SUSTAINABLE MINING AND GEOINFORMATION

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Week – 03

Lecture 12: Environmental Management

Welcome. So, let us move ahead with the 12th lecture on environmental management. So, this is the 12th lecture as far as the course on sustainable mining and geoinformation is concerned. So, the topics we will be covering are monitoring environmental impacts of mining using remote sensing in a broad way, using geoinformation technologies. We will talk about deforestation, air pollution, and water pollution.

These are two important aspects as far as mining is concerned. As far as mining and environmental management in the mining industry are concerned. We will also talk about GIS for managing mining waste disposal, tailings, and reclamation activities as far as the mining sector is concerned. We will also take one or two case studies to discuss the environmental monitoring of large-scale mining projects and compliance with regulations. Friends, there are many rules and laws as far as pollution and the environment are concerned.

So, we will see how this geoinformation technology is useful in complying with these regulations, and that is how it is tagged as a cleaner or greener technology. So, what is environmental management? Sustainable mining aims to balance economic growth with

environmental preservation and social responsibility. So, the three components of sustainable mining are, yes, on one side, there has to be economic growth, but on the other side, you have environmental preservation and social responsibility. So, these three must have a balance among and between them; only then can sustainable mining be achieved.

So, the EIA (Environmental Impact Assessment), EMP (Environmental Management Plans) these are indispensable tools for achieving sustainable management. So, EIA and EMP these are tools these are also protocols we all need to achieve this in order to achieve sustainable mining. So, environmental management involves strategies, practices and tools to mitigate the environmental impacts of mining operations and thereby promote sustainable use, particularly sustainable mineral resources utility. It is in terms of EIA, it is a systematic process. In this systematic process, what is done evaluation of the environmental consequences of the proposed mining projects before granting approval.

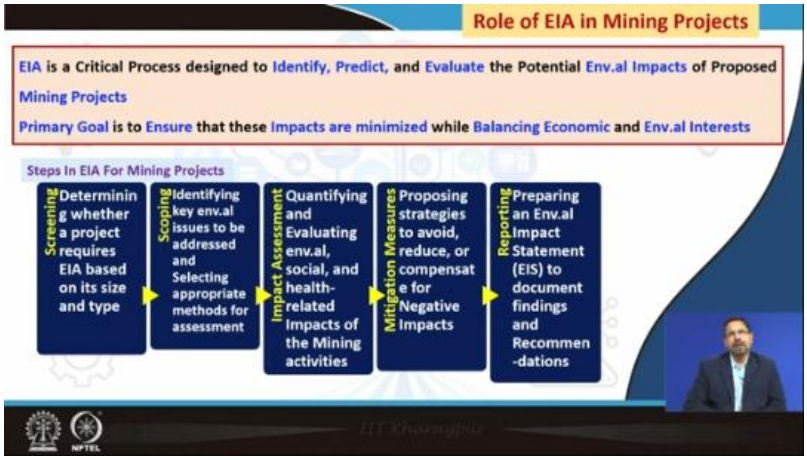
So, EIA mostly happens before setting off or before giving approval to a mining project. So before an activity is going to be taken up, one has to come out with an assessment that based on the target of what you say excavation or you say exploration, exploitation. How much it will affect the environment, the water, air, noise and also the socio-cultural environment. So, this all this has to be assessed and that is brought in form of a document called environmental impact assessment. It is a binding before granting approvals.

Coming to the next one is EMP, Environmental Management Plan. It is a detailed framework outlining measures to mitigate environmental impacts identified in the EIA to ensure compliance throughout the mining lifecycle. So, what it does in the previous activity in the EIA when we mention that yes because of this particular activity or mining activity the water environment will hamper to this extent the air environment will hamper

to this extent so and so. In the EMP, in the environmental management plan, we need to come out with the measures, how we are addressing to that. So, we say that yes, in this direction, we will do this much of plantation.

Here, we will do these activities to ensure the water quality. So, these fall under the environmental management plan to ensure compliance throughout the mining activities or the mining life cycle. So, EIA and EMP are two important activities that govern or ensure environmental management as far as the mining sector or mining environment is concerned. The integration of EIA, EMP, and EM—environmental impact assessment, management plan, and environmental management—plays a key critical role in ensuring that mining activities minimize ecological degradation and contribute to long-term sustainability. So, these ensure minimal loss to the ecosystem, to the ecology of the area where mining activities are going to happen, in line with the principle of sustainable development.

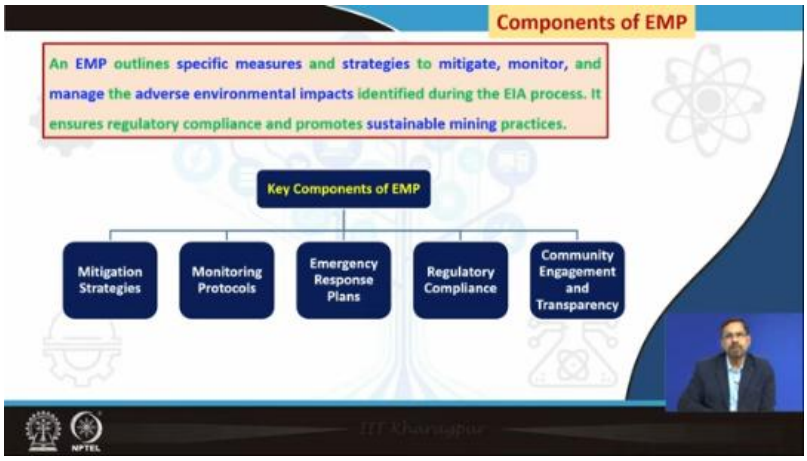
Now, let us talk about the role of EIA in mining projects. So, the EIA is a critical process designed to identify, predict, and evaluate the potential environmental impacts of proposed mining projects, as we just discussed. The primary goal of EIA is to ensure that these impacts are minimized while balancing economic and environmental interests. So, the steps involved in EIA for mining projects could be screening, scoping, impact assessment, mitigation measures, and then the fifth one is reporting. So, in terms of screening, it helps determine whether a mining or mineral exploration project requires EIA based on its size and type.



So, initially, we need to screen if it falls under the purview of conducting an EIA a priori. If it passes, then the second one is scoping. So, in scoping, identification of key environmental variables to be addressed and then selection of appropriate methods for

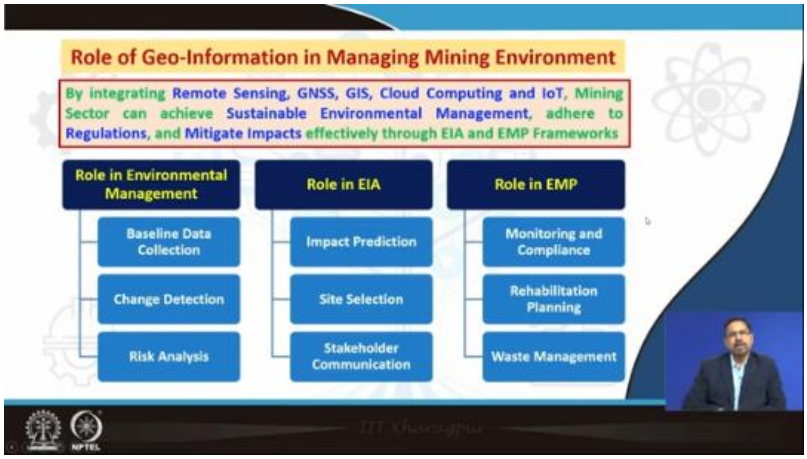
assessment. The scoping is about what parameters or environmental variables may be affected because of these forthcoming mineral activities. Once those key components or key variables are identified, then the methodology of assessing these key components is spelled out. Then, the third one is impact assessment. In impact assessment, we need to quantify and evaluate the environmental, social, and health-related impacts that may arise because of the mining activities. So, once the impacts are assessed and quantified, we need to come out with any mitigation measures if it is affecting the health and the ecosystem.

Yes, in many of these cases, it has the potential to affect the ecosystem and health, but we come up with a standard that, below a certain threshold, we must implement mitigation measures. So, we propose strategies to avoid, reduce, or compensate for any negative impacts that may arise from these proposed activities, including mining or mineral exploration. Now, once these are done—meaning the screening is complete, the scoping is defined, the impact assessment studies are conducted, and the mitigation measures are clearly outlined—they all need to be reported in the form of a statement called an Environmental Statement (ES). This becomes the document, and this document contains the findings and recommendations regarding the proposed project activity or mining industry. Now, let us examine the components of an Environmental Management Plan (EMP). An EMP outlines the specific measures and strategies used to mitigate, monitor, and manage any adverse environmental impacts that may occur due to the proposed mining activity.



So, once they are identified through the EIA process, the specific mitigation strategies are outlined in the EMP. In this way, the Environmental Management Plan (EMP) ensures regulatory compliance and thereby promotes sustainable mining practices. The key

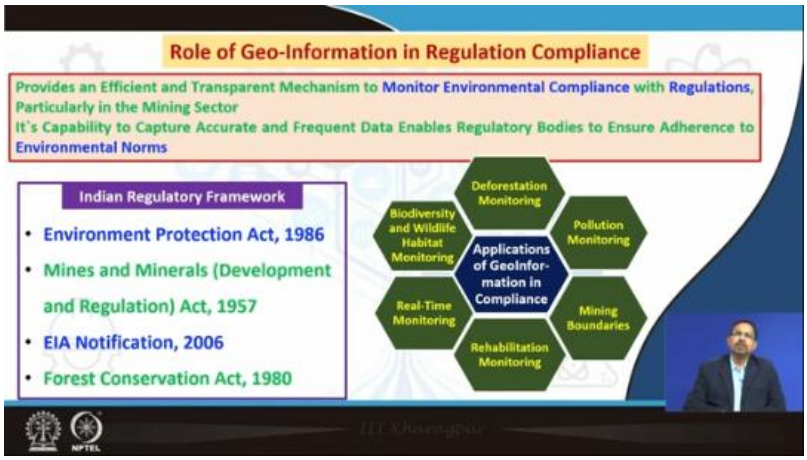
components of an EMP could include mitigation strategies, monitoring protocols, emergency response plans, regulatory compliance, community engagement, and transparency. Let us now examine the role of geoinformation in managing the mining environment. By integrating all these technologies—which form part of geoinformation, such as remote sensing, GNSS, GIS, cloud computing, and IoT, as we discussed—



over the last two weeks, the mining sector can potentially achieve sustainable environmental management. This allows adherence to various prescribed rules and regulations and effectively mitigates impacts through the EIA and EMP frameworks. So, let us explore the role in environmental management, the role in environmental impact assessment, and the role in EMP. Regarding the role in environmental management, baseline data must be collected, including pre- and post-activity change detection. What is the status before, and what could happen after the activity begins? Pre- and post-conditions are assessed through change detection, for which GIS and remote sensing are the most powerful tools. Satellite images provide authentic data, making remote sensing highly reliable. Once we have this data, we can conduct extensive analysis, including risk assessment. Then, in the role of EIA, it can influence impact prediction, site selection, and stakeholder communication—the three key pillars of EIA.

So, once we have different what you say datasets then we can have we can come out with the we can predict various impacts because of the proposed mining activities. So in that sense, we can also look at the other options of site selection. Can we move from this site to that site a bit to minimize or optimize the environmental degradation or the risk? So that is how we optimize in terms of the site selection. The third one is we communicate with the stakeholders, the people who are involved, who are attached to that particular project or activities including the local inhabitants.

So that way role of EIA is very very important. The role of EMP, it helps in monitoring and complying to the different measures what has been what has been promised or taken out of the mentioning in the EIA document and based on that we can also have different rehabilitation planning and similarly so like waste management in mining sector or mining industry we have lot of waste that needs to be managed so EMP helps ensures that that the waste are properly managed in a mining environment The role of geo-information in regulation compliance. Friends, we have different rules, legal instruments, laws as far as Government of India or any national or state government is concerned.

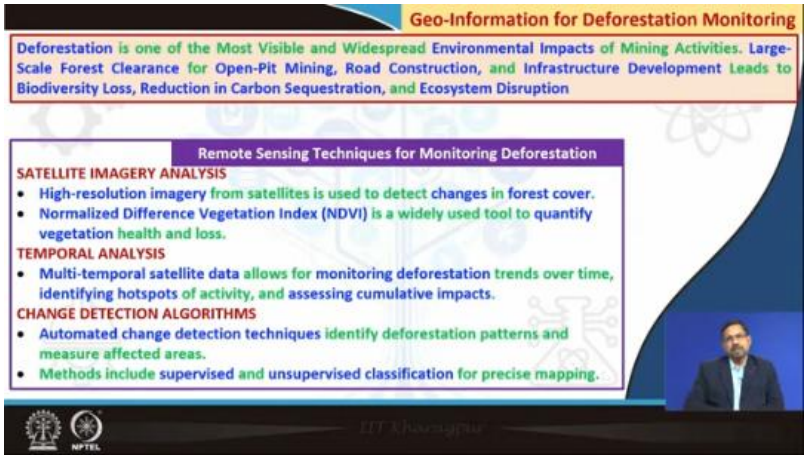


So, geo-information provides an efficient and transparent mechanism to monitor environmental compliance with regulations particularly in the mining sector. Its capability, the capability of geo-information technologies is to capture accurate and frequent data. In the 10th class, we discussed about the real time tracking and monitoring from using different sensors. So that means the frequency of the data collection and its accuracy is very, very high. So once we have the high level, the high frequency data with good accuracy, this helps or enables the regulatory bodies to ensure adherence to various environmental norms.

So, some of the environmental norms or the framework could be, as far as our country India is concerned. We have the base one, which is the EPA, the Environmental Protection Act of 1986, as all of us know. The Mines and Minerals (Development and Regulation) Act passed in 1957, the EIA notification which came into existence in 2006, and the Forest Conservation Act of 1980. So, the application of geo-information, as far as compliance with these rules and regulations is concerned, could be useful in various ways in various sectors, such as deforestation monitoring in the mining sector. Pollution

monitoring in industrial or mining areas, the boundaries of mining sites, and biodiversity and wildlife habitat monitoring in mining areas, as well as real-time monitoring.

Also, rehabilitation monitoring. So, geo-information has several applications that are really useful in terms of complying with various rules and regulations, as far as the national or state government is concerned. So, let us have a look at deforestation monitoring using geoinformation tools. Deforestation is one of the most visible and widespread environmental impacts of mining activities. Friends, we all know that most of these mineral ore deposits have forest cover on the earth's surface.

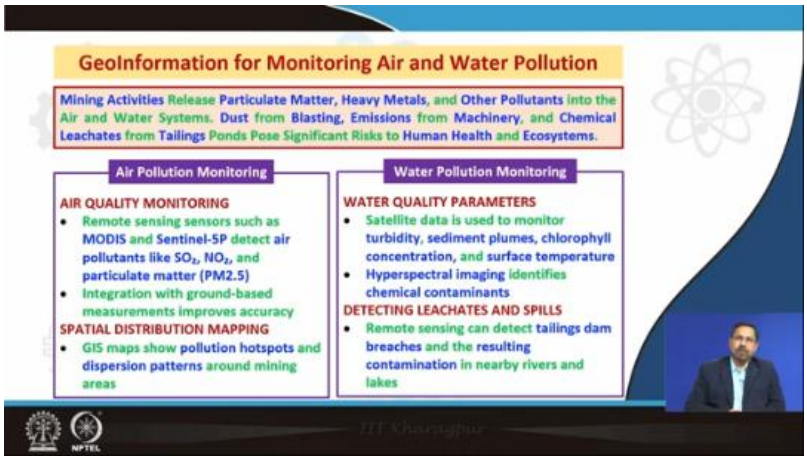


So, if we need to proceed with open-cast mining, then perhaps we need to consider deforestation in terms of removing the forest cover that overlays the mineral deposits. So, deforestation is one of the most visible and widespread environmental impacts of mining activities. Large-scale forest clearance for open-pit mining, road construction to the site, and infrastructure development could lead to biodiversity loss. Reduction in carbon sequestration because forests, due to the presence of the green pigment chlorophyll, fix atmospheric CO2 through the process of photosynthesis, and it can also minimize ecosystem disruption. So, the various techniques, as far as remote sensing and geo-information are concerned, include satellite imagery analysis.

Yes, high-resolution imagery from various satellites is useful to detect changes as far as forest cover is concerned. NDVI and various vegetation indices are very widely and commonly used to quantify vegetation health and changes, including loss or gain. As far as temporal analysis is concerned, multi-temporal satellite data allows for monitoring deforestation trend patterns over time—over months, seasons, and years. So, that is how they can help in identifying where more or less deforestation activities are happening, thereby prioritizing hotspot areas in terms of deforestation. And the change detection

algorithms—these days, various automated change detection algorithms are available—help in identifying deforestation patterns, and that is how they assist in measuring affected areas.

There are various methods that include supervised and unsupervised classification for mapping. There are various methods. They are involved in automated change detection as far as deforestation monitoring is concerned, using geoinformation tools. Next, geoinformation for monitoring air and water pollution. Mining activities release a lot of particulate matter, heavy metals, and other pollutants into the air and water systems near and around the location, as well as dust from blasting activities, emissions from machinery, plumes, and chemical leachates from tailings.



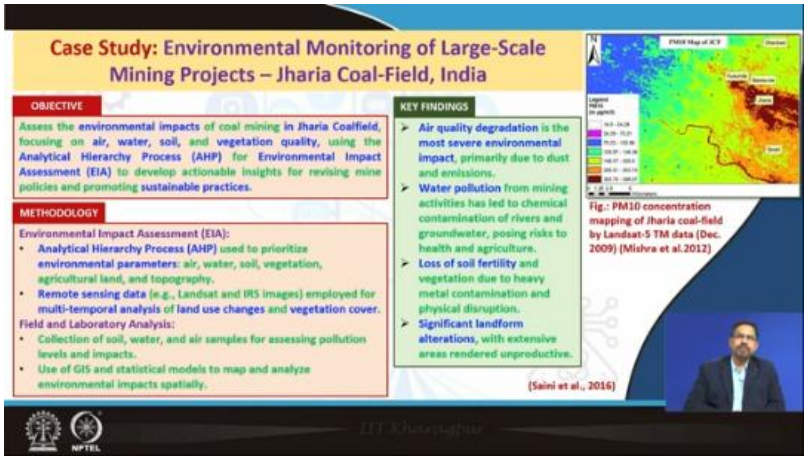
So, all these tailing ponds pose significant risks to the ecosystem as well as human and animal health. It could be air quality and spatial distribution mapping as far as geoinformation tools are concerned. Remote sensing sensors such as MODIS and Sentinel-5P from ESA (European Space Agency) or the European Union, particularly from the Copernicus program. The Sentinel-5P sensor detects air pollutants such as sulfur dioxide, nitrogen oxide, and particulate matter (PM2.5). Integration of this information with ground-based measurements helps improve accuracy.

And the GIS maps show pollution hotspots and dispersion patterns around mining areas. Now, coming to water pollution monitoring. As far as satellite data is concerned, it is useful to monitor water quality parameters such as turbidity, sediment plumes, chlorophyll concentration, surface temperature, and a few other parameters related to water quality. Hyperspectral imaging is useful in identifying many chemical contaminants because the presence of various chemical contaminants results in different imaging and spectroscopy, as far as spectral reflectance is concerned, using more spectral

bands—that is, hundreds of bands—which we use in hyperspectral remote sensing. Then, detecting the leachates and spills is important as far as water pollution monitoring is concerned.

Remote sensing can detect tailing dam breaches and the resulting contamination in nearby rivers and lakes. It often happens that in many industrial or mining areas, the tailings and leachates reach ponds, lakes, and nearby rivers. This is why the risk of contamination increases. They contaminate the water and pose a threat to life and the biota that depend on that water. Detecting leachates and spills using geo-information tools is a safe technology and represents one of the potential applications of geo-information technologies.

Let us look at a case study. Environmental monitoring of large-scale mining projects: Jharia coal field as an example from India. The objective of this study is to assess the environmental impacts of coal mining in the Jharia coal field. Focusing on air, water, soil, and vegetation quality, the study uses an Analytical Hierarchy Process (AHP) for Environmental Impact Assessment (EIA) to develop actionable plans. This study assesses the environmental impacts of coal mining, focusing on air, water, soil, and vegetation quality parameters using an AHP (Analytical Hierarchy Process) algorithm.



So, the methodology is AHP was used for prioritization, environmental parameters such as air, water, soil, vegetation, agriculture, land and topography has been used and remote sensing data like our Indian remote sensing data IRS and the Landsat data were employed for multi-temporal analysis of land use change and vegetation cover. So, field and laboratory analysis also done soil water and air samples are collected for pollution related analysis and levellings. And finally, what happened all this database were integrated using GIS so that it can go for statistical analysis and modeling and maps can be

generated which gives us in terms of analyzing the environmental impact in a spatial framework in a map format. So, the key findings out of this study are air quality degradation is the most severe environmental impact primarily due to dust and emission. Hence, a mining industry like coal field, the coal mining activities releases lot of primarily dust pollution or pollution emerging from dust deposition and various emissions.

And as far as water pollution is concerned from mining activities led to chemical contamination of rivers, groundwater posing risk and health impact as well as to the agriculture sector. Loss of soil fertility was also noticed because of heavy vegetation loss and metal contamination and the significant alteration in terms of land form over the area that made lot of land unproductive because when lot of other dust gets deposited, pollutants gets deposited, get contaminated. So, all this actually lead to a land farm alteration by affecting the productivity in terms of agriculture productivity and also the what you say affecting the social or the sociocultural activities and the human health. So, on the right-hand corner you can see a map of particulate matter 10 concentration mapping of Jharia coal field that has come from the Landsat 5 TM data of December 2009 given by Mishra et al in 2012 publication. So here we can very well see in terms of different concentration of PM10 which is shown in form of micron gram per meter cube.

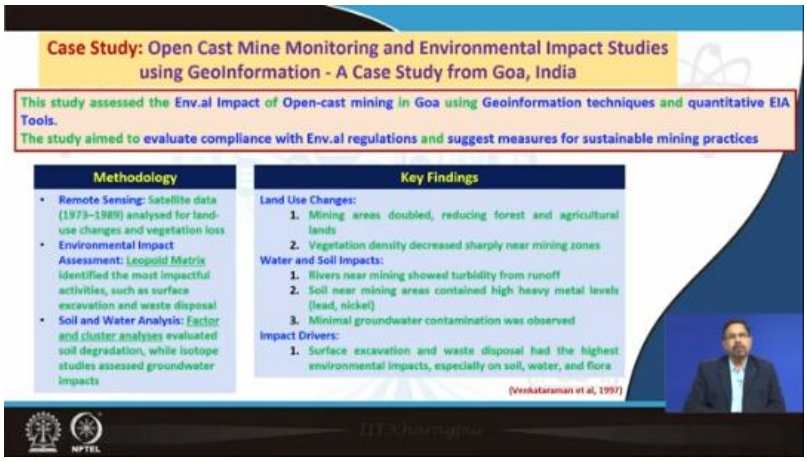
So over a spatial variation we can see the spread of PM10 the particulate matter 10. let us look at the disposal management and the benefit it gets using geo information tools mining also generate the mining activities generates lot of waste substantial amount of weights including overburden tailing and chemical byproducts this these have risk or pose potential risk to soil water and air quality affecting the management and that is why it also affect or contribute to environmental contamination. So, we need to minimize this in terms of environmental contamination, in terms of what you say was minimizing the risk to soil water and air quality that is why that is how we can come out with effective management of mining sector. So, what are the roles that geoinformation plays?

So, the tools—geoinformation, GIS, and remote sensing—together are useful in enhancing mining waste management by enabling mining waste disposal. So, for this, mapping the waste disposal site is important. Identification and categorization of waste disposal sites, highlighting sensitive zones such as nearby water bodies or residential areas. Risk assessment and modeling, modeling environmental impacts such as leachate migration and groundwater contamination risk. Hydrological modeling in GIS also helps in identifying areas that are vulnerable to water contamination.

Waste accumulation monitoring is very well done using geoinformation, particularly time-series satellite data, and drones could be useful in tracking the accumulated waste over time. As far as planning in the mining sector and optimization of various activities are concerned, geoinformation helps in designing sustainable management systems, and running scenarios can also be analyzed to ensure regulatory compliance. Coming to tailing monitoring and reclamation activities, tailings are the residual materials left over after mineral extraction. So, the residual materials left over after mineral extraction are regarded as tailings. These often contain toxic substances that can leak into the surrounding environment in the form of leachate, causing severe ecological damage.

So, that is why monitoring and reclamation are essential to mitigate these tailing impacts—the impacts emerging from tailings. So, for monitoring tailings, we need satellite remote sensing and geoinformation tools, which are useful in the identification and assessment of tailings at risk. They map the areas where there could be potential risks and are thereby helpful in monitoring at regular intervals. Coming to various reclamation activities, yes, vegetation monitoring and land restoration can be very well done using geoinformation technologies. Because once we have the change detection or the time-series satellite data, it helps in change detection—that is how it helps in monitoring the vegetation.

And different lands also for the land restoration and reclamation activities, the geoinformation is a very valuable and a useful tool. Let us have a look at the case study. Opencast mine monitoring and environmental impact studies using geoinformation. This is a case study from Goa as far as our own country India is concerned. This study assessed the environmental impact of open-cast mining in Goa using geoinformation techniques and quantitative environmental impact assessment tools.



And this study also aimed at evaluating compliance with environmental regulations and that is how it is capable of suggesting measures for sustainable mining practices. So, the methodology followed in this case study are satellite data during 1973 to 1989 particularly it could be Landsat data was used to monitor the change as far as vegetation loss or gain is concerned. Environmental impact was assessed using Leopold matrix. So this Leopold matrix it is useful in identifying the impact such as surface excavation and waste disposal and also the analysis of soil and water parameters were done using cluster or cluster technique, cluster analysis. And the key findings of this study are land use change, water and soil impacts and impact driver.

So, based on this the drivers were identified in terms of surface excavation and waste disposal. These two are found as the drivers they are having higher environmental impacts especially on soil, water and flora. So, in these studies based on geo information using time series remote sensing data the change detection could be done and environmental impact assessment was done using Leopold matrix and the cluster analysis was done finally to come out with the drivers that particularly the drivers were identified those are the surface excavation and waste disposal were emerged as two important drivers. which have the highest environmental impacts as far as soil, water and flora is concerned. These three references were used in this slide in this lecture of in this 12th lecture.

So, let us conclude with these three broad points. Mining projects pose significant environmental challenges, including deforestation, pollution, and land degradation, which require robust management through EIA and EMP activities. Remote sensing and GIS technologies are essential for real-time monitoring, compliance, and reclamation efforts, offering precise and scalable solutions. Effective environmental management necessitates

stronger regulatory enforcement, adoption of cleaner technologies, proactive rehabilitation strategies, and active community engagement to ensure sustainable practices that can maintain a critical balance between economic growth, environmental preservation, and ecosystem health.

And I am sure geoinformation has a definite role to play in this, in the sense of smarter management of the mining environment. Thank you very much.