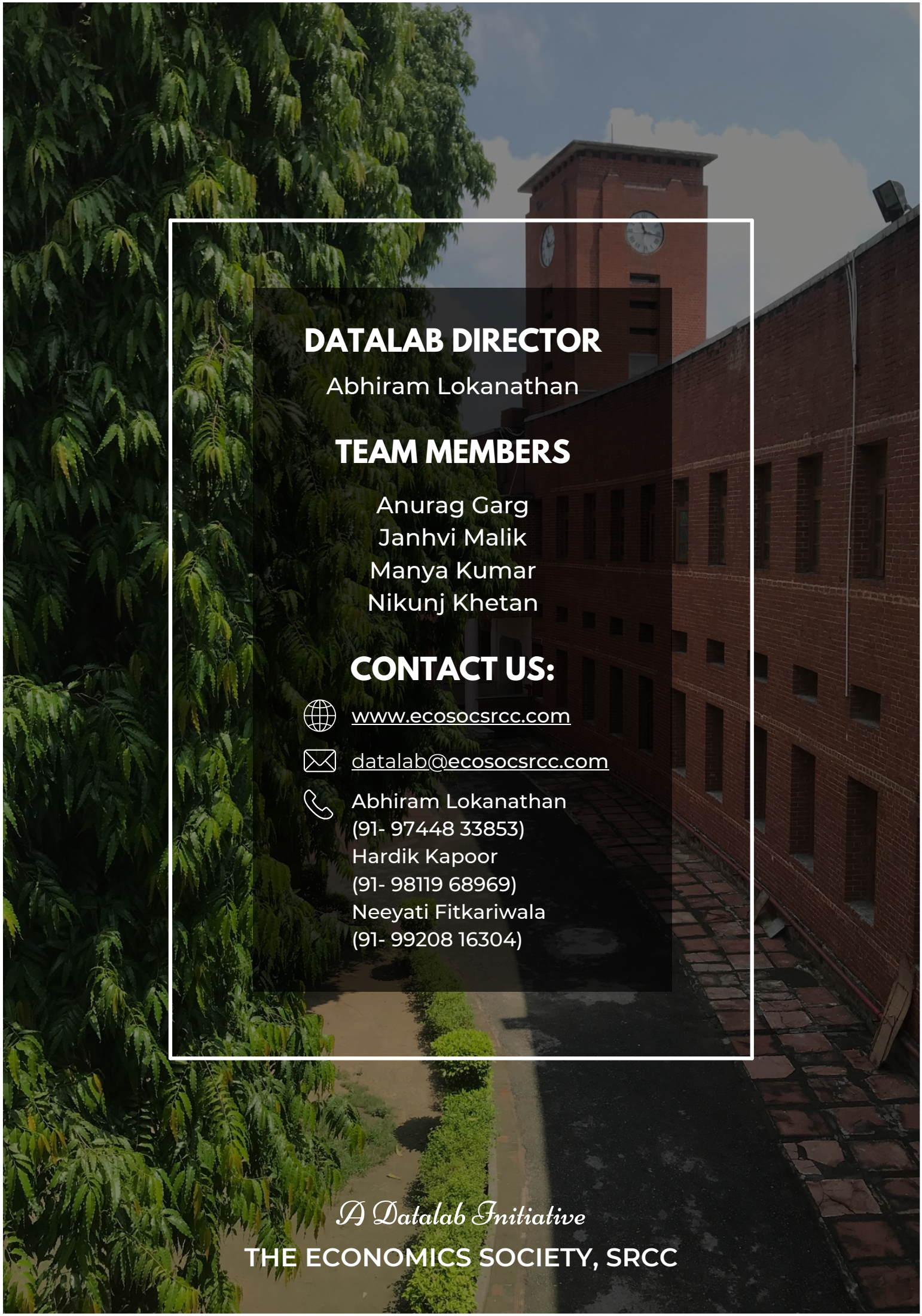
ANNEXURES

https://docs.google.com/spreadsheets/d/1i-Yd1NbBS1eD5si6Nbl-c4M_Et9rORUp/edit?usp=sharing&ouid=103063781320091143227&rtpof=true&sd=true



DATALAB DIRECTOR

Abhiram Lokanathan

TEAM MEMBERS

Anurag Garg
Janhvi Malik
Manya Kumar
Nikunj Khetan

CONTACT US:

www.ecosocsrcc.com

datalab@ecosocsrcc.com

Abhiram Lokanathan
(91- 97448 33853)
Hardik Kapoor
(91- 98119 68969)
Neeyati Fitkariwala
(91- 99208 16304)

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