GMR
The Original

INTEGRATED APPROACHES FOR SUSTAINABLE NATURAL RESOURCE MANAGEMENT: A GLOBAL REVIEW

Shrijal Gupta[1], Ayushi Trivedi[2*], M.Suguna Devakumari[3], Amit Dixit[4], Nirjharnee Nandeha[5], Bommanna K[6]

[1]Research Scholar, Department of Forest Resource Management, College of Forestry and Research Station, Sankara, Patan, Mahatma Gandhi Udyanikee Evam Vanikee Vishwavidyalaya, Sankara, Patan, Durg-491111, Chhattisgarh, India.
[2]Assistant Professor, Department of Natural Resource Management, College of Forestry and Research Station, Sankara, Patan, Mahatma Gandhi Udyanikee Evam Vanikee Vishwavidyalaya, Sankara, Patan, Durg-491111, Chhattisgarh, India.
[3]Assistant Professor Grade 2, School of Agricultural Sciences, Karunya Institute of Technology and Sciences, Coimbatore, India
[4]Professor, Department of Vegetable Science, College of horticulture and Research Station, Sankara, Patan, Mahatma Gandhi Udyanikee Evam Vanikee Vishwavidyalaya, Sankara, Patan, Durg-491111, Chhattisgarh, India
[5]Department of Agronomy, Kumari Devi Chaubey College of Agriculture and Research Station, Saja, Indira Gandhi Krishi Vishwavidyalaya, Raipur, 492001, India
[6]Associate Professor, Department of Mechanical engineering. Krupanidhi Institute of Technology, Bangalore, India
***Corresponding author**: Ayushi Trivedi, (ayushikhandwa@gmail.com)

ABSTRACT
Land, water, forests, biodiversity and minerals are natural resources which are important for people's health, socio-economic development, and environmental sustainability. But in recent years, these resources have been strained worldwide as a result of fast population growth, urbanization, climate change, deforestation, land degradation and water scarcity. Hence, a holistic approach to natural resource management has become a promising way to ensure sustainable use of the natural resources and environmental resilience in the long term. This review considers the primary integrated strategies implemented worldwide for managing natural resources sustainably, and their contribution to the current environmental problems. The review emphasizes sustainable forest management, watershed management, agroforestry, climate-smart natural resource management, conservation of biodiversity, and community-based natural resource management. These methods include strategies for resource-use efficiency, ecosystem restoration and soil and water conservation; carbon sequestration and livelihood enhancement. Special attention is given to the importance of participatory governance, indigenous knowledge systems, ecosystem-based adaptation and nature-based solutions for promoting environmental sustainability. The review also addresses the increasing use of sophisticated technologies including Geographic Information Systems (GIS), Remote Sensing (RS) and digital monitoring technologies for resource assessment, planning and management. Moreover, policy and institutional supports for integrated NRM at international level are explored. The results showed that integrated and participatory management strategies have a significant positive impact on the resilience of the ecosystem, conservation of biodiversity, water security, adaptation to climate change and sustainable livelihoods. But the policy conflicts, institutional coordination problems, budgetary limitations and growing population pressure remain key challenges in the effective implementation. The review concludes that the use of multidisciplinary, technology-based and community-based approaches are crucial for sustainable natural resource management and to reach the global environmental and development goals.

KEYWORDS: Agroecology, Ecosystem services, Precision agriculture, Livelihood diversification, Stakeholder participation

1. INTRODUCTION
1.1 Meaning of Natural Resource Management
Resilient livelihoods and environmental sustainability are crucial. Depend on managing natural resources well. Natural resources such as land, water, forests, fisheries and minerals are essential for ecosystem services. Support human livelihoods and socio-economic development. These resources are vital for millions of people in rural areas, where people's livelihoods are closely tied to using them in a sustainable way, which is necessary for socio-economic stability and long-term well-being of people. (Ahmed *et al.*, 2020; Arslan *et al.*, 2022). Peoples health is really connected to the environment. We need to take care of the earth and its resources. The environment and people's health are closely linked. (Morse, 2025; Su *et al.*, 2025).
1.2 Deforestation
Deforestation is a problem for our environment. It is happening because of things, like people moving to cities farms getting bigger, industries growing, mining and trees being cut down in a way that is not sustainable. When we cut down trees it hurts the environment in ways. It causes animals to lose their homes soil to get washed away and it

disrupts the way water moves around our planet. It also makes the air get worse because of all the things we release into it. When forests get smaller it affects the people who live near them and depend on them for food and other things. Deforestation also costs us a lot of money that we do not even see. For example, trees help pollinate plants absorb air and regulate water. The TERI Report 2020 says that India is losing about ₹1.75 trillion every year because of the way we are treating our environment and a big part of that is because of deforestation (Knutson *et al.*, 2020).

1.3 Land Degradation

The world is facing a problem with natural resources. This is because the population is growing and there is industry, which is using up a lot of natural resources in a way that is not good for the earth. This has caused a lot of damage to the land in places. We are seeing soil erosion the soil is becoming too acidic it is losing nutrients. It is getting too salty. The land is also becoming a desert The environment is getting worse because of farming methods that're not good, for the land. People are using many chemicals and cutting down too many trees (Ahmed *et al.*, 2020).

1.4 Water Scarcity

Another big problem that is affecting the world and making it hard to develop sustainably is water scarcity. The world is running out of water because of many reasons. One reason is that the population is growing and more people need water. Many people need water for farming and for industries. The ground water is also getting depleted and polluted. Farming uses a lot of the worlds water. Almost 70%. This puts a lot of pressure on the water supplies in parts of the world. The agriculture sector is using up a lot of water resources. Water scarcity is an issue for agriculture. (FAO, 2023). Additionally, climate change is exacerbating water shortages due to altered precipitation, higher evapotranspiration, and more droughts (IPCC, 2023). conclude that water resource management is crucial for food security and sustainable development Rockström *et al.* (2014).

1.5 Climate Change

Climate change is one of the problems we face when it comes to taking care of our natural resources. Climate change is causing a lot of issues like the sea level rising, bad weather and things like droughts and floods. These things are hurting our land, water, forests and the variety of animals that live here.They are also affecting the systems that help us grow food. Climate change is making it harder for the earth to bounce back from problems. It is making existing environmental problems worse. This affects how safe our food is and if we can make a living in a way that's good for the earth. (Leal Filho *et al.*, 2021; Feliciano *et al.*,). 2022).

Climate change is a problem. Scientists have been studying it. They found out that a lot of places will have really bad heat waves, droughts and heavy rain. (Herring *et al.*, 2019). The number of bad storms will get bigger as the temperature goes up. This will have bad effects on people who live near the coast all around the world. The number of storms with the intensities will get worse because of this. The Food and Agriculture Organization says that the Food and Agriculture Organization thinks many places, in the world will have a lot of trouble getting water. This is because the way it rains is changing and it is getting hotter. The Food and Agriculture Organization also says that climate change is hurting the environment and this is causing many plants and animals to disappear. The Food and Agriculture Organization thinks this will make it harder for the environment to do things like clean the air we breathe by taking in carbon (Knutson *et al.*, 2020).

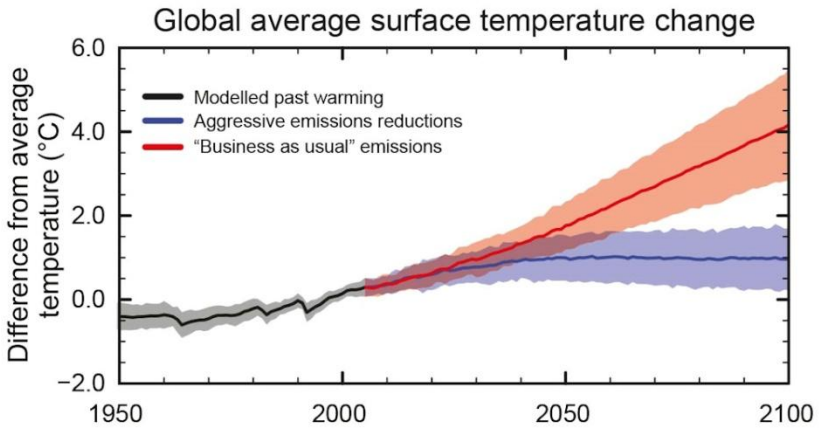


Figure 1: Global Average Surface Temperature Change (Source: IPCC 2014)

1.6 Need for Integrated Approaches

We need to deal with the problems that are affecting our planet and our communities. So people are using livelihood approaches to manage natural resources. These approaches are about making the most of the resources we have helping people and the environment get through times giving local communities more control and making sure everyone gets

a fair share of the benefits. (Chiang, 2024). Sustainable livelihood strategies bring together economic and ecological aspects to help everyone and protect the environment. To really make a difference in situations and when people are involved it is necessary to understand how ecological systems and socio-economic factors work together. Sustainable livelihood strategies are about finding a balance between these things. The connections between these things are important. People think that using many different areas of knowledge and working with many different groups is a good way to manage natural resources. These strategies are effective in increasing resource-use efficiency, building adaptive capacity and resilience to climate change and other uncertainties (Natarajan *et al.*, 2022).

We need to find ways to use our resources so they last forever. Things like agroforestry, managing water sources, conservation agriculture, climate-smart agriculture and integrated farming systems can really help. Research shows that when we plan and take care of these systems properly they can produce food and also help keep our environment healthy by saving water, soil and all the different kinds of plants and animals. This is good for people too because it can improve our lives and help our communities.

They make sure environmental protection and human development work together. This helps ensure that we can keep using resources for a long time (A. Kumar *et al.*, 2023; Arslan *et al.*, 2022).

Although we cannot manage resources in a way that lasts without looking at everything as a whole and working together. This means thinking about how our actions affect the environment and people. It's about keeping species alive making sure nature works properly and people have what they need. These strategies are important for making sure that future generations have what they need. They can help us deal with problems, like climate change, food security and sustainability. (Shah *et al.*, 2021; Singh *et al.*, 2024; Mensah & Amoah, 2024).

The livelihood and well-being of communities around the world are significantly affected by natural resources (Figure 2). These things include resources like land, water, forests, minerals, fisheries and all the different kinds of animals and plants. The natural resources support things that people do to make money, such as farming, fishing cutting down trees digging for minerals and tourism. Natural resources are really important for people. We need them for food and energy and other things that we cannot live without. These resources are also very important for our culture and spiritual beliefs. We like to look at them and enjoy them. We are using them in ways that are not good for the environment. This is a problem for people who depend on natural resources to survive. There are things that people are doing that are bad for the environment. For example, we are taking many fish out of the water cutting down too many trees and making the soil dirty. We are also making the water dirty. Hurting the animals that live in these places. All of these things are making it harder for ecosystems to stay healthy. This is a problem because many people depend on natural resources to live (Li *et al.*, 2024; Sangha, 2020).

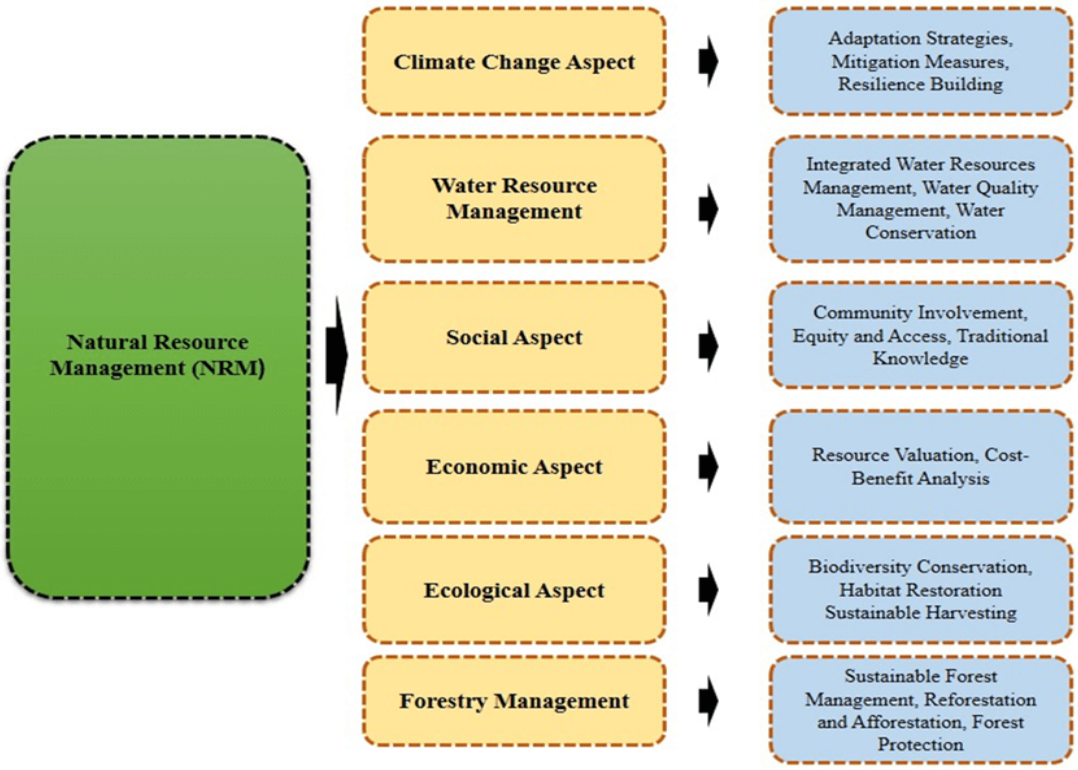


Figure 2: Different aspects of natural resource management (Li *et al.,*2024; Sangha, 2020)

1.7 Objectives

1. To discuss integrated methods on Sustainable Natural Resource Management (NRM).
2. To examine forest and ecosystem-based management (FSM) systems.
3. To pinpoint problems and solutions for sustainable resource use.

2. REVIEW METHODOLOGY

The present review is the result of a comprehensive analysis of research papers, policy documents, organizational reports, books and conference papers on Integrated Natural Resource Management (INRM). Information relevant to the principles, approaches and applications of INRM at the global level were collected from peer-reviewed and secondary sources.

3. Major Integrated Approaches

Natural resource management is about finding a balance between the environment, the economy and people. The strategies for natural resource management look for this balance. Natural ecosystems and human livelihoods are connected. Natural resource management needs to involve people and consider many things. It also needs to be flexible and change when necessary Elinor Ostrom's (2009A).

3.1 Integrated Forest Resource Management

Forest management is really important for keeping our forests healthy. People are looking at something called forest management to make sure our forests can survive. This way of managing forests is good because it helps the forest stay strong. When we take care of the land and the forests in a way it helps the soil and makes the forest more stable (Rattan Lal 2015). Anna Tengberg and Sara Valencia (2018) found that integrated forest governance (that integrates ecological restoration, engagement of stakeholders and adaptive management) results in better biodiversity conservation and long-term sustainable outcomes.

Elinor Ostrom's (2009A) study showed that community involvement and collective management make a difference in managing common forest resources. The study found that when institutions work well and local communities are involved, they often do a job of managing forest resources than centralized systems. Community involvement is important for managing forest resources.

Forests help a lot in reducing climate change. They take in 2.6 billion tons of carbon dioxide every year. Forests are very helpful. In some research done in Nepal and India it was found that when communities took care of forests it helped to increase the forest area.

To help the environment and pay for conservation we need to use our resources in a way. This means we have to make sure we are using our resources in the possible way stop wasting things and use money tools like taxes and subsidies to help with conservation efforts (Sadeghi *et al.*,2024).

The aridity index, which is also called AI is a way to figure out what drylands are. It is basically a ratio between how much rain falls in a year and how much water could evaporate from the ground, which is called evapotranspiration or PE for short. Drylands are the places where this ratio, the aridity index 's less than 0.65. The United Nations Environment Programmed or UNEP for short has a system to classify drylands into groups based on the aridity index. These groups are Hyperacid lands Arid lands, Dry sub humid lands and Semi-arid lands.

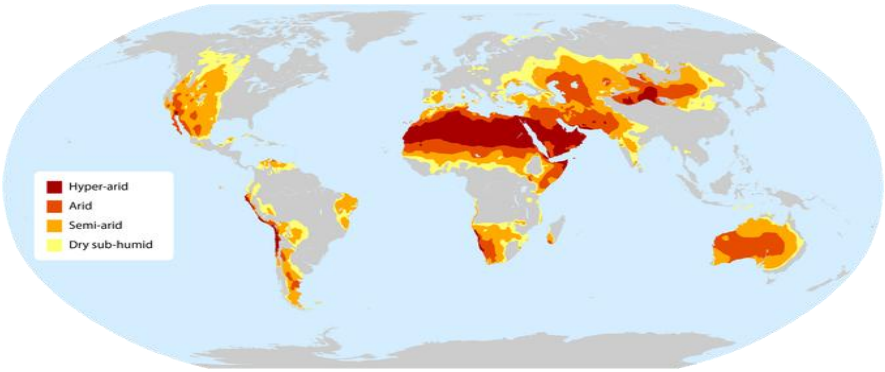


Figure 5. Dryland areas of the world. Source: FAO, 2020.

Sustainable Forest Management

Forests are really important for our climate. They also help with biodiversity storing carbon and supporting people's lives. Sustainable Forest Management is about keeping forests healthy and productive. It helps keep a balance in the ecosystem and preserves the variety of plants and animals.

Forests are like sponges that soak up carbon dioxide from the air and help reduce the effects of climate change. Sustainable forest management practices are good for forests and forests are good, for us because they help with soil stabilization, water regulation and habitat conservation. Forest management helps forests. (Hazarika *et al.*, 2021).

Community Forestry

CBFM is a tool that allows the local community to conserve and use forest resources. The people of Sherdukpen tribe of Arunachal Pradesh have some good ways of managing natural resources. They work together to take care of the forests. The Sherdukpen tribe also uses farming practices. The Sherdukpen tribe has its ways of conserving the environment Pangping G *et al.* (2016).

This is what makes Forest Landscape Restoration (FLR) one of the most promising approaches to achieve degraded forest ecosystem restoration and improve biodiversity conservation, carbon sequestration and rural livelihoods. While the traditional afforestation programmes mainly concentrate on planting of trees, FLR takes a landscape-scale approach, focusing on restoring the ecosystem functions and enhancing the social and economic value of forests. The United Nations Decade on Ecosystem Restoration (2021-2030) has also helped catalyze worldwide action towards rehabilitating degraded landscapes as part of integrated planning, involving stakeholders, and enabling sustainable forest governance. Recent research has shown that FLR can have significant positive effects on the resilience of the ecosystem, the functions of the watersheds, soil organic carbon, and importantly, carbon storage and climate change mitigation over the long-term. In addition, the synergies between agroforestry, assisted natural regeneration, enrichment planting and sustainable silviculture in FLR programmes offer several ecological and socio-economic benefits over traditional forest restoration methods (UNEP & FAO, 2021; Rawat *et al.*, 2024).

The global research over the last few years has brought about a paradigm shift in sustainable forest management: from interventions at the stand level to the concept of Forest Landscape Restoration (FLR), which combines ecological restoration with livelihoods and climate resilience. FLR takes a different approach to afforestation programmes, which are mostly focused on increasing the number of trees being planted.Whereas conventional afforestation programmes focus mainly on tree planting, FLR focuses on restoring ecological functions, biodiversity, watershed services, and socio-economic benefits on landscapes as a whole. Recent reviews have suggested that FLR is beneficial for habitat connectivity, nutrient cycling, hydrological functions, and ecosystem resilience, and that it can benefit local livelihoods by providing sustainable forest-based enterprises. Integrated restoration strategies are becoming more effective than isolated restoration programmes as they optimize for environmental, economic and social goals in a single management approach (Brouwer *et al.*, 2024; Löhr *et al.*, 2024).

New evidence also shows that governance, institutional framework and stakeholder involvement are important determinants of the success of forest restoration. Across Africa, Asia and Latin America, systematic reviews show that better restoration is delivered when local communities are engaged in the design, delivery and mechanisms of benefit sharing for restoration projects. Participatory governance enhances long-term protection of forests, institutional accountability, and expands community ownership of forest restoration efforts. On the other hand, restoration programmes based on a centralized bottom-up approach tend to have poor maintenance, poor socio-economic impacts and poor institutional coordination. Accordingly a key tenet of modern forest landscape restoration programmes is the use of scientific knowledge in conjunction with indigenous resource management practices (Owusu *et al.*, 2023; Löhr *et al.*, 2024).

Further significant progress in sustainable forest management is the increased linkage of climate finance instruments, including REDD+ with ecosystem restoration processes. While the primary purpose of REDD+ was to help limit greenhouse gas emissions via avoided deforestation, recent evaluations indicate that it can also provide a range of other non-carbon benefits, such as biodiversity conservation, watershed protection, livelihood diversification, improved governance, and ecosystem resilience, that will be key in the long-term. There has been a recent push to highlight the importance of transparent governance, equitable benefit-sharing, the reliability of carbon accounting, and the importance of institutional capacity in maximizing carbon and non-carbon outcomes. With this in mind, sustainable forest management is increasingly seen as a multi-disciplinary activity which can also help in reducing climate change, conserving biodiversity, improving sustainable livelihoods and achieving sustainable development goals.

Table 3.1. Major Research Findings on Integrated Forest Resource Management

Approach	**Major Findings**	**Key References**
Forest	Carbon sequestration, FLR, REDD+	FAO (2022), Löhr *et al.* (2024)
Watershed	Recharge, erosion control	Wani *et al.* (2013), FAO (2023)

Approach	Major Findings	Key References
Agroforestry	Carbon, biodiversity	Fahad *et al.* (2021)
Climate Smart	Adaptation, AI	IPCC (2023)

3.2 Watershed Management

Managing water and land is really good for the soil for having enough water and for growing crops. In parts of India where the crops depend on rain managing the water and land in a way made the crops grow 30 to 80 percent better. The water under the ground was also filled up more and less water was wasted as runoff. Managing the water and land together or what we call watershed management is very useful, for soil conservation, water availability and agricultural production. reported by Suhas Wani *et al.* (2013).

The recent watershed management programmes have shifted from engineering-based soil conservation to integrated landscape management that involves simultaneous efforts for addressing land degradation, water security, biodiversity conservation and rural livelihoods. The results from Asia and Africa show that comprehensive watershed interventions result in a significant improvement of groundwater recharge and a reduction in sediment loss, increased vegetation cover and better agricultural productivity. A recent integrated planning framework further highlighted that participatory land-use planning backed by science and stakeholder participation enhances the sustainability of watershed interventions and promotes up-scaling of conservation actions at the community level (Environmental Research, 2023). Likewise, FAO has noted that the restoration of watersheds is becoming a popular tool to ensure climate resilience, food security and sustainable land management in the face of environmental change.

Singh *et al.* (2020) reported that the vegetative barriers and bamboo check dams were found to be really good, at reducing soil erosion. They helped to stabilize the slopes. They also enhanced the groundwater recharge in landscapes that were degraded. The vegetative barriers and bamboo check dams did a job in these landscapes.

Abbasi *et al.* (2019) also made a positive finding that the agricultural income and livelihood resilience in drought-prone areas improved due to watershed restoration projects.

The world is dealing with a lot of crises right now. The United Nations Water organization, also known as UN-Water said in 2024 that we need to manage water in a way. This is because a lot of people around 3.2 billion live in areas where food is grown and these areas are facing water stress

Conservation of soil and water.

Watershed management is a way to take care of the land and water in an area. This means managing the soil, water and plants in that area. A watershed is not about the earth and water it is also about people and how they affect the environment (Orke & Li, 2021; Unial *et al.*, 2020).

When it comes to lands that're not very steep, like lands with a slope of less than 2% agronomical measures are usually what people suggest. For lands that are steeper like lands with a slope of more than 2% people usually recommend using engineering and bioengineering measures, for Watershed based interventions. (Jinger *et al.*, 2019).

Rainwater Harvesting

Rainwater harvesting is really important in areas where water's scarce. This is because it helps to improve the water that's underground. Climate change and the fact that it does not rain regularly have made droughts and water stress worse over the world. In India people do not have a lot of water to use. The amount of water that each person in India has is very low. By the year 2050 the amount of water per person, in India is expected to go down a lot. (Singh *et al.*, 2009a; Wani *et al.*, 2013; Mukherji, 2022). Water scarcity is a pressing issue show in Table 1 because it impacts billions of individuals all over the world, and most importantly, agricultural production and food security are severely impacted.

Table 3.2: Global Water Scarcity Indicators

Indicator	Value /Population Affected
People in high/critical water stress (2021)	720 million (10% global population)
People in water-stressed agricultural areas	3.2 billion people
People in severely constrained agricultural areas	1.2 billion people
Children in high/extreme water vulnerability	450 million children
Annual drought costs (current)	$307 billion+
Projected drought-affected population (2050)	3 out of 4 people globally

Agricultural water withdrawal percentage	72% of total withdrawals

Sources: UN-Water (2024); FAO (2020); UNU-INWEH (2024); UNICEF (2021)

Watershed Restoration

There are four parts to fixing a watershed: drainage line treatments check dams vegetation cover enhancement runoff management Using live bamboo check dams and bori bund check dams helps in several ways. They slow down the speed of the water runoff. These dams catch sediments. Help in stabilizing slopes. They also improve the recharge of groundwater. (Singh *et al.*, 2020). Check dams are really important for saving water. They also help people who farm because check dams let them use water to irrigate their fields and for things they need to do at home. (Abbasi *et al.*, 2019).

This section covers agroforestry systems where research results have been found to be strong.

Agroforestry is a way to manage land in a sustainable way. It has been shown to work Jules Pretty found out in 2008 that in developing countries Integrated Farming Systems and agroforestry systems really help increase productivity. According to Rattan Lal (2015), Agroforestry systems are really good for the earth. They help increase the amount of carbon in the soil, which's very important. Agroforestry systems also help the soil hold water better and stop land from getting damaged. The Food and Agriculture Organization has done some research. Found that agroforestry can increase the amount of food we grow by 20 to 60 percent. This is a deal. Agroforestry also helps keep the air clean and protects animals and plants. Fahad *et al.* (2021) showed that conservation agriculture and agroforestry can help reduce greenhouse gas emissions. They also help make soil more fertile over time. This is really important when we think about climate change.

Carbon Sequestration

Agroforestry systems help a lot in reducing carbon in the air and slowing down climate change. They do this by growing plants and trees and by making soil store more carbon. Some farming practices, like: using tillage to preserve soil. rotating crops to keep soil fertile .using organic farming methods and integrating trees into farming have been found to make soil healthier and stronger against the effects of climate change. (Fahad *et al.*, 2021).

Livelihood Support

Agroforestry gives farmers ways to earn money. They can sell timber, fodder, fruits, fuelwood and other products from the forest. This approach helps farmers have a stable income and not rely too much on growing just one crop. Agroforestry systems make farming more resilient. They reduce dependence on the monocropping system.

In recent years, studies have showed that agroforestry is one of the most promising NbS for sustainable NRM due to its triple benefits in the areas of agriculture, biodiversity and climate. Crop and livestock integration with trees can increase soil organic carbon, nutrient cycling, minimize soil erosion, and increase soil infiltration, all of which helps to increase ecosystem functioning. Worldwide, there are several reports of a substantial reduction in GHGs and the ability to capture C by using agroforestry systems rather than conventional monocropping. Furthermore, agroforestry offers several ecosystem functions such as pollination support, biological pest control, microclimate regulation and habitat connectivity which, combined, ensure longterm environmental sustainability (Feliciano *et al.*, 2022; FAO, 2022).

Agroforestry has also been shown to benefit smallholder farmers with socio-economic advantages in recent studies. Diversification of farm enterprise by timber, fruit trees, fodder, medicinal plants and fuelwood helps to generate income and cut reliance on a single crop. Moreover, agroforestry can enhance resilience to climate variability by supplying stable farm income in times of drought and extreme climate events. Scoping studies conducted in various tropical and subtropical countries have shown that agroforestry systems are effective in improving resource-use efficiency and food and livelihood security. Therefore, agroforestry is gaining growing importance as a method to address various SDGs focused on poverty alleviation, food security, climate action and biodiversity protection (FAO, 2022; van Noordwijk *et al.*, 2025).

Recent studies also indicate that the use of digital technologies such as Geographic Information Systems (GIS), remote sensing, and machine learning has become more frequent and is being used to enhance agroforestry planning and monitoring. These technologies help species selection, land suitability, carbon stock estimation and future assessment of ecosystem services. Digital decision support tools can be integrated with agroforestry management to optimize resource utilization and facilitate sustainable land-use planning in the face of climate change, enhancing the long-term impact of agroforestry.The incorporation of digital decision-support tools into agroforestry management allows for the optimization of resource use and for the support of sustainable land-use planning in variable climate, which will have a positive long-term effect on the impact of agroforestry measures (Van Noordwijk *et al.*, 2025).

3.4 Climate-Smart NRM

Natural resource management is really important for dealing with climate change and making sure our ecosystems can handle it. We need to find ways to make natural resource management work well with the climate. Things like planting different types of crops conserving the soil and using water wisely can really help farming deal with the ups and downs of the climate. as described by Bruce Campbell (2014).

Ampaire *et al.* (2020) found that combining climate adaptation measures with other measures enhances food security and adaptive capacity of vulnerable farming communities in Africa and Asia. Likewise, Maja and Ayano (2021) The ecosystem-based adaptation strategies are really important. They help to make us stronger against drought, flood and land degradation. We need to manage our climate and natural resources in a way to achieve the Sustainable Development Goals, especially when it comes to climate action, poverty reduction and taking care of ecosystems. Ecosystem-based adaptation strategies play a role, in this. The Sustainable Development Goals are important and ecosystem-based adaptation strategies can help us get there. Jeffrey Sachs (2015) posited. Recent reports by the IPCC also say that Nature-based Solutions or NbS are one of the ways to fight climate change and adapt to it at a low cost. Other options include restoring wetlands, planting trees and farming sustainably.
The extraction and processing of resources have side effects, on the environment. These side effects are complex and significant. The table below shows environmental impact indicators. Table 2:

Table 3.3: Environmental Impacts of Resource Extraction and Processing

Impact Category	Percentage Contribution
Total Greenhouse Gas Emissions	Over 60%
Health-related Air Pollution Impacts	40%
Land-related Biodiversity Loss (Biomass)	90%
GHG Emissions from Biomass Processing	33%
GHG Emissions from Fossil Fuels & Minerals	35%

Source: UNEP (2024); Resource Panel (2024).

Recent developments in digital technology have considerably bolstered natural resource management for climate smartness through greater efficiency in resource monitoring, assessment and decision making. The use of Artificial Intelligence (AI), Internet of Things (IoT), unmanned aerial vehicles (UAVs), Geographic Information Systems (GIS), and Remote Sensing (RS) has been increasingly promoted in the context of precision agriculture and sustainable utilization of resources. Predictive models powered by AI help forecast crop yields, identify pests and diseases, plan irrigation, and evaluate climate risk, and IoT sensors continuously gather data on soil moisture, temperature, and nutrient levels for resource management. Similarly, the use of UAV-based and satellite remote sensing technologies allows for quick land-use change assessment, forest degradation monitoring, monitoring of biodiversity and watershed conditions, and prompt actions based on these data to ensure evidence-based planning and interventions (Raman *et al.*, 2024; Miller *et al.*, 2025).
The uptake of these digital technologies, however, is low in many developing countries for various reasons, including their high implementation costs, poor digital infrastructure, lack of technical skills, and concerns about data privacy and governance. Therefore, the institutional capacity strengthening, digital connectivity, and digital policy support of smart technologies are essential in the context of natural resources management under climate change to attain resilient and sustainable management. The integration of AI with geospatial technologies and decision-support systems will likely continue to improve adaptive resource governance and climate resilience in agricultural and natural ecosystems in the future (Miller *et al.*, 2025).

Climate Adaptation

Natural resource management for climate smart is about making our resources strong enough to handle climate change. This way we can make sure they stay productive and healthy for a time. Water resources Water quality Soil health Biodiversity Agricultural systems are all in danger because of climate change. We need to protect water resources because climate change affects water quality and water resources. (Ampaire *et al.*, 2020; Maja & Ayano, 2021).

Nature-Based Solutions

Nature based solutions like wetland restoration mangrove conservation and sustainable agriculture can really help with the environment. These nature-based solutions can also help with ecosystem restoration.

Ecosystem Resilience

People are working together to make the earth stronger. They do this by using the land in a way saving all the different kinds of plants and animals and making good decisions. We need to grow food in a way that does not hurt the earth. We also need to use water. This helps when the weather gets really bad because of climate change. It helps the farms stay okay. Some farmers are trying things like growing many kinds of crops using water better and taking care of the soil. Climate smart agriculture practices like crop diversification and conservation agriculture are good, for the earth. Better irrigation methods also help. Crop diversification is a climate agriculture practice. by Bruce Campbell (2014) as a way of being more resilient to climate variability and lower greenhouse gas emissions.

3.5 Biodiversity Conservation

Biodiversity conservation is really important for keeping ecosystems stable and making sure people can make a living. We need to make sure biodiversity conservation happens so that ecosystems can stay healthy.To do this we should set

up protected areas where animals and plants can thrive. We should also create biodiversity corridors to connect these protected areas. (Brown *et al.*, 2022).

Habitat Restoration

Habitat restoration is when we fix damaged habitats so that plants and animals can live there again. This is connected to keeping ecosystems strong and making sure people have a life. The Food and Agriculture Organization says that in 2024 we can make soil healthier hold water in the soil and grow more food if we restore ecosystems. Some new studies show that restoring nature can help fix the damage we did to the environment and it is very important for dealing with climate change. When we restore ecosystems, they start working again and we get many benefits like clean water more bees to pollinate plants, healthy soil. We are safer from natural disasters.The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services noted in 2024 that if we work to save and restore habitats we can slow down the loss of species and make ecosystems stronger so they can handle big environmental problems.

Wildlife Conservation

Conservation measures help protect wildlife and keep the ecosystem balanced. Protected areas provide food, ecological services. Help regulate the climate. Lately people have started to understand how important it is to conserve wildlife for biodiversity and to keep resources stable and under control. The loss of wildlife due to habitat destruction climate change, pollution and over-exploitation has become an environmental problem worldwide. The International Union for Conservation of Nature says one million species are, in danger of disappearing so it's crucial that we come up with effective conservation plans to save them.

Protected Areas

The protected areas, biodiversity corridors and conservation reserves are really important for keeping the diversity and the ecosystem functions of the protected areas biodiversity corridors and conservation reserves working properly. (Brown *et al.*, 2022). Biodiversity conservation also gives a contribution to the cultural values, traditional knowledge systems and sustainable livelihoods.

3.6 Community-Based Resource Management

The benefits of community natural resource management for the environment and socio-economic development are well known around the world. Community natural resource management helps people living in areas to have better lives. It does this by making sure they have food, shelter and other basic needs met. (Frank Place *et al.*, 2003).

Elinor Ostrom (2009) They gave us the evidence and the theory that the management of natural resources can be sustained through people working together and institutions cooperating at the local level

Das *et al.* (2023) The indigenous knowledge systems are very important for managing bioresources in a way and taking care of the environment. For example, Pangping G and others found out in 2016 that the Sherdukpen community in Arunachal Pradesh uses the forest resources in a way and takes care of the biodiversity through their traditional methods of managing the forest and farming.

Indigenous Knowledge

Traditional practices and TEK are really important for managing resources in a way that's good for the earth. Some people like Das and his team wrote a paper in 2023 that said indigenous people have a lot of knowledge that helps them use natural resources in a way that does not harm the environment.

Participatory Governance

The main idea of IDEM is to get people involved make decisions together and learn as we go. Some people, like Sayer and Campbell said back in 2004 that INRM is a way to look at all the parts of using resources because it includes working together and learning. The World Bank said in 2023 that it is really important for governments, local communities, schools that do research and private companies to work together to take care of resources in a sustainable way. Getting the community involved is a part of making sure we conserve resources in a sustainable way and share the benefits fairly. IDEM is about stakeholder engagement and learning by doing which is important, for the sustainable management of natural resources.

Local Community Involvement

The community plays a role in managing resources making policies work and keeping people safe. When local people are involved, it is fairer for everyone. We can deal with problems better in the long run. It is very important to make sure women are included in community decisions about resources. (Parpart, 2014; AfDB, 2013).

4. Role of Technology

Over the few years studies have shown that new technologies have changed how we manage natural resources. Technological innovation helps us use resources efficiently. It also supports circular economy systems. Reduces environmental damage. (Liu and Liang 2024).

People are using Geographical Information Science. Remote sensing more and more for things like watching over forests, planning and taking care of watersheds making maps of all the different types of plants and animals and figuring out the risks from climate change. According to FAO (2023), deforestation and forest fires and land use change can be monitored by satellite to a great extent.

The geo-information system and Remote Sensing.

Geographic Information Systems and remote sensing are useful tools. They help us make maps of how land's used figure out the boundaries of watersheds keep an eye on forests and see how many different kinds of plants and animals live in an area. We also use them to plan for the environment. Programmed (2024).

5. Policy Framework

Natural resource management is really important. It is supported by international policies. Jeffrey Sachs said in 2015 that we need to manage land, water, forests and biodiversity together to achieve the Sustainable Development Goals. The Paris Agreement and the Convention on Biological Diversity are deals that talk about restoring ecosystems capturing carbon and making sure we can handle climate change. The UNEP and FAO recently said that we can make the environment better if we work together on policies. The Government of India has started projects to plant more trees restore watersheds and manage land in a sustainable way like the Green India Mission, the CAMPA and the National Forest Policy.

6. Challenges

People are starting to pay attention to Integrated Natural Resource Management or INRM because it is really important. There are still some big problems that need to be solved so that Integrated Natural Resource Management can work well everywhere. Integrated Natural Resource Management approaches have some issues. They are not sustainable and they are not effective because of things like the environment being damaged institutions not working well not having money and social and economic pressures. Integrated Natural Resource Management is held back by these things. Reed *et al.* (2016),

Integrated Natural Resource Management (INRM) has proven to be an effective method to ensure environmental sustainability and livelihood security. But its effective implementation is limited by various interlinked challenges such as disjointed governance, weak institutions, policymaking conflicts, lack of financial resources, climate change, and growing pressures on natural resources. These difficulties can diminish the effectiveness of conservation programmes and severely impact the sustainability of integrated resource management programmes (Baral, 2024).

The research also shows that the conditions of limited institutional coordination, lack of technical capacity, weak stakeholder involvement and financial constraints are still very much present in the way sustainable resource management practices are not taken up. The Tranchina *et al.* (2024) review of sustainable land use systems around the world revealed that high implementation costs, policy uncertainty, inadequate extension services, and the absence of financial incentives were significant challenges for adoption. More effective governance, policies that are interdependent and intergovernmental cooperation between research institutions, local communities and governments are needed to address these constraints.

6.1 Policy Conflicts

Natural resource management is a challenge because there are a lot of policy conflicts and different groups are in charge. This is a problem in areas like farming taking care of forests, managing water, mining and building cities. Sometimes the people in charge of these areas do not work well together. They want different things. This makes it hard to manage resources in a way and it hurts the environment. Natural resource management is very important. We need to make sure that the people in charge of farming and the people in charge of taking care of forests and the people in charge of managing water and the people in charge of mining and the people, in charge of building cities all work together (Sachs, 2015). Despite this, institutional fragmentation and lack of implementation mechanisms still remains a problem in many developing countries.

Recent research shows that policy disagreements in NRM have become more multifaceted and are compounded by alternative development priorities, weak institutional arrangements and limited coordination and integration across different sectors. Planning of policies in the fields of agriculture, forestry, water resources, mining, biodiversity conservation & climate change is often independent, leading to overlapping mandates and conflicting resource-use objectives. These discrepancies often result in the inefficient use of land, conservation work that is duplicated and the unsustainable use of natural resources for land use planning. The United Nations Environment Programme (UNEP, 2024) recognises that policy coherence and integrated governance is a key element to find a balance between economic growth and environmental sustainability, as well as to ensure long-term resilience of ecosystems.

Although, the formation of participatory government, decision-making processes that are transparent, and effective collaboration among government agencies, local communities, research institutions, and the private sector are needed for effective conflict resolution. There is recent evidence that the introduction of integrated landscape governance and ecosystem-based planning significantly lower policy conflicts and enhance the conservation of biodiversity, the adaptation to climate change, and the sustainable livelihoods. Building laws and policies, expanding stakeholders'

involvement and facilitating science-based policy formulation are then viewed as essential for the effective implementation of integrated natural resource management programmes (UNEP, 2024; OECD, 2023).

Likewise, Anna Tengberg and Sara Valencia (2018) highlighted that the lack of cross-sectoral cooperation and lack of representation of stakeholders are significant challenges for effective integrated management.

It is suggested that policy conflicts have emerged as one of the major challenges in the effective implementation of Integrated Natural Resource Management (INRM), especially in a context where agriculture, forestry, water and infrastructure development are managed by separate institutions. These segmented policy systems tend to lead to duplication of roles, conflicting land-use priorities and the inefficient use of resources, which in turn has negative impacts on the effectiveness of conservation programmes. Restrictive policy design and low levels of decentralization remain two challenges that restrict community involvement and adaptive resource governance in developing countries, as Baral (2024) noted. Likewise, OECD (2023) emphasized the need for the coordination of policies across sectors and for policy coherence in achieving a balance between economic development and environmental sustainability.

In addition, recent findings suggest that conflicts in policies can be significantly lowered by implementing participatory decision-making and integrated landscape governance, through improved institutional collaboration and involvement of stakeholders. The importance of harmonizing sectoral policies, fostering transparent governance, and integrating scientific knowledge and indigenous knowledge into policy decision-making for better implementation and sustainable natural resource management is now widely acknowledged (OECD, 2023; Baral, 2024).

Table 6.1 Policy Conflicts in Integrated Natural Resource Management (INRM)

Policy Conflict Area	Nature of Conflict	Impact on Natural Resources
Agriculture vs Forest Conservation	Agricultural expansion into forests	Deforestation and biodiversity loss
Economic Development vs Environment	Infrastructure in sensitive ecosystems	Habitat degradation and pollution
Water Allocation Conflicts	Competition among sectors	Water scarcity and depletion
Energy Development vs Conservation	Mining and hydropower projects	Habitat fragmentation
Land Use Planning vs Conservation	Urbanization and land conversion	Loss of natural habitats

Source UNEP (2024)

6.2 Climate Change

Climate change is a problem for managing natural resources in a way that lasts. When the temperature gets really hot and it rains a lot one time and not all another time this causes big problems. We also have droughts and floods and big storms and the ice at the poles is melting. According to Lal (2020) climate-induced land degradation is an issue for food security and environmental sustainability. Land degradation affects our food supply and the environment in a way. The hydrological cycles are changing, leading to water scarcity and also floods and droughts in many areas worldwide. Climate change causes land degradation, desertification and ecosystem instability as reported by the IPCC in parts of the world. The IPCC reports that climate change affects parts of the globe. Reported by Ampaire *et al.*, (2020). Climate related risks pose a threat to food security, water availability and ecosystem resilience, especially for rain-fed agriculture, as noted by Bruce Campbell 2014.

New studies suggest that the effects of climate change are making droughts, flooding, heatwaves and extreme weather events more frequent and worse, putting more of a strain on natural resources and ecosystem functions around the globe. The impacts of these climate induced disturbances lead to increased soil erosion, decreased water availability, changes in species composition, decreased forest and agricultural system resilience. The IPCC (2023) estimated that the synergies between these effects of global warming and shifts in precipitation will have a major impact on agriculture yields, land degradation and biodiversity, especially in tropical and subtropical areas. Finally, climate adaptation and disaster risk reduction measures need to be integrated into natural resource management strategies in order to reduce the long-term environmental and socio-economic impacts.

Furthermore, the impact of climate change is exacerbating resource use conflicts by raising competition for land, water and forest resources between various resource users. Growing evidence shows that adaptive management approaches, ecosystem-based adaptation, climate resilient agriculture, and sustainable watershed development can significantly mitigate climate vulnerability and increase the resilience of ecosystems. Increasing the capacity of early warning systems, climate information services, rehabilitation of degraded ecosystems and community-based adaptation programmes is being seen as effective ways to increase resilience in the face of future climate scenarios (IPCC, 2023; FAO, 2023).

6.3 Weak Coordination

The government departments, agencies, researchers, NGOs and communities do not work together very well. This is a problem, for natural resource management programs. They are not very effective because the government departments, local agencies, researchers, NGOs and communities do not talk to each other or plan things together. Elinor Ostrom (2009) noted that collective action, cooperation in institutions, and participatory governance is essential for a successful management of common natural resources.

6.4 Financial Limitations

The big problem with using Natural Resource Management is that it costs a lot of money especially in countries that are not very rich. You need to spend money on things like roads, computers and people to make sure that the natural resources are used in a way. The United Nations Environment Programmed says that in 2024 many countries do not have money to fix the damage that has been done to the environment to protect animals and plants and to deal with climate change Liu and Liang (2024) .

6.5 Lack of institutional coordination

This is one of the main constraints of successfully implementing integrated natural resource management programmes. In many developing countries, the agriculture, forestry and water sector, the rural development sector, and the environment and forestry sectors are not co-ordinated and may operate independently, with separate planning and some duplication of conservation efforts. Lack of information sharing, lack of involvement of stakeholders, and poor inter-agency cooperation decrease the effectiveness of the interventions on resource management and slow down policy implementation. Recent research highlights that good policy coherence can be achieved through integrated governance approaches with multi-sectoral coordination, which can significantly boost ecosystem resilience (UNEP, 2024; OECD, 2023).

Although, coordination relies on the active involvement of local communities, research institutions, NGOs and private organisations in planning, implementation and monitoring. The institutional partnerships, knowledge exchange, decentralised governance and participatory decision-making methods can make a substantial contribution to the sustainability of natural resource management programmes, and reduce conflicts between multiple resource user groups.

6.6 Population Pressure

The world is feeling a lot of pressure on its resources because the population is growing very fast and more people are moving to cities. We are losing trees animals are disappearing our underground water is running out and the land is getting damaged. All these problems are getting worse because the earth is being asked to provide food, water, energy and things for industries. The pressure on the land where we grow food the forests and the fresh water is increasing because there are people and they are using more things. as stated by Foley et al (2011).

Soil degradation is a problem. This is because the population is getting bigger and people are not using the land in a way. This affects how well the land can be used for farming in the run. The world will need a lot food and water by 2050. This will put more pressure on the earth and its natural resources, like water and soil. Soil degradation and the pressure on resources are very important issues. The world needs to find a way to deal with soil degradation and the increasing demand, for food and water (Rattan Lal *et al.* 2015).

7. RESULT AND CONCLUSION

The environment is getting worse with climate change, loss of biodiversity, water scarcity and pressure on land and natural ecosystems. These issues have made managing resources sustainably one of the most important problems today. Traditional solutions that focus on one sector have not solved the connections between ecology, economy and society. That is why Integrated Natural Resource Management (INRM) was developed. It is an approach that aims to create long-term environmental sustainability and secure livelihoods. A review of methods shows that integrated approaches like sustainable forest management, watershed management and agroforestry systems work well. Conservation of biodiversity climate- agriculture and community-based resource management also significantly improve how efficiently resources are used. These approaches make ecosystems stronger and improve socio-development. These interventions have benefits. They help with soil erosion; recharge groundwater improves soil fertility and increase carbon sequestration. They also conserve biodiversity. Help people adapt to climate chandelier and similar approaches can boost resource-use efficiency, ecosystem resilience and socio-economic development. Sustainable natural resource management is key, to addressing issues. It helps create a sustainable future.

8. Research Gap

The field of Integrated Natural Resource Management or INRM for short has made some progress. although there are still some holes in the research when it comes to actually putting these ideas into practice making policies work together using technology and figuring out if these ideas will last in the long run. Most of the time researchers have looked at parts of the problem such as saving the soil, managing water taking care of the forests or dealing with climate change. They have not often looked at how all these things connected and how they affect each other. INRM is about looking at the picture and considering the environment, the economy, people and technology all at the same time.

Most studies are small and only look at what is happening in one place. They do not compare what is working in parts of the world with different environments and social situations. We need long-term studies to see how using Integrated Natural Resource Management approaches affects the health of the environment the variety of plants and animals the amount of carbon in the air how well people are doing and how well we can adapt to climate change.

REFRENCE

5. Abbasi, S. A., Abbasi, N., & Abbasi, T. (2019). Watershed restoration and sustainable rural development: Impacts on livelihood resilience and ecosystem services. Environmental Monitoring and Assessment, 191(4), 1–15.
6. African Development Bank (AfDB). (2013). Gender and natural resource management in Africa. African Development Bank.
7. Ahmed, S., Islam, M. A., & Rahman, M. M. (2020). Sustainable natural resource management and rural livelihood improvement: A review. Journal of Environmental Management, 256, 109984.
8. Ampaire, E. L., Acosta, M., Huyer, S., Kigonya, R., Muchoki, C., Muthoni, F., & Jassogne, L. (2020). Gender and climate-smart agriculture in East Africa. Climate and Development, 12(5), 1–13.
9. Arslan, A., McCarthy, N., Lipper, L., Asfaw, S., & Cattaneo, A. (2022). Climate-smart agriculture and sustainable livelihood outcomes in developing countries. Agricultural Systems, 198, 103375.
10. Baral, K. (2024). Revisiting Decentralised Governance of Natural Resources in India: Conceptual Binaries and Restrictive Policy Design. Journal of Development Policy and Practice, 9(2), 219–237.
11. Brouwer, R., Bongers, F., Peña-Claros, M., Zuidema, P. A., Brancalion, P., Lohbeck, M., *et al.* (2024). Forest restoration, biodiversity, and ecosystem services. In Restoring Forests and Trees for Sustainable Development: Policies, Practices, Impacts, and Ways Forward. Oxford University Press.
12. Brown, C., Martin, A., & Pfaff, A. (2022). Protected areas, biodiversity conservation and ecosystem resilience. Conservation Biology, 36(4), e13875.
13. Campbell, B. M. (2014). Climate-smart agriculture: Opportunities and challenges for sustainable development. Agricultural Systems, 126, 1–3.
14. Chiang, Y.C. (2024). Sustainable livelihood approaches and community resilience in natural resource management. Sustainability, 16(4), 1520–1535.
15. Convention on Biological Diversity (CBD). (2023). Global biodiversity framework progress report. CBD Secretariat.
16. Das, B., Sharma, P., & Singh, R. (2023). Indigenous knowledge systems and sustainable bioresource management. Journal of Ethnobiology and Ethnomedicine, 19(1), 45–58.
17. Fahad, S., Saud, S., Chen, Y., Wu, C., Wang, D., & Khan, I. A. (2021). Conservation agriculture and agroforestry for climate change adaptation and mitigation. Sustainability, 13(6), 3258.
18. Feliciano, D., Ledo, A., Hillier, J., & Nayak, D. R. (2022). Which agroforestry options give the greatest soil and ecosystem service benefits in different world regions? Agriculture, Ecosystems & Environment, 323, 107670.
19. Feliciano, D., Ledo, A., Hillier, J., & Nayak, D. R. (2022). Which agroforestry options give the greatest soil and ecosystem service benefits in different world regions? Agriculture, Ecosystems & Environment, 323, 107670.
20. Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., Mueller, N. D., O'Connell, C., Ray, D. K., West, P. C., Balzer, C., Bennett, E. M., Carpenter, S. R., Hill, J., Monfreda, C., Polasky, S., Rockström, J., Sheehan, J., Siebert, S., & Zaks, D. P. M. (2011). Solutions for a cultivated planet. Nature, 478(7369), 337–342.
21. Food and Agriculture Organization of the United Nations (FAO). (2021). The state of the world's land and water resources for food and agriculture: Systems at breaking point.
22. Food and Agriculture Organization of the United Nations (FAO). (2023). The status of the world's land and water resources for food and agriculture: Systems at breaking point.
23. Food and Agriculture Organization of the United Nations (FAO). (2020). Global forest resources assessment 2020: Main report.
24. Food and Agriculture Organization of the United Nations (FAO). (2022). The state of the world's forests 2022: Forest pathways for green recovery and building inclusive, resilient and sustainable economies.
25. Food and Agriculture Organization of the United Nations (FAO). (2024). Ecosystem restoration for sustainable agriculture and biodiversity conservation.
26. Food and Agriculture Organization of the United Nations (FAO). (2023). The status of the world's land and water resources for food and agriculture: Systems at breaking point. FAO.
27. Food and Agriculture Organization of the United Nations. (2022). The State of the World's Forests 2022: Forest Pathways for Green Recovery and Building Inclusive, Resilient and Sustainable Economies. FAO.
28. Food and Agriculture Organization of the United Nations. (2023). The Status of the World's Land and Water Resources for Food and Agriculture – Systems at Breaking Point. FAO.

29. Food and Agriculture Organization of the United Nations. (2023). The Status of the World's Land and Water Resources for Food and Agriculture – Systems at Breaking Point. FAO.
30. Frank Place, F., Barrett, C. B., Freeman, H. A., Ramisch, J. J., & Vanlauwe, B. (2003). Prospects for integrated soil fertility management using organic and inorganic inputs. Food Policy, 28(4), 365–378.
31. Hazarika, P., Jha, C. S., & Dadhwal, V. K. (2021). Sustainable forest management and ecosystem services in tropical forests. Forest Ecology and Management, 496, 119414.
32. Herring, S. C., Christidis, N., Hoell, A., Kossin, J. P., Schreck, C. J., & Stott, P. A. (2019). Explaining extreme events of 2018 from a climate perspective. Bulletin of the American Meteorological Society, 100(9), S1–S117.
33. Intergovernmental Panel on Climate Change (IPCC). (2014). Climate change 2014: Synthesis report. IPCC.
34. Intergovernmental Panel on Climate Change (IPCC). (2023). Climate change 2023: Synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC.
35. International Panel for Sustainable Resource Management. (2024). Global resources outlook 2024. United Nations Environment Programme.
36. International Union for Conservation of Nature (IUCN). (2024). The IUCN Red List of Threatened Species 2024. IUCN.
37. IPBES. (2024). Assessment report on biodiversity and ecosystem services. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.
38. Jinger, D., Meena, H. N., & Singh, R. (2019). Soil and water conservation measures for sustainable watershed management in India. Indian Journal of Soil Conservation, 47(2), 101–110.
39. Kelly, R. P., Erickson, A. L., Mease, L. A., & Battista, W. (2013). Embracing complexity in natural resource management. Frontiers in Ecology and the Environment, 11(3), 138–144.
40. Knutson, T. R., Camargo, S. J., Chan, J. C. L., Emanuel, K., Ho, C.-H., Kossin, J., Mohapatra, M., Satoh, M., Sugi, M., Walsh, K., & Wu, L. (2020). Tropical cyclones and climate change assessment: Part II. Projected response to anthropogenic warming. Bulletin of the American Meteorological Society, 101(3), E303–E322.
41. Kumar, A., Singh, R., & Sharma, P. (2023). Integrated farming systems for sustainable natural resource management and livelihood security. Agricultural Systems, 205, 103560.
42. Lal, R. (2015). Restoring soil quality to mitigate soil degradation. Sustainability, 7(5), 5875–5895.
43. Lal, R. (2020). Soil health and climate change: An overview. Soil Security, 1, 100001.
44. Leal Filho, W., Balogun, A.-L., Olayide, O. E., Azeiteiro, U. M., Ayal, D. Y., Muñoz, P. D. C., Nagy, G. J., Bynoe, P., Oguge, N., & Toamukum, N. Y. (2021). Assessing the impacts of climate change in agriculture and food security. Environment, Development and Sustainability, 23, 11339–11368.
45. Li, X., Wang, Y., Zhang, H., & Chen, J. (2024). Natural resources and sustainable livelihoods: Interactions between ecosystem services and human well-being. Sustainability, 16(2), 845.
46. Liu, Y., & Liang, X. (2024). Technological innovation and sustainable natural resource management in the circular economy era. Resources, Conservation and Recycling, 204, 107482.
47. Löhr, K., Eshetu, S. B., Moluh Njoya, H., *et al.* (2024). Toward a social-ecological forest landscape restoration assessment framework: A review. Discover Sustainability, 5, 155.
48. Maja, M. M., & Ayano, S. F. (2021). The impact of climate change on agriculture and food security in Africa. Environmental Systems Research, 10(1), 1–13.
49. Mensah, J., & Amoah, P. A. (2024). Sustainable development, environmental governance, and natural resource management in developing economies. Environmental Development, 49, 100957.
50. Miller, T., *et al.* (2025). The IoT and AI in Agriculture: The Time Is Now—A Systematic Review. Sensors, 25(12), 3583.
51. Morse, S. (2025). Sustainable livelihoods and natural resource management: Concepts and applications (2nd ed.). Routledge.
52. Mukherji, A. (2022). Water security challenges and groundwater governance in South Asia. Water Policy, 24(2), 201–218.
53. Natarajan, M., Singh, R., & Kumar, A. (2022). Integrated natural resource management: Participatory approaches for sustainable ecosystem development. Environmental Management, 69(3), 421–435.
54. Organisation for Economic Co-operation and Development. (2023). Policy Coherence for Sustainable Development 2023. OECD Publishing.
55. Orke, B., & Li, Z. (2021). Watershed management as a socio-ecological system: Challenges and opportunities. Water Resources Management, 35(9), 2851–2865.
56. Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. Science, 325(5939), 419–422.

57. Owusu, R., Kimengsi, J. N., & Giessen, L. (2023). Outcomes of Forest Landscape Restoration Shaped by Endogenous or Exogenous Actors and Institutions? A Systematic Review on Sub-Saharan Africa. Environmental Management, 72, 246–261.
58. Pangging, G., Riba, T., & Tsering, J. (2016). Traditional natural resource management practices of the Sherdukpen community of Arunachal Pradesh, India. Indian Journal of Traditional Knowledge, 15(4), 650–657.
59. Parpart, J. L. (2014). Gender and natural resource governance: New directions for research and policy. Gender, Place & Culture, 21(5), 593–601.
60. Pretty, J. (2008). Agricultural sustainability: Concepts, principles and evidence. Philosophical Transactions of the Royal Society B: Biological Sciences, 363(1491), 447–465.
61. Raman, R. K., Singh, A., & Kumar, S. (2024). Reconnoitering precision agriculture and resource management through artificial intelligence and machine learning: A systematic review. Society for Environment and Education.
62. Rawat, Y. S., Kala, C. P., & Tekleyohannes, A. T. (2024). Forest landscape restoration and carbon storage dynamics: Emerging trends and future perspectives. Frontiers Research Topic.
63. Rockström, J., Falkenmark, M., Allan, T., Folke, C., Gordon, L., Jägerskog, A., Kummu, M., Lannerstad, M., Meybeck, M., Molden, D., Postel, S., Savenije, H., Svedin, U., Turton, A., & Varis, O. (2014). The unfolding water drama in the Anthropocene: Towards a resilience-based perspective on water for global sustainability. Ecohydrology, 7(5), 1249–1261.
64. Sachs, J. D. (2015). The age of sustainable development. Columbia University Press.
65. Sadeghi, H., Rahmani, M., & Karimi, S. (2024). Economic efficiency and financial instruments for sustainable natural resource management. Resources Policy, 89, 104623.
66. Sangha, K. K. (2020). Natural resources and sustainable livelihoods: An integrated perspective. Springer.
67. Sayer, J., & Campbell, B. (2004). The science of sustainable development: Local livelihoods and the global environment. Cambridge University Press.
68. Shah, T., Giordano, M., & Mukherji, A. (2021). Water governance and sustainable development: Emerging challenges and opportunities. Water Policy, 23(2), 245–260.
69. Singh, R., Kumar, P., & Sharma, S. (2020). Effectiveness of bamboo check dams and vegetative barriers in watershed restoration and groundwater recharge. Land Degradation & Development, 31(12), 1456–1468.
70. Singh, R., Wani, S. P., & Garg, K. K. (2009). Rainwater harvesting and watershed management for sustainable water resources development in India. Agricultural Water Management, 96(10), 1441–1450.
71. Singh, V., Patel, A., & Verma, N. (2024). Integrated natural resource management for climate resilience and sustainable development. Sustainability, 16(5), 2148.
72. Su, Y., Zhang, X., Wang, H., & Li, J. (2025). Natural resource sustainability and ecosystem resilience under global environmental change. Sustainability, 17(3), 1125.
73. Suhas, P. Wani, Rockström, J., & Oweis, T. (2013). Rainfed agriculture and watershed management for improving livelihoods in semi-arid regions. Agricultural Water Management, 97(4), 543–550.
74. Tengberg, A., & Valencia, S. (2018). Integrated landscape approaches and ecosystem-based management for sustainable development. Sustainability Science, 13(6), 1469–1484.
75. TERI. (2020). Environmental degradation and economic losses in India. The Energy and Resources Institute.
76. Thapa, M. S. (2025). Institutional dynamics in community-based forest restoration. Discover Sustainability.
77. Tranchina, M., Reubens, B., Frey, M., Mele, M., & Mantino, A. (2024). What challenges impede the adoption of agroforestry practices? A global perspective through a systematic literature review. Agroforestry Systems, 98, 1817–1837.
78. UNICEF. (2021). The climate crisis is a child rights crisis: Introducing the children's climate risk index. UNICEF.
79. United Nations Environment Programme (UNEP). (2024). Global environment outlook 2024. UNEP.
80. United Nations University Institute for Water, Environment and Health (UNU-INWEH). (2024). Global water security assessment report 2024. UNU-INWEH.
81. Uniyal, B., Sharma, R., & Singh, K. (2020). Watershed management and sustainable natural resource conservation in mountainous ecosystems. Journal of Environmental Management, 270, 110892.
82. UN-Water. (2024). United Nations world water development report 2024: Water for prosperity and peace. United Nations.
83. Van Noordwijk, M., *et al.* (2025). Agroforestry as a climate-resilient land-use system: Recent advances in ecosystem services and sustainable development. (Recent review article).
84. Wani, S. P., Rockström, J., & Oweis, T. (2013). Rainfed agriculture and watershed management for improving livelihoods in semi-arid regions. Agricultural Water Management, 97(4), 543–550.
85. World Bank. (2023). Natural resource governance and sustainable development report. World Bank.