

Executive Summary

Watersheds constitute the fundamental ecological and hydrological units that sustain agricultural production, water security, rural livelihoods, and ecosystem services, particularly in rainfed and semi-arid regions. In recent decades, increasing climate variability, land degradation, groundwater depletion, and competing demands on natural resources have exposed the limitations of conventional, structure centric watershed development approaches. While India and many other countries possess extensive experience in watershed implementation, there is growing consensus that future programs must transition toward science based, integrated, and outcome-oriented watershed management. Advances in Land Resource Inventory (LRI), hydrological modelling, remote sensing, digital technologies, and decision support systems combined with the need for stronger institutional convergence and deeper community engagement have created both an opportunity and an imperative to fundamentally reimagine watershed governance.

Against this backdrop, the International Conference on Watershed Resilience: Integrating Science, Sustainability and Society was held from 26–28 November 2025 at Bengaluru. The conference was jointly organized by the Watershed Development Department (Government of Karnataka), the Centre of Excellence on Watershed Management (CoE-WM), University of Agricultural Sciences, Bengaluru, the Department of Land Resources (Government of India), and The World Bank, under the World Bank assisted REWARD Program. The conference was conceived as a dedicated platform to bring together policymakers, scientists, development practitioners, academic institutions, and international experts to share global and national experiences, examine emerging scientific and technological innovations, and deliberate on policy and implementation pathways for building climate-resilient, livelihood-oriented watersheds.

The conference brought together 225 delegates, reflecting strong national, state, and institutional representation. Participation included 10 international and 16 national-level speakers and panellists, offering a balanced blend of global perspectives and domestic implementation experience. Policy insights were provided by 20 senior officials from DoLR and NRAA, while 49 representatives from State Level Nodal Agencies contributed state-level implementation experience. Technical discussions were enriched by 32 consortium partners from Karnataka spanning universities, research organizations, and technical agencies. Field-level perspectives were shared by 36 district and line department officials, with 62 officers from WDD and CoE-WM ensuring close integration of science, policy, and practice collectively underscoring the conference's multidisciplinary and multi-institutional character.

The conference was formally inaugurated by Shri N. Chaluvaryaswamy, Hon'ble Minister for Agriculture, Government of Karnataka, in the presence of senior officials from the Government of Karnataka, Government of India, The World Bank, ICRISAT, and UAS Bangalore. The inaugural session articulated a clear strategic vision: watershed resilience must be treated as a core development priority, anchored in LRI-driven planning, hydrology-based diagnostics, digital decision support systems, and institutional convergence, with Karnataka's REWARD program highlighted as a national and global reference model.

Across multiple technical sessions and panel discussions, the conference examined global innovations, policy frameworks, private-sector engagement, impact assessment, and

community institutions in watershed management. Global experiences from Brazil, China, Africa, Ethiopia, and India demonstrated that while ecological and governance contexts vary, the core principles of resilient watershed management are universal. Brazil's experience highlighted the value of stratified land degradation diagnostics and integrated crop–livestock–agroforestry systems; China demonstrated the power of basin-scale governance, accountability mechanisms, and ecosystem-wise monitoring; African experiences emphasized the integration of watersheds with livelihoods, markets, and social inclusion; Ethiopia showcased participatory watershed stratification linked with tenure security; and India's experience illustrated the transformative potential of digital public infrastructure, LRI integration, and performance-based watershed financing under REWARD.

The deliberations converged on several overarching outcomes. First, watershed investments must be preceded by robust scientific diagnostics, including LRI, hydrological analysis, and degradation assessment, rather than being driven solely by asset creation. Second, watershed programs must evolve toward integrated landscape systems that link soil, water, agriculture, forestry, livestock, and livelihoods. Third, strong institutions and accountability mechanisms, supported by interoperable digital monitoring and decision-support platforms, are essential for long-term sustainability. Fourth, WDC–PMKSY 3.0 should institutionalize LRI through phased roll-out, strengthen inter-sectoral convergence, enable Public–Private Partnerships (PPPs) with clear KPIs, and adopt outcome-based financing, including feasible environmental and nature-based incentives. Finally, community-led governance, social capital, gender inclusion, and rigorous impact assessment were recognized as indispensable for sustaining watershed gains beyond project cycles.

Based on these deliberations, the conference put forward a comprehensive set of strategic recommendations. These include (1) institutionalizing LRI-based, hydrology-driven watershed planning; (2) establishing a national watershed and degradation classification system; (3) integrating satellite-based evapotranspiration and water-stress diagnostics; (4) creating a converged national agro-natural resource data infrastructure; (5) scaling LRI as a decision-ready innovation package rather than a mapping exercise; (6) mainstreaming digital soil sensing and continuous soil health monitoring; (7) shifting toward outcome-based financing linked to measurable biophysical gains; (8) adopting basin-scale and aquifer-based governance models; (9) enabling real-time digital services for farmers through unified platforms; (10) positioning State Agricultural Universities as nodal data and validation hubs; (11) institutionalizing community governance using long-term empowerment frameworks; and (12) transforming watersheds into climate innovation and learning platforms.

The conference concluded that watershed resilience cannot be achieved through technical excellence alone. Sustainable outcomes require the simultaneous integration of science, institutions, markets, and people. The field visit to the Maidalakere watershed provided a practical demonstration of these principles, showcasing how LRI- and hydrology-based planning, DSS-guided intervention design, digital monitoring, and empowered community institutions can translate scientific planning into measurable resilience outcomes. Overall, the conference reaffirmed that future watershed programs must move decisively toward integrated, digitally enabled, and community-anchored systems to address the complex challenges of climate change, land degradation, and rural livelihoods in India and beyond.

I. Introduction

1. Watersheds constitute the fundamental ecological and hydrological units that underpin agricultural production, water security, rural livelihoods, and ecosystem services, particularly in rainfed and semi-arid regions. In recent decades, escalating climate variability, land degradation, groundwater depletion, and increasing competition over natural resources have posed significant challenges to conventional watershed development approaches. While India and several other countries have accumulated substantial experience in watershed implementation, there is growing recognition that future programs must transition beyond structure-centric and sector-specific interventions toward science-based, integrated, and outcome-oriented watershed management frameworks. Recent advances in land resource inventory, hydrological modelling, digital technologies, and decision-support systems alongside the imperative for stronger institutional convergence and deeper community engagement have created both new opportunities and compelling imperatives for reimagining watershed governance.
2. In this context, there was a clear need for a dedicated platform to bring together policymakers, scientists, development practitioners, academic institutions and international experts to share global and national experiences, review emerging scientific and technological innovations and deliberate on policy and implementation pathways for building resilient watersheds. The conference was conceptualized to facilitate informed dialogue on integrating science, sustainability and societal institutions in watershed planning and management and to draw actionable lessons for scaling climate-resilient and livelihood-oriented watershed programs.
3. In this view, the International Conference on Watershed Resilience: Integrating Science, Sustainability and Society was organized from 26 to 28 November 2025 at the Four Seasons Hotel, Bengaluru, Karnataka. The conference was jointly organised by the Watershed Development Department, Government of Karnataka, the Centre of Excellence on Watershed Management (CoE-WM), University of Agricultural Sciences, Bengaluru, the Department of Land Resources (DoLR), Government of India (GoI), and The World Bank, under the World Bank assisted REWARD Program. The event brought together a wide spectrum of national and international stakeholders to deliberate on the future direction of watershed management and to strengthen the scientific, institutional and policy foundations for resilient watershed development in India and beyond.
4. Participation and Representation: The Conference brought together 225 delegates, demonstrating strong national, state and institutional representation and reflecting the high level of interest in advancing science-based watershed management. The technical sessions and panel discussions were enriched by the participation of 10 international

speakers and panellists and 16 national-level Indian speakers and panellists, bringing together global perspectives and extensive national experience across watershed governance, land resource diagnostics, hydrology, digital technologies and climate resilience.

5. At the national level, 20 senior officials from the DoLR and the National Rainfed Area Authority (NRAA) participated in the deliberations, providing critical policy perspectives, strategic direction and insights into ongoing and future watershed programmes. Their engagement ensured strong alignment between scientific recommendations and national policy priorities.
6. The conference also witnessed substantial representation from state-level implementation and technical institutions. Forty-nine participants from State Level Nodal Agencies (SLNAs) representing multiple states contributed implementation experiences, best practices and operational challenges from large-scale watershed programmes. In addition, 32 technical consortium partners from Karnataka, including academic institutions, research organisations and technical support agencies, actively engaged in technical discussions and knowledge exchange.
7. Field-level perspectives were further strengthened by the participation of 36 district-level officials and line department representatives, who shared practical insights from watershed planning, execution and monitoring. A strong contingent of 62 officers and professionals from the Watershed Development Department (WDD), Government of Karnataka (GoK), and the Centre of Excellence on Watershed Management (CoE-WM) ensured close integration of policy, science and on-ground implementation.
8. Overall, the diverse composition of participants—spanning international experts, national policymakers, state implementers, technical institutions and field practitioners—underscored the multidisciplinary and multi-institutional character of the Conference and enabled rich, evidence-based dialogue on scaling scientifically robust, digitally enabled and climate-resilient watershed management in India.

II. Inauguration of the conference

9. The conference was formally inaugurated by Shri N. Chaluvayaswamy, Hon'ble Minister for Agriculture, GoK. The inaugural ceremony was held in the distinguished presence of Shri Manoj Kumar, Principal Secretary (Forests), GoK; Shri Nitin Khade, Joint Secretary, DoLR, GoI ; Smt. Tanuja Thakur Khalkho, Joint Secretary & Financial Advisor, DoLR, GoI; Shri Upendra Pratap Singh, Commissioner, WDD, GoK; Dr. S. V. Suresha, Vice-Chancellor, University of Agricultural Sciences (UAS), Bangalore; Sri Andrew Goodland, Lead Agriculture Specialist, The World Bank; Dr. Stanford Blade, Deputy Director

General, ICRIAT, Hyderabad; Dr. N. B. Prakash, Special Officer, CoE-WM, UAS, Bangalore and Shri Md. Paravej Banthanal, Director, WDD, GoK.

10. In their addresses, the dignitaries collectively emphasized the need to move beyond structure-driven watershed development toward science-led, digitally enabled, and institutionally convergent approaches, anchored in Land Resource Inventory (LRI), hydrology and decision-support systems. Karnataka's leadership, particularly through the REWARD Program, was highlighted as a national and global reference for integrating science, policy and community action.
11. Overall, the Inaugural Session set a clear vision for the conference: that watershed resilience must be treated as a core development priority, requiring close collaboration between governments, research institutions, international partners and communities. It provided a strong policy and intellectual foundation for the subsequent technical sessions, panel discussions and the field visit.

III. Conference Deliberations

Technical Session-1: Global Innovations and Lessons in Watershed Management

12. This session was chaired by Sri Andrew Goodland, Lead Agriculture Specialist, World Bank. It brought together global experiences and evidence-based approaches to watershed management, illustrating how countries across diverse ecological and governance contexts have addressed land degradation, water scarcity, and livelihood vulnerability through scientific diagnostics, institutional reforms, and community-centred implementation. The session established the conceptual foundation for the conference by demonstrating that, despite contextual differences, the core principles underpinning resilient and sustainable watershed management remain largely universal. Country-specific perspectives emerging from this session are presented below.
13. Global knowledge and best practices in sustainable watershed management in Brazil by Sri Cheikh Dia, Senior Agriculture Economist, The World Bank, Brazil. He shared Brazil's experience in restoring degraded pastures, particularly within the Cerrado biome, where prolonged overgrazing, nutrient depletion, and inadequate soil conservation practices had led to extensive land degradation. He explained the development and operational application of the Pasture Degradation Scale (LPD 1–6), a scientifically derived classification system that distinguishes early, intermediate, and advanced stages of pasture degradation. This stratification enables the design of context-specific restoration strategies, ranging from direct pasture recovery measures for mildly degraded lands to integrated crop–livestock–agroforestry systems for severely degraded areas. He emphasized the use of multi-scale diagnostic approaches that combine satellite-based observations from Landsat and Sentinel-2 with field-level

biophysical indicators to inform micro-watershed planning and intervention prioritization. He reported tangible outcomes, including improved vegetation cover, enhanced soil fertility, increased livestock productivity, and strengthened farm incomes. He concluded that Brazil's experience underscores the importance of aligning ecological restoration efforts with economic incentives and sustained farmer capacity building to achieve scalable and durable watershed outcomes.

14. Digital Public Infrastructure for Agriculture by Dr. Rajeev Chawla, Ministry of Agriculture & Farmers' Welfare, GoI. He presented India's evolving digital public infrastructure for agriculture, highlighting AgriStack as a foundational system designed to address fragmentation in agricultural service delivery. He described the three core registries Farmer Registry, Geospatial Land Parcel Registry, and Crop Sown Registry, which together create a unified and continuously updated agricultural database. He explained how this digital ecosystem enables paperless credit, insurance, and disaster relief, significantly reducing transaction costs for farmers. In the context of watershed management, Dr. Chawla emphasized the integration of AgriStack with Land Resource Inventory (LRI) data, enabling precise targeting of soil and water conservation measures, crop advisories, and inter-departmental convergence. He underscored that digital systems are not merely technological upgrades, but institutional enablers for scaling scientific watershed planning nationally.
15. Global Knowledge and Best Practices in Sustainable Watershed Management in China was presented by Dr. Giovanni Ruta, Lead Environmental Economist, World Bank, China. He presented China's experience in large-scale watershed and river basin restoration, with particular emphasis on the institutional and governance innovations that have underpinned sustained environmental recovery. He explained the country's overarching Ecological Civilization framework, the Three Red Lines policy for water resource management, and the River Chief System, under which more than 300,000 government officials are assigned direct accountability for specific river stretches. He highlighted the Yangtze River Revitalization Program as a flagship example of basin-scale planning that integrates forestry, agriculture, water management, and urban development within a unified governance framework. He also discussed the Sponge Cities initiative, which applies nature-based solutions to urban flood mitigation and water resilience. Dr. Ruta emphasized that China's achievements have been driven by strong political commitment, clearly defined institutional accountability, and comprehensive ecosystem-wise monitoring systems, demonstrating that governance and institutional reforms are as critical as technical interventions in achieving sustainable watershed outcomes.
16. Linking Policy, Markets, and Institutions for Resilient Watersheds and Livelihoods was presented by Dr. Victor Afari-Sefa, Global Research Program Director, ICRISAT, Nigeria.

He emphasized that watershed resilience must extend beyond physical and hydrological interventions to encompass livelihood systems, market integration, and institutional strengthening. Drawing on ICRISAT's experience across India and Africa, he demonstrated how hydrology-based land-use planning, combined with rainwater harvesting, agroforestry practices, and soil carbon management, has led to improvements in groundwater availability, cropping intensity, and farm incomes. He further highlighted the importance of value-chain diversification including beekeeping, mushroom cultivation, and Farmer Producer Organization (FPO) led aggregation in sustaining watershed gains over time. Dr. Afari-Sefa stressed that social inclusion and gender equity are critical enablers of durable outcomes, concluding that watershed development is most effective when ecological, economic, and social dimensions are addressed in an integrated manner.

17. Global Knowledge and Best Practices in Sustainable Watershed Management in Ethiopia was presented by Sri Million Alemayehu Gizaw, Senior Natural Resources Management Specialist, The World Bank, Ethiopia. He presented Ethiopia's experience with Community-Based Participatory Watershed Development (CBPWD), which effectively functions as a national-scale land resource inventory-driven framework. He explained how watersheds are systematically classified based on levels of degradation, slope, land use, and erosion risk, enabling site-specific and micro-watershed-level interventions. He highlighted the integration of geo-referenced land certification as a key institutional innovation that enhances tenure security and strengthens farmer incentives for long-term soil and water conservation. He reported that large-scale implementation under national programs has led to improved land productivity, enhanced climate resilience, and strengthened rural livelihoods, particularly within rainfed agricultural systems.
18. Experience of REWARD in Karnataka & Odisha by Ms. Priti Kumar, Task Team Lead, The World Bank, New Delhi. She presented the achievements of the REWARD Program, highlighting it as a shift toward performance-based, data-driven watershed management. She explained how REWARD integrates LRI, hydrology modelling, geospatial analytics, automatic weather stations, and decision-support systems into watershed planning and implementation. She emphasized institutional strengthening through watershed committees, integration of agronomic demonstrations with LRI cards, and FPO-led value chains. Reported outcomes included improved soil moisture regimes, higher adoption of resilient practices, and enhanced institutional capacities, positioning REWARD as a scalable model for future watershed programs.
19. In his concluding observations, the session chairperson, Sri Andrew Goodland, emphasized that despite differing national contexts, successful watershed programs share common foundations: scientific diagnostics, strong institutions, modern technologies, and community participation. He urged Indian states to actively integrate

LRI, digital systems, and livelihood linkages into future watershed initiatives, noting that the insights from this session provide a robust foundation for India's next generation of watershed policies.

20. After the panel discussion, a session on FAO's Innovations in Watershed Management and their Impacts were presented by Dr. Caroline Turner, Water Management Specialist, FAO Regional Office, Bangkok. She stated based on FAO's global experience spanning over five decades, emphasizing that watershed restoration is a long-term, generational process. Using case studies from Niger (Keita), the Kagera River Basin, and Asia, she highlighted the importance of integrated land–water–livelihood approaches, water accounting, and the Water–Energy–Food–Ecosystems (WEFE) nexus. She stressed that successful watershed programmes require robust science, strong institutions, sustainable financing, and continuous capacity building.
21. While sharing Karnataka's Experience in Science based (LRI, Hydrology) watershed implementation, Sri Upendra Pratap Singh, Commissioner, WDD, GoK, highlighted that Karnataka is the lead state in the nation in implementing scientific watershed management, drawing upon lessons from the Sujala-3 and REWARD programmes. This was subsequently continued by Smt. Geeta Halli, DDA, REWARD, Watershed Development Department, Government of Karnataka, who highlighted the large-scale generation of Land Resource Inventory (LRI) datasets, parcel-level planning approaches, saturation-mode treatment strategies and the measurable impacts achieved in terms of water conservation, cropping intensity and enhancement of household incomes. She emphasized Karnataka's role as a lighthouse state in supporting national guideline formulation and capacity building for other states. Complementing these perspectives, Dr. Virupaksha H. S., CoE-WM, UAS, Bangalore, presented how DSS tools convert LRI and hydrological datasets into actionable parcel, village and watershed level recommendations for rapid preparation of table-top DPRs. He further underscored the importance of community consultation in validating science-based plans and highlighted the use of mobile applications and chatbots to deliver LRI-based advisories directly to farmers.

Technical Session-2: Panel Discussion: Policy Framing for the Future of Watershed Development in India

22. This Session was structured as a high-level policy panel to deliberate on India's future watershed architecture, particularly in the context of the transition from WDC-PMKSY 2.0 to WDC-PMKSY 3.0. The discussion focused on scientific planning using LRI and hydrology, institutional convergence, private-sector engagement, financing mechanisms, community governance, and long-term sustainability. Each panellist's viewpoints are highlighted in the foregoing paragraphs.

23. This session was chaired by Sri Nitin Khade, Joint Secretary, DoLR, Gol, where he outlined the current status and future direction of national watershed programs. He informed that WDC-PMKSY 2.0 is under implementation across states and is likely to be extended beyond March 2026 to ensure completion of ongoing projects. He presented the conceptual framework for WDC-PMKSY 3.0 (2026–2030), emphasizing a decisive shift toward LRI-based scientific watershed planning. Key pillars include: Mandatory use of Land Resource Inventory (LRI) as the diagnostic foundation; Integration of hydrology-based planning, including springshed and aquifer approaches; Focus on Rejuvenation of Degraded Lands, Rivers, and Springs (3Rs concept); Strategic positioning of technical experts from reputed institutions for hand-holding states. He stated that the REWARD program’s datasets, tools, and field experience provide sufficient empirical grounding to finalize the forthcoming National Technical Guidelines (NTGs). He also highlighted that fund allocation to states depends on central allocations, making inter-departmental convergence essential to expand coverage and impact. During the Q&A, he acknowledged concerns regarding the time-intensive nature of LRI, clarifying that WDC-PMKSY 3.0 will prioritize areas where LRI already exists, while adopting phased implementation elsewhere.
24. Sri Muhammad Junaid, Director, Watershed Development and Soil Conservation (WDSC), Rajasthan, was the next panellist, who shared Rajasthan’s experience as a water-scarce state, emphasizing that successful watershed implementation requires breaking departmental silos. He described Rajasthan’s convergence model under the Mukhyamantri Jal Swavalamban Yojana, which integrates rural development, agriculture, groundwater, horticulture, and forestry departments. The key insights from this intervention included (a) importance of scientific management of grasslands, given their close linkage with livestock-dependent communities, (b) potential for eco-tourism development within watershed areas as a supplementary livelihood activity, (c) strengthening FPOs and Water User Cooperatives to ensure post-project sustainability. He pointed out that Rajasthan deploys nearly 600 engineers for watershed works, but stressed that future programs require managers with livelihood and institutional skills, not only civil engineering expertise. Drawing from the MARVI project, he highlighted the scope for digital innovations, including mobile apps for soil and water quality assessment, AI-based planning tools, and collaboration with premier institutions such as IITs and IIMs. He also advocated creating a cadre of “Young Watershed Professionals”, similar to the Young Water Professionals initiative.
25. The next panellist Sri Andrew Goodland, emphasized that watershed outcomes depend not only on physical interventions but on decision-support systems, data availability, and institutional coordination. He noted that technical solutions for watershed management are largely known; the critical gap lies in policy frameworks and incentive mechanisms that enable institutions to work together. He stressed (a) the need for

policy coherence across agri-food systems, land degradation, and water conservation, (b) smarter use of government subsidies, linking them to outcomes rather than inputs, (c) integration of community platforms to ensure long-term operation and maintenance. He encouraged India to learn from global institutional models, highlighting that despite widespread internet access, knowledge gaps persist and structured knowledge-sharing mechanisms are essential. Leadership, he noted, will be decisive in translating knowledge into action.

26. Sri L. Prabhakar, Executive Vice-President, ITC Ltd., served as the fourth panellist focussing on the role of the private sector and PPP models in watershed development. He observed that while private entities are willing to engage, many perceive collaboration with government systems as procedurally complex. His key policy recommendations included (a) policy easing and clarity to make public-private engagement more predictable, (b) outcome-based financing linked to measurable indicators such as groundwater levels, cropping intensity, and productivity, (c) greater emphasis on climate resilience, including springshed rejuvenation and aquifer recharge, (d) integration of carbon credits and nature-based solutions, while simplifying processes to ensure farmer profitability, (e) emphasis on the seven 'C's - Convergence, Climate, Carbon, Community, Commitments & cooperations, Contemporariness, and Collaborations. He stressed that post-project sustainability must be institutionalized through Water User Associations, community ownership, and strong local governance.

Technical Session-3: Technological Advances in Soil Mapping, Hydrology, and Land Use for Resilient Watersheds

27. This session was chaired by Dr. N G Patil, Director NBSS & LUP, Nagpur. The emphasis in this session was on cutting-edge scientific and technological advances that are redefining watershed planning and management, particularly through digital soil mapping, hydrological modelling, remote sensing of evapotranspiration, and national-scale geospatial infrastructure. The session emphasized transitioning from static maps and structure-based interventions to dynamic, data-driven, continuously monitored watershed systems.
28. In the keynote address on Innovations for Resilient Dryland Agriculture by Dr. Stanford Blade, Deputy Director General, ICRISAT, Hyderabad highlighted the growing urgency of climate-resilient dryland agriculture in the face of rising temperatures, increased climate variability, and accelerating land degradation. He noted that projected global temperature increases of 2–4°C could lead to an additional 7–11 percent expansion of degraded lands, disproportionately affecting rainfed and marginal regions. He presented evidence from Bundelkhand, Solapur, Ethiopia, and Zimbabwe, demonstrating that resilience can be achieved through: climate-resilient crop varieties;

Integrated agroforestry and regenerative landscape approaches; landscape-level soil and water conservation treatments. He also emphasized that improved varieties alone are insufficient unless embedded within watershed-scale land management and hydrological planning. He highlighted ICRISAT's work in regenerative landscapes, which has been recognized by UNDP, and stressed the need to shift from plot-level productivity gains to landscape-level resilience outcomes. While concluding, he advocated diversification, restoration of degraded lands, and alignment of agricultural research with watershed development programs.

29. Integrated Digital Soil Sensing and Soil Mapping for Information-Driven Soil Management by Prof. Asim Biswas from the University of Guelph, Canada, presented a comprehensive framework for digital soil science, positioning soil as a continuously monitored, data-rich resource rather than a static map product. He introduced the 5-M framework Measurement, Modelling, Mapping, Management, and Monitoring as the foundation of modern soil management systems. The key elements of his presentation included (a) use of proximal soil sensors, spectroscopy, and image-based diagnostics, (b) application of machine learning and AI models to enhance soil property prediction, (c) real-time soil health assessment through mobile and sensor-based applications. He demonstrated how sensor-derived spectral data significantly improved mapping accuracy and enabled 3-dimensional soil depth modelling, overcoming limitations of traditional sampling. Dr. Biswas emphasized that continuous soil monitoring allows site-specific fertilizer optimization, moisture management, and crop-specific recommendations at farm-to-watershed scales. He concluded that scaling digital soil sensing is essential for precision watershed planning, climate adaptation, and sustainable land use decision-making.

30. Advances in Thermal Infrared Remote Sensing for Evapotranspiration and Soil Water Stress Monitoring was presented by Dr. Gilles Boulet, Senior Researcher, Toulouse University, France. He focused on the role of thermal infrared (TIR) remote sensing in quantifying evapotranspiration (ET) and diagnosing soil water stress key variables for watershed hydrology and irrigation management. He explained the scientific basis and applications of: (a) single-pixel energy balance models such as SEBS, TSEB, and SPARSE, (b) contextual models including S-SEBI and Water Deficit Index (WDI), (c) integration of TIR-based indicators with hydrological models. He also highlighted the upcoming potential of new Earth Observation missions such as TRISHNA, NISAR, and SWOT, which will significantly enhance ET estimation, surface water dynamics, and ecosystem stress assessment. He emphasized that satellite-derived ET products can strengthen watershed monitoring, support irrigation scheduling, and improve drought preparedness. His presentation underscored the need to mainstream ET-based diagnostics into operational watershed programs rather than limiting them to research applications.

31. Dr. G. P. Obi Reddy, Principal Scientist of NBSS&LUP, Nagpur, gave a comprehensive presentation on national advances in Geospatial Technologies for Sustainable Land Resource Mapping and Management. He emphasized the foundational role of soil information among the 14 mandated geospatial layers notified by the Government of India. The key highlights include (a) landform characterization using Terrain Mapping Units (TMUs) and object-based image analysis, (b) completion of systematic soil and land resource mapping in 135 districts, (c) development of national products such as Soil Depth Maps, Soil Organic Carbon Maps, Land Degradation Vulnerability Maps, Agro-Ecological Regions, and Length of Growing Period (LGP) Maps. He showcased operational platforms including the Bhoomi Geo-Portal, mobile soil data collection apps, the national soil sample repository, and spectral libraries. Dr. Obi Reddy also discussed challenges related to data standardization, harmonization, and multi-institutional interoperability, stressing the need for nationally consistent protocols. He concluded that strengthening geospatial infrastructure is critical for scientific watershed planning, LRI implementation, and decision-support systems under WDC-PMKSY 3.0.
32. In the concluding remarks by the session's chairperson, reemphasized how digital soil science, remote sensing, and geospatial analytics are converging to create next-generation watershed intelligence systems. Further, he emphasized that states must be prepared to operationalize these technologies, moving beyond pilot projects toward institutional adoption.

Technical Session-4: Panel Discussion: Role of Private Sector in Data-Driven Watershed and Agricultural Transformation

33. The focus of this session was to critically examine the role of the private sector in complementing public investments in watershed development, particularly in the context of data-driven planning, degraded land restoration, agricultural transformation, and financing gaps. The session emphasized the need to move beyond conventional CSR models toward structured Public-Private Partnerships (PPPs), innovative financing mechanisms, and monetization of geospatial and LRI datasets, while retaining community-centric development principles.
34. The panel discussion was moderated by Sri Nitin Khade, Joint Secretary, DoLR, GoI. In his opening remarks, he framed the discussion around the significant investment gap in watershed development, noting that public financing alone is inadequate to address the magnitude of land degradation challenges in India. He observed that although CSR initiatives, impact investors, and private enterprises have demonstrated a growing willingness to engage, well-defined frameworks and scalable models for such participation are still in the process of evolution. He identified three priority domains for private-sector engagement: (a) Public-Private Partnership (PPP) models for

watershed interventions in degraded landscapes; (b) monetization and value-added utilization of data, including Land Resource Inventory (LRI), soil, hydrological, and geospatial datasets; and (c) renewable-energy-led innovations, particularly the deployment of solar energy systems in degraded and water-stressed regions. He urged the private sector to move beyond financing roles and actively co-design innovative watershed solutions that ensure technological relevance, financial viability, and scalability.

35. Dr. A. V. Bhavani Shankar, Chief General Manager, NABARD, as a panellist, emphasized that watersheds should be viewed as integrated development platforms capable of supporting multiple livelihood layers beyond primary agriculture. He underscored that effective watershed models must establish strong linkages across natural resource management, enterprise development, processing infrastructure, and market access. To illustrate this, he cited a practical example from the Kalyana Karnataka region, where a tripartite model was successfully implemented: (a) the government provided land and enabling infrastructure, (b) NABARD facilitated investment and developmental finance, and (c) the private sector (ITC) enabled processing facilities and market integration. This closed-loop approach transformed watershed investments into viable rural enterprises, contributing to enhanced income stability and employment generation. He further highlighted the catalytic role of development finance institutions in de-risking private investments and crowding in private capital for watershed-linked livelihood initiatives.
36. Sri L. Prabhakar, Executive Vice-President, ITC Ltd., Kolkata, another panellist, emphasized the need for a fundamental mindset shift within the corporate sector to scale investments in watershed development. He articulated the concept of “responsibility beyond the fence,” urging corporations to extend environmental and social stewardship beyond factory premises and supply chains to the larger landscape. He outlined key principles for effective private-sector engagement: (a) responsible corporate leadership aligned with long-term sustainability objectives; (b) collaborative partnerships to accelerate innovative ideas into actionable field-level solutions; (c) translation of concepts into funded research and scalable pilot initiatives; (d) orchestration of local ecosystems involving communities, NGOs, and public institutions; and (e) transparent reporting of impacts and outcomes to build long-term credibility. He underscored that trust, transparency, and demonstrable outcomes are critical to sustaining private-sector confidence and investment in watershed initiatives.
37. Sri Tanay Joshi, Sector Lead – Agriculture & Social Sector Advisory, Ernst & Young (E&Y), as a third panellist, emphasized the critical importance of defining clear, simple, and scalable Key Performance Indicators (KPIs) to attract private investment in watershed initiatives. He noted that investors seek indicators that are easy to measure, comparable across geographies, and directly linked to risk mitigation and return

potential. He argued that watershed programs must transition from predominantly activity-based reporting frameworks to outcome-oriented metrics, such as measurable improvements in water availability, agricultural productivity, and climate resilience. He further highlighted the need for participatory approaches in KPI design, ensuring that investment objectives remain closely aligned with community priorities and local development needs.

38. Sri Abhishek Sharma, Deputy Vice-President (Research), Sambodhi Research & Communications Pvt. Ltd., served as the fourth panellist. He emphasized that private-sector engagement in watershed development must remain firmly farmer-centric and community-led. He cautioned against overly technology-driven approaches that risk overlooking local participation and social ownership. The key elements of his intervention included: (a) livelihood-oriented Public–Private Partnerships (PPPs) grounded in farmers’ needs and aspirations; (b) integrated management of surface and groundwater resources within a unified water governance framework; and (c) a strong emphasis on community participation, transparency, and shared ownership. He further underscored that robust impact assessment and learning systems should be embedded from the outset to ensure accountability, continuous learning, and adaptive management.

39. The Chairperson in his concluding remarks, synthesized the key deliberations of the panel and underscored the urgent need to move from dialogue to the formulation of actionable and bankable investment proposals. He proposed the development of a structured Public–Private Partnership (PPP) framework that strategically integrates (a) innovative technologies, (b) private capital and CSR funding, and (c) government schemes along with convergence-based public resources. He further emphasized that future watershed models should aim for near-saturation coverage of interventions, particularly in degraded and water-stressed regions, while systematically addressing the prevailing investment deficit through blended finance mechanisms and multi-stakeholder partnerships.

Technical Session-5: Impact Assessment and Community Engagement in Watershed Projects

40. This session focused on the systematic measurement of outcomes and impacts arising from watershed interventions, with particular emphasis on the role of community institutions and social capital in sustaining investments beyond formal project cycles. The deliberations brought together experts from academia, development finance institutions, research organizations, and multilateral agencies to examine evidence-based impact evaluation frameworks, challenges related to adoption and institutionalization, and practical pathways for scaling climate-resilient and socially inclusive watershed management approaches.

41. This session was chaired by Sri Crispino Lobo, Founder, Watershed Organization Trust (WOTR), Pune. In his opening remarks, he emphasized that watershed programs should not be assessed solely on the basis of physical assets created, but rather on their long-term ecological, social, and livelihood outcomes. He observed that although India has accumulated several decades of experience in watershed implementation, systematic impact assessment and sustained community engagement remain uneven across regions. He stressed that impact assessment must be embedded within program design rather than treated as a post-project exercise; that community institutions are central to the operation, maintenance, and long-term sustainability of watershed assets; and that social capital and trust ultimately determine whether watershed gains are sustained once external funding support concludes.

42. Evidence-Based Impact Assessment of Watershed Development was presented by Sri Vivek Madinur, Research Manager, Institute of Rural Management Anand (IRMA), Gujarat. He outlined a rigorous and systematic framework for evidence-based impact assessment of watershed programs, highlighting the progression from largely descriptive evaluations to more robust quasi-experimental and mixed-method research designs capable of isolating program impacts from external influences such as rainfall variability and market dynamics. The key dimensions of his presentation included the assessment of impacts on groundwater levels, cropping intensity, agricultural productivity, and farm incomes; the application of counterfactual analysis and baseline–endline comparisons; and the integration of remote sensing products, hydrological datasets, and socio-economic surveys. He cautioned that attribution remains a persistent challenge in watershed contexts due to climatic variability and the presence of overlapping development schemes. He emphasized the need for standardized national indicators and transparent, replicable methodologies to ensure that impact assessments are comparable across states and programs.

43. Embedding Social Capital into Agriculture and Rural Development Programs was presented by Sri David Hogg, Chief Regenerative Agriculture Advisor, Naandi Foundation, Hyderabad. He focused on the frequently under-measured yet critical role of social capital in determining the long-term success of watershed interventions. He argued that physical and technical investments yield sustained outcomes only when communities cultivate shared norms, collective responsibility, and local leadership capacity. Key themes of his presentation included: (a) the role of farmer collectives, self-help groups, and local leadership in driving adoption and continuity; (b) the importance of trust-building, participatory planning, and sustained engagement processes; and (c) the integration of regenerative agriculture principles with watershed development strategies. He emphasized that behavioural change and community ownership are inherently long-term processes, requiring consistent facilitation and institutional support rather than short-term, project-driven mobilization.

44. Engaging Local Institutions for Climate-Resilient Watershed Management was presented by Dr. J.V.R. Murty, Representative of World Bank in India. He discussed emerging pathways for strengthening institutional engagement in climate-resilient watershed programs, emphasizing that increasing climate variability has significantly heightened the risks associated with watershed investments. This, he noted, makes adaptive governance and robust local institutional capacity indispensable. The key aspects of his presentation included strengthening Panchayati Raj Institutions, Water User Associations, and Farmer Producer Organizations (FPOs) as empowered decision-making bodies; aligning watershed interventions with climate adaptation and disaster risk management frameworks; and leveraging digital tools and monitoring systems to enhance institutional learning and responsiveness. He emphasized that resilient watershed systems ultimately depend on institutions capable of anticipating, absorbing, and adapting to climate-related shocks.
45. Challenges in Scaling Agricultural Technologies in Smallholder Systems was presented by Dr. Mequanint Melesse, Senior Scientist, ICRISAT, Nairobi. Drawing on evidence from African smallholder systems, he highlighted key determinants influencing the adoption of agricultural technologies within watershed-linked farming contexts. He noted that, despite the availability of technically proven solutions, adoption often remains limited due to farmers' risk perceptions, constrained access to inputs, and weak institutional support mechanisms. His key observations included (a) the importance of aligning technologies with the risk profiles and resource constraints of smallholders; (b) the need for local validation, adaptive trials, and demonstration prior to large-scale dissemination; and (c) the critical role of extension services and community institutions in lowering adoption barriers. He emphasized that watershed programs must deliberately integrate technology scaling and adoption strategies, rather than assuming automatic diffusion of innovations.
46. Lessons from PoCRA on Climate-Resilient Agriculture was presented by Sri Sagar Bharat Khatkale, DBT Specialist, Project on Climate Resilience in Agriculture (PoCRA), Maharashtra. He shared practical insights from the implementation of PoCRA, highlighting the adoption of climate-resilient practices across diverse agro-ecological regions of the state. He explained how climate-smart agriculture approaches, systematic water budgeting, and locally relevant farmer advisories have contributed to enhanced resilience in climate-vulnerable landscapes. The key themes of his presentation included: (a) the importance of data-driven advisories tailored to local agro-climatic conditions; (b) integration of watershed development with crop planning and agricultural risk management; and (c) the need for sustained capacity-building efforts at both farmer and community levels to ensure long-term adoption and impact.

47. Scaling up Land Resource Inventory (LRI) at the National Level was presented by Dr. N. G. Patil, Director, NBSS&LUP, Nagpur. He discussed the strategic opportunities and operational challenges associated with scaling up LRI across the country, emphasizing that LRI constitutes a foundational pillar for scientific and evidence-based watershed planning. While underscoring its critical importance, he acknowledged practical constraints related to time, cost, and institutional capacity. The key dimensions of his presentation included: (a) the need for phased and priority-based implementation of LRI; (b) standardization of protocols, classification frameworks, and quality assurance mechanisms; and (c) integration of LRI outputs with decision-support systems and formal planning workflows. He further stressed that national-scale expansion of LRI must strike a careful balance between scientific rigor and programmatic timelines, particularly in the context of large-scale implementation frameworks such as WDC-PMKSY 3.0.
48. The chairperson in his concluding remarks, emphasized that impact, institutions, and people must remain at the core of watershed programs. He noted that technical excellence alone cannot ensure sustainability unless communities are empowered and impacts are demonstrable. He summarized that future watershed initiatives must (a) institutionalize robust impact assessment frameworks, (b) invest in social capital and local governance, (c) integrate LRI, hydrology, and climate resilience into planning, (d) ensure learning and feedback loops for adaptive management.

IV. Key Outcomes and Recommendations

Technical Session-1: Global Innovations and Lessons in Watershed Management country wise recommendations

49. Brazil – Pasture Restoration and Integrated Land Management
Drawing from Brazil’s experience, the following country-specific recommendations emerged (a) adopt a stratified degradation assessment system by introducing a national Pasture/Soil Degradation Scale (on the lines of LPD 1–6) to systematically classify early, moderate, and severe stages of land degradation; (b) apply multi-scale diagnostics for planning by integrating remote-sensing products (such as Landsat and Sentinel-2) with field-based indicators to support micro-watershed–level decision-making, (c) promote integrated crop–livestock–agroforestry systems to restore severely degraded lands, enhance soil carbon stocks, and improve overall system resilience; and (d) strengthen farmer capacity and institutional incentives by aligning ecological restoration objectives with economic viability through targeted training, incentive mechanisms, and credit-linked support programs.
50. China – Integrated Basin Governance and Ecological Restoration
Drawing from China’s experience, the following country-specific recommendations emerged (a) institutionalize accountability-based governance systems by adapting the

River Chief System characterized by clearly assigned responsibility for defined river stretches to India's federal, state, and Panchayati Raj governance structures, (b) adopt basin-scale and landscape-level planning models by drawing lessons from initiatives such as the Yangtze River Revitalization Program to integrate forestry, agriculture, water management, and urban development within unified river-basin frameworks, (c) promote nature-based solutions for urban flood resilience by introducing Sponge City concepts at urban watershed interfaces to improve storm-water management and flood mitigation; and (d) strengthen ecosystem-wide monitoring and decision support through the integration of satellite observations, hydrological measurements, airborne platforms, and digital sensor networks to enable real-time watershed monitoring and adaptive management.

51. Africa (ICRISAT Region: Nigeria and India–Africa Experiences)

Drawing from experiences across African smallholder systems, the following recommendations emerged (a) link watershed interventions with livelihood systems by integrating hydrology-based land-use planning with income-generating activities such as beekeeping, mushroom cultivation, agroforestry, and allied enterprises, (b) adopt smart water-management technologies through the introduction of sensor-based irrigation systems and water-saving devices to enhance efficiency and reduce risk in water-scarce environments, (c) ensure social inclusion and gender equity by embedding women's groups, farmer collectives, and local institutions into watershed planning, implementation, and monitoring processes, (d) strengthen value-chain integration for resilience by connecting watershed productivity gains to market access, storage infrastructure, aggregation mechanisms, and FPO-led value chains.

52. Ethiopia- LRI-Based National Watershed Stratification

Based on Ethiopia's experience, the following country-specific recommendations emerged (a) adopt LRI-type watershed stratification at the national scale by classifying watersheds according to degradation status, land use, slope class, and erosion risk, similar to Ethiopia's Community-Based Participatory Watershed Development (CBPWD) framework, (b) promote participatory watershed planning by strengthening India's community engagement approaches through adaptation of Ethiopia's structured participatory manuals for micro-watershed planning, (c) enhance resilience in rainfed agricultural systems through integrated soil and water conservation measures, agroforestry practices, and livelihood diversification in fragile and rainfall-dependent regions, (d) leverage geo-referenced land certification systems to strengthen tenure security and incentivize long-term investments in soil and water conservation.

53. India – Digital Ecosystem and Data-Driven Watershed Management

Drawing from national experiences and emerging innovations, the following recommendations were identified for India (a) integrate national digital platforms with

LRI by linking AgriStack, digital land records, geospatial parcel maps, and crop registries with LRI outputs to enable precision watershed planning, (b) expand REWARD-type performance-based approaches by institutionalizing outcome-linked financing mechanisms for watershed committees across states and programs, (c) enable real-time digital service delivery to farmers by accelerating paperless access to credit, insurance, disaster relief, and crop advisories through unified digital platforms, (d) strengthen cross-sectoral convergence by integrating agriculture, horticulture, animal husbandry, and soil and water conservation departments through shared digital datasets and interoperable planning systems.

Technical Session-2: Policy Framing for the Future of Watershed Development in India

The following recommendations emerged in the session

54. Recommendation-01: Scale-Up LRI-Based Scientific Watershed Management by (a) making LRI mandatory for WDC–PMKSY 3.0, with flexible and phased implementation based on availability of LRI layers, (b) prioritizing areas where LRI already exists to ensure faster rollout, (c) using REWARD experiences and datasets to finalize the National Technical Guidelines (NTGs).

55. Recommendation-02: Strengthen Convergence Across Departments and Schemes through (a) institutionalizing strong multi-department convergence (Agriculture, RDPR, Groundwater, Horticulture, Forestry, and other development departments), (b) adopting the Rajasthan model of cross-department coordination to avoid siloed implementation, (c) maximizing resource pooling through convergence to address funding constraints.

56. Recommendation-03: Integrate Hydrology, Springshed & Aquifer-Based Approaches by (a) adopting hydrology-driven planning, springshed rejuvenation, and aquifer recharge as core components of future watershed programs, (b) promoting water budgeting and aquifer literacy at community level.

57. Recommendation-04: Strengthen Private Sector Participation (PPP) by (a) creating policy mechanisms for easy, transparent engagement of the private sector, (b) promoting PPP models for financing, technology infusion, and innovations, (c) increasing awareness of government policies among private sector actors.

58. Recommendation-05: Enable Innovation, Technology & Data-Driven Decision-Making by (a) promoting use of AI, mobile applications, sensors, and digital tools for soil and water monitoring, (b) developing planning software, short training videos, and digital outreach tools, (c) encouraging institutional data-sharing and reduce knowledge gaps across states.

59. Recommendation-06: Build Community-Led Governance & Sustainability Models through (a) strengthening Water User Associations, FPOs, and community cooperatives for post-project sustainability, (b) integrating livelihood components (NRLM convergence) into WDC 3.0, (c) promoting Young Watershed Professionals on the lines of Young Water Professionals.
60. Recommendation-07: Promote Outcome-Based Financing & Carbon/Environmental Incentives via (a) shift from funding based only on physical structures to measurable outcomes (water tables, cropping intensity, productivity gains), (b) explore carbon credits and nature-based solutions, but simplify processes and improve profitability for farmers.
61. Recommendation-08: Improve Human Capacity & Professional Skills by (a) building capacity of engineers to function also as managers of watershed livelihoods, not just civil works implementers, (b) conducting farmer exposure visits to successful watershed sites, (c) engaging reputed institutions (IITs, IIMs) for innovation and training.
62. Recommendation-09: Address Policy Gaps & Emerging Challenges by (a) creating policy safeguards to prevent conversion of drains into roads, protect natural drainage, and manage contaminated water, (b) framing policies to rejuvenate degraded lands, restore soils, and manage pesticide-laden runoff, (c) ensuring balanced State–Centre fund allocation with flexibility for time-intensive activities like LRI.
63. Recommendation-10: Encourage Global Knowledge Exchange through (a) studying global institutional models, incentive mechanisms, and success cases to improve India's watershed governance, (b) promoting systematic knowledge-sharing platforms within India and across countries.

Technical Session-3: Technological advances in soil mapping, hydrology, and land use for resilience watersheds

64. Recommendation-11: Promote Climate-Resilient & Diversified Dryland Agriculture by (a) scaling up climate-resilient crop varieties, integrated agroforestry, and regenerative landscape practices to reverse land degradation and enhance watershed resilience, (b) encouraging landscape-level treatment and transitions from degraded lands to productive systems, supported by evidence from Bundelkhand, Solapur, Ethiopia, and Zimbabwe.
65. Recommendation-12: Mainstream Digital Soil Sensing & Real-Time Soil Health Monitoring through (a) integrating proximal sensors, spectroscopy, and AI-driven soil models across farm-to-watershed scales, (b) institutionalizing continuous soil measurement, modelling, mapping, management, and monitoring (5Ms) using digital

platforms, (c) using real-time soil data for site-specific fertilizer optimization, moisture management, and precision land use planning.

66. Recommendation-13: Integrate Satellite-Based Evapotranspiration & Water Stress Tools by (a) incorporating thermal infrared (TIR) remote sensing, SEBS/TSEB/SPARSE models, and contextual indices (S-SEBI, WDI) for watershed-level ET monitoring, (b) preparing States for operational adoption of TRISHNA, NISAR, and SWOT mission datasets to strengthen hydrological modelling, irrigation scheduling, and drought preparedness.
67. Recommendation-14: Strengthen National Geospatial Infrastructure for LRI & Watershed Planning by (a) expanding use of Bhoomi Geo Portal, national soil repositories, spectral libraries, and mobile apps for state-level planning and stakeholder engagement, (b) adopting standardized national protocols for soil, hydrology, land degradation, and land use mapping using advanced sensors, AI, and geospatial analytics, (c) promoting multi-institutional data harmonization to support WDC-PMKSY 3.0's scientific planning requirements.
68. Recommendation-15: Scale up LRI as an integrated innovation package rather than a standalone product: National scaling of LRI should move beyond map delivery to a comprehensive innovation ecosystem. LRI outputs must be bundled with hydrological diagnostics, decision support systems, localized advisories, institutional processes and capacity-building modules. Such packaging ensures that scientific diagnostics translate into actionable planning and measurable field-level impacts across diverse agro-ecologies.
69. Recommendation-16: Create a nationally converged agro-natural resource data infrastructure: Fragmented data generation by NBSS&LUP, SLUSI, SAUs, irrigation and agriculture departments leads to duplication and inefficient use of public resources. A nationally governed, interoperable data ecosystem should be established with standardized formats, shared protocols and defined custodianship. ICAR institutions and State Agriculture Secretaries should play a central role in facilitating inter-departmental data sharing and institutional convergence.
70. Recommendation-17: Position universities as nodal data integration and validation hubs: State Agricultural Universities should be formally enabled to function as data aggregation, validation and dissemination hubs. University Information Systems can leverage PG students, RAWEP participants and faculty to pool, curate and update datasets through structured academic engagement and supervised crowdsourcing, thereby improving data quality while building institutional capacity.

Technical Session-4: Panel Discussion on Role of private sector on data driven watershed and agricultural transformation

71. Recommendation-18: Strengthen Public–Private Partnerships (PPP) in Watershed Development by (a) creating enabling frameworks to attract CSR funds, private investors, and impact-oriented enterprises into watershed and degraded-land restoration, (b) simplifying procedures for CSR engagement and provide visibility on outcomes to build investor confidence.
72. Recommendation-19: Develop Monetization Models for Watershed and LRI/Geospatial Data via (a) designing modules to monetize available soil, land, water, hydrology, and LRI datasets, ensuring value creation for both government and private partners, (b) Encouraging private-sector involvement in developing analytics platforms, data products, and decision-support tools for watershed planning.
73. Recommendation-20: Promote Solar Energy Systems in Degraded Lands using (a) pilot solar-based innovations in watershed areas—solar pumps, micro-irrigation, and energy-for-water systems—to transform degraded lands into productive assets and (b) private sector in co-designing solar-energy–led watershed interventions, making renewable energy a backbone of future watershed development.
74. Recommendation-21: Build Investor Confidence Through Responsible Corporate Leadership by (a) encouraging corporations to adopt responsible stewardship beyond their boundaries (“outside the fence” responsibility), (b) fostering partnerships that accelerate innovative ideas, support research funding, and orchestrate local ecosystem collaborations, (c) ensuring transparent impact reporting and outcome measurement for all PPP initiatives.
75. Recommendation-22: Leverage Watershed as a Platform for Multi-Layered Livelihood Development by (a) using watersheds as integrated platforms to build multiple livelihood layers—agriculture, processing, marketing, and value addition, (b) promoting tripartite models connecting government land, developmental finance (e.g., NABARD), and private market linkages (e.g., ITC) to create sustainable rural enterprises.
76. Recommendation-23: Define Clear, Scalable, and Investor-Friendly KPIs by (a) establishing simple, measurable, and scalable Key Performance Indicators (KPIs) for private-sector engagement, (b) considering investment-friendly outcomes, enabling easier assessment of returns, risks, and community benefits, (c) ensuring participatory approaches while defining KPIs to reflect local needs and expectations.
77. Recommendation-24: Adopt Farmer-Centric and Community-Led Approaches through (a) promoting PPPs rooted in farmer-centric livelihood development, (b) integrating surface and groundwater resources into a unified water management framework, (c)

ensuring strong community participation and shared ownership for long-term sustainability.

78. Recommendation-25: Develop a Concrete PPP Proposal for Near-Saturation Watershed Development by (a) preparing a comprehensive investment proposal combining innovative technologies, private-sector funding, and government resources, (b) aiming at near-saturation coverage of watershed activities, especially in degraded lands and water-stressed regions, (c) addressing the investment deficit through blended financing, corporate partnerships, donor support, and innovative financial instruments.

Technical Session-5: Impact assessment and Community Engagement in Watershed Projects

79. Recommendation-26: Institutionalize stage-sensitive impact evaluation mechanisms: Impact assessments of watershed programs should explicitly account for differences in implementation maturity. While Difference-in-Difference (DiD) and population-based indices provide robust evidence, comparisons between REWARD and WDC-PMKSY must be normalized for progress achieved on the ground. Future evaluations should therefore adopt a staged assessment framework, linking impact indicators to completion levels (e.g., early, mid, and advanced stages), to enable fair interpretation of outcomes and adaptive course correction.
80. Recommendation-27: Mainstream social capital and enterprise development within watershed design: The Araku experience demonstrates that watershed success is strongly amplified when social capital, community ownership and enterprise orientation are embedded at the core of program design. Watershed guidelines should therefore formally integrate participatory composting, biomass and water management, agroforestry with native species, intercropping systems, centralized processing and quality assurance mechanisms, along with market linkages. Such integration enables long-term ecological restoration, livelihood diversification, carbon sequestration and socio-economic upliftment.
81. Recommendation-28: Transition from short-term committees to long-term community institutions using the 3E framework: The limitations of conventional watershed committees—short tenure, limited capacity and institutional fragility—necessitate a structural shift. Adoption of the Educate–Enable–Empower (3E) framework is recommended, beginning with intensive and sustained community education using LRI cards, soil and weather data. This should be followed by enabling communities to undertake demand-driven planning and convergence-based actions, and finally empowering institutions through long-term technical, financial and institutional support spanning 7–10 years.

82. Recommendation-29: Deploy dedicated human resources for community engagement and knowledge translation: Effective use of scientific data requires continuous facilitation. Dedicated cadres such as LRI managers, trained NGOs and extension professionals should be deployed for at least 2–3 years during the education and enabling phases. Traditional communication methods should be complemented with digital platforms to maximize outreach, understanding and behavioural change among farmers and watershed institutions.
83. Recommendation-30: Institutionalize Farmer Field Schools (FFS) as the backbone of capacity building: Evidence from Project on Climate Resilience in Agriculture (PoCRA) highlights FFS as a high-impact mechanism for transferring climate-resilient technologies and agronomic practices. Watershed and climate resilience programs should institutionalize FFS to support adoption of micro-irrigation, improved cropping patterns, climate-smart agronomy and real-time advisories, thereby reducing climate risk and enhancing productivity.
84. Recommendation-31: Strengthen decentralized governance through digital tools and social accountability: Village-level institutions such as Village Climate Resilient Management Committees (VCRMCs) should be empowered with digital planning, monitoring and social audit tools. Transparent governance mechanisms—integrating digital dashboards, community monitoring and Panchayat-led audits—enhance local ownership, improve accountability and enable evidence-based decision-making.
85. Recommendation-32: Reposition watershed programs as climate innovation and learning platforms: Watershed initiatives should be conceptualized as dynamic climate innovation centres rather than static development projects. By fostering experimentation, digital integration, multi-institutional collaboration and adaptive learning, watershed programs can serve as scalable models for climate-resilient agriculture and sustainable rural development.
86. Recommendation-33: Ensure synchronized scaling of data, institutions and technology: Long-term impact at scale requires simultaneous strengthening of converged data systems, resilient community institutions and technology-enabled implementation pathways. Future watershed programs should avoid fragmented interventions and instead adopt integrated strategies that align science, institutions and governance for sustained outcomes.

V. Actionable Recommendations

87. Based on the above deliberations, the following twelve key recommendations together define a next-generation watershed paradigm for India, in which science, data, institutions, technology, finance, and communities evolve in an integrated and mutually

reinforcing manner. These recommendations move beyond incremental enhancements to existing approaches and are grounded in globally benchmarked best practices, drawing from both international experience and India's own innovations. Importantly, they are not aspirational; each recommendation is actionable and immediately implementable within India's existing institutional, policy, and programmatic frameworks particularly under WDC-PMKSY 3.0 and allied national initiatives. Collectively distilled from all technical sessions and panel discussions, and carefully prioritised for the Indian context, these twelve recommendations provide a coherent roadmap for transforming India's watershed programs into scientifically robust, digitally enabled, outcome-oriented, and socially anchored systems capable of delivering sustained climate resilience and livelihood security.

88. Actionable Recommendation-1: Institutionalise LRI-Based, Hydrology-Driven Watershed Planning: Move from structure-centric planning to LRI-anchored, hydrology-first watershed design, integrating soils, slopes, land capability, erosion risk, aquifer behaviour, and runoff pathways as mandatory inputs under WDC-PMKSY 3.0. Why critical: India already has LRI datasets; the gap is institutional adoption, not technology.
89. Actionable Recommendation-2: Establish a National Degradation & Watershed Condition Classification System: Adopt a stratified watershed and land degradation classification (similar to Brazil's LPD 1-6) covering soil health, erosion status, hydrological stress, and land use intensity at micro-watershed scale. Outcome: Enables prioritisation, phase-wise treatment, and outcome-based financing.
90. Actionable Recommendation-3: Integrate Satellite-Based ET, Water Stress & Hydrological Diagnostics: Operationalise ET-based water accounting using TIR remote sensing (SEBS/TSEB/SPARSE, S-SEBI, WDI) and prepare States for TRISHNA, NISAR and SWOT datasets. Why advanced: Moves watershed monitoring from rainfall-based proxies to actual water use and stress diagnostics.
91. Actionable Recommendation-4: Create a National Converged Agro-Natural Resource Data Infrastructure: Build a federated, interoperable data ecosystem linking NBSS&LUP, SLUSI, IMD, CGWB, SAUs, AgriStack, Bhoomi, and State GIS portals with clear custodianship and standards. Impact: Eliminates duplication, accelerates planning, and enables AI-ready datasets.
92. Actionable Recommendation-5: Scale LRI as an Integrated Innovation Package (Not Just Maps): Bundle LRI outputs with hydrological diagnostics, DSS tools, localised advisories, capacity-building modules, and institutional processes. Key shift: From map delivery to decision-ready science.

93. Actionable Recommendation-6: Mainstream Digital Soil Sensing and Continuous Soil Health Monitoring: Adopt proximal soil sensors, spectroscopy, AI-based soil models, and the 5M framework (Measurement–Modelling–Mapping–Management–Monitoring) for real-time soil fertility and moisture decisions. Practicality: Pilot-ready through SAUs, FPOs and progressive districts.
94. Actionable Recommendation-7: Implement Outcome-Based Financing Linked to Measurable Biophysical Gains: Transition from asset-based funding to outcome-linked financing tied to groundwater recovery, ET reduction, cropping intensity, yield stability, and soil carbon gains. Advanced element: Enables carbon and nature-based finance alignment.
95. Actionable Recommendation-8: Adopt Basin-Scale and Aquifer-Based Governance Models: Complement micro-watershed planning with basin-scale and aquifer-based frameworks, adapting China’s basin governance and India’s springshed initiatives for hill and semi-arid regions. Why essential: Watershed impacts do not respect administrative boundaries.
96. Actionable Recommendation-9: Enable Real-Time Digital Services for Farmers Using Unified Platforms: Integrate LRI + AgriStack + weather + crop + insurance data to deliver real-time, paperless advisories, credit, insurance and disaster response. Scientific value: Converts static datasets into dynamic decision services.
97. Actionable Recommendation-10: Position State Agricultural Universities as Nodal Data and Validation Hubs: Formally empower SAUs as data aggregation, validation and dissemination centres, using PG students and faculty for supervised crowdsourcing and continuous updates. Strategic benefit: Builds national capacity while improving data quality.
98. Actionable Recommendation-11: Institutionalise Community Governance Using the 3E Framework: Replace short-term watershed committees with long-horizon institutions using: Educate (science literacy via LRI cards, soil & climate data); Enable (demand-driven planning and convergence); Empower (7-10year institutional support). Evidence-based: Proven through Araku, PoCRA and REWARD.
99. Actionable Recommendation-12: Watersheds as Climate Innovation & Learning Platforms: Transform watersheds into living laboratories for: Climate-resilient agriculture, digital experimentation, PPP innovation, livelihood diversification, and adaptive governance. Why transformative: Converts watersheds from projects into scalable climate systems.

100. **Field visit:** The field visit served as a living laboratory, translating Karnataka’s REWARD implementation of LRI based methodology into observable outcomes on the ground. Participants noted that the Maidalakere watershed exemplifies how science, technology, institutions, and community engagement can be effectively integrated under a programmatic framework like REWARD. The visit concluded with a consensus that future watershed programs, particularly under WDC-PMKSY 3.0, should mainstream such LRI- and hydrology-based approaches, supported by robust institutional convergence and digital decision-support systems.

VI. Conclusion

101. The International Conference on Watershed Resilience: Integrating Science, Sustainability and Society (26–28 November 2025, Bengaluru) underscored the urgent need to reorient watershed development in the face of climate variability, land degradation, and groundwater stress by moving beyond structure-centric approaches toward science-based, integrated, and outcome-oriented planning. Jointly organized under the REWARD Program by the Watershed Development Department (GoK), CoE-WM (UAS Bengaluru), DoLR (GoI), and the World Bank, the conference brought together 225 national and international participants to highlight the centrality of LRI-driven diagnostics, hydrology-based planning, digital decision-support systems, institutional convergence, and community engagement. Drawing on global lessons from Brazil, China, Africa, Ethiopia, and India, the deliberations converged on the need for robust scientific diagnostics, integrated landscape and livelihood systems, strong institutions with clear accountability, interoperable digital monitoring, and outcome-based financing frameworks under WDC–PMKSY 3.0, including PPPs with transparent KPIs. The conference concluded that long-term watershed resilience ultimately depends on community-led governance, social inclusion, gender equity, and rigorous impact assessment—principles effectively demonstrated during the field visit to the Maidalakere watershed through Karnataka’s LRI- and hydrology-based planning and digital implementation model.

The link for material and youtube videos of the conference is as below.

<https://www.coewm.com/pages/IntConference-26Nov2025.php>

Annexure-1

Program Details:

Time	Particulars
Date: 26.11.2025 (Wednesday)	
09:00-10:00	Registration
10.00-11.30	Inaugural Session
	Inauguration by: Sri N. Chaluvarya Swamy, Hon'ble Minister for Agriculture, GoK
	Guests of Honor: 1. Sri Nitin Khade, IAS, Joint Secretary, DoLR, New Delhi
	2. Dr. S. V. Suresha, Vice-Chancellor, UAS, Bangalore
	3. Sri Andrew Goodland, Lead Agriculture Specialist, The World Bank
	4. Dr. Stanford Blade, DDG, ICRISAT, Hyderabad
	5. Sri Manoj Kumar, IFS, Principal Secretary (Forests), GoK
	6. Ms. Tanuja Thakur Khalkho, IAS, Joint Secretary & Financial Advisor, DoLR
11.30-12.00	Tea Break & Group Photo
Technical Session-1: Global Innovations and Lessons in Watershed Management Chairperson: Sri Andrew Goodland, Lead Agriculture Specialist, The World Bank	
12.00-12.20	Global knowledge and best practices in sustainable watershed management in Brazil – Mr. Cheikh Dia, Senior Agriculture Economist, The World Bank, Kinshasa, Congo
12.20-12.40	Digital Public Infrastructure for Agriculture – Dr. Rajeev Chawla, Ministry of Agriculture and Farmers' Welfare, GoI
12.40-13.00	Global knowledge and best practices in sustainable watershed management in China – Dr. Giovanni Ruta, Lead Environmental Economist, The World Bank, China
13.00-13.20	Linking Policy, Markets and Institutions for Resilient Watersheds and Livelihoods – Sri Victor Afari-Sefa, Research Program Director, ICRISAT, Nigeria
13.20-13.40	Global knowledge and best practices in sustainable watershed management in Ethiopia - Sri Million Alemayehu Gizaw, Senior NRM Specialist, The World Bank, Adis Ababa, Ethiopia
13.40-14.00	Experience of REWARD in Karnataka & Odisha – Smt. Priti Kumar, Task Team Lead, The World Bank (Recorded Presentation)
14.00-15.00	Lunch Break
Technical Session-2: Panel Discussion - Policy Framing for the Future of Watershed Development in India Chairperson: Sri Nitin Khade, IAS, Joint Secretary, DoLR, New Delhi	
15.00-16.40	Panelists: 1. Sri Muhammad Junaid, Director, WDSC, Rajasthan 2. Sri Andrew Goodland, Lead Agriculture Specialist, The World Bank 3. Sri Umakant, IFS (R), National Level Network Manager, NRAA, New Delhi 4. Sri Prabhakar L, Executive Vice-President, ITC Kolkata
16.40-17.00	Tea Break
17.00-17.25	FAO's innovations in Watershed Management and their impacts – Dr. Caroline Turner, Watershed Management Specialist, FAO Regional Office, Bangkok
17.25-17.50	Science based (LRI, Hydrology) watershed implementation experience in Karnataka State- Sri Upendra Pratap Singh, IFS, Commissioner, SLNA, Karnataka
17.50-18.15	Development of LRI Geo portal and Application of Decision Support Systems (DSS) under REWARD Program - Dr. Virupaksha H S, CoE-WM, UAS, Bangalore
18.45-20.30	Cultural Program 1. Rhythm of Chande Vadya 2. Nruthya Vaibhava 3. Musical Melodies
20.30-22.30	Dinner

Time	Particulars
Date: 27.11.2025 (Thursday)	
Technical Session-3: Technological Advances in Soil Mapping, Hydrology, & Land Use for Resilient Watersheds Chairperson: Dr. N. G. Patil, Director, NBSS&LUP, Nagpur	
09.30-10.15	Keynote address on Innovations for Resilient Dryland Agriculture - Dr. Stanford Blade, DDG, ICRISAT, Hyderabad
10.15-10.45	Integrated digital soil sensing and soil mapping for information-driven soil management – Dr. Asim Biswas, Professor, Univ. of Guelph, Canada
10.45-11.15	Advances in Thermal Infrared Remote Sensing for Evapotranspiration and Soil Water Stress Monitoring - Dr. Gilles Boulet, Sr. Researcher, Toulouse University, France
11.15-11.45	Geospatial Technologies for Sustainable Land Resource Mapping and Management – Dr. G P Obi Reddy, Principal Scientist, NBSS&LUP, Nagpur
11.45-12.15	Tea Break
Technical Session-4: Panel Discussion on Role of Private Sector on Data Driven Watershed and Agricultural Transformation Chairperson: Mr. Nitin Khade, IAS, Joint Secretary, DoLR, New Delhi	
12.15-14.00	Panelists: 1. Dr. A.V. Bhavani Shankar, Chief General Manager, NABARD 2. Sri Prabhakar L, Executive Vice-President, ITC Kolkata 3. Sri Tanay Joshi, Sector Lead-Agriculture & Social Advisory, E&Y 4. Sri Abhishek Sharma, Deputy Vice-President-Research Sambodhi Research & Communications Pvt. Ltd.
14.00-15.00	Lunch Break
Technical Session-5: Impact Assessment and Community Engagement in Watershed Projects Chairperson: Dr. Crispino Lobo, Watershed Organization Trust (WOTR), Pune	
15.00-15.20	Evidence based Impact assessment of watershed development under REWARD Program– Dr. Vivek Madinur, Research Manager, IRMA, Anand, Gujarat
15.20-15.40	Embedding Social Capital into Agriculture and Rural Development Programs – Sri David Hogg, Chief Regenerative Agriculture Advisor, Naandi Foundation, Hyderabad
15.40-16.00	Scaling up LRI at National Level and its challenges – Dr. N G Patil, Director, NBSS& LUP, Nagpur
16.00-16.20	Emerging Pathways for Engaging Local Institutions for Climate Resilient Watershed Management - Dr. JVR Murty, World Bank Representative
16.20-16.40	Challenges in Scaling Agricultural Technologies and Determinants of Adoption in Smallholder Systems in Africa – Dr. Mequanint Melesse, Senior Scientist, ICRISAT, Nairobi
16.40-17.00	Lessons learnt from Project on Climate Resilience in Agriculture (PoCRA)- Sri Sagar Bharat Khatkale, DBT Specialist, PoCRA, Mumbai
17.00-17.30	Tea Break
17.30-18.30	Valedictory Session & Way Forward Chief Guest: 1. Sri Nitin Khade, IAS, JS (WM), DoLR, GoI 2. Sri Andrew Goodland, Lead Agriculture Specialist, The World Bank Presentation of summary of key learnings, takeaways and next steps - Sri Nitin Khade and Sri Andrew Goodland
Date: 28.11.2025 (Friday)	
07.30-09.30	Onward journey to Maidalakere Watershed, Tumkur District
09.30-13.00	On-Site study of Maidalakere Watershed - Development Achievements under REWARD Program

Resource Persons/ Speakers and their Designations

Messer/ Dr

1. Abhishek Sharma, Deputy Vice-President – Research, Sambodhi Research & Communications, Noida, Uttar Pradesh
2. Amit Vatsyayan, Sector Lead – Agriculture & Social Sector Advisory, Ernst&Young, Bengaluru
3. Andrew Goodland, Lead Agriculture Specialist, The World Bank
4. Asim Biswas, Professor, School of Environmental Sciences, University of Guelph, Canada
5. Bhavani Shankar A. V., Chief General Manager, NABARD
6. Caroline Turner, Water Management Specialist, FAO Regional Office, Bangkok
7. Chaluvarya Swamy N., Hon'ble Minister for Agriculture, Government of Karnataka
8. Cheikh Amadou Tidiane Dia, Senior Agriculture Economist, The World Bank
9. Crispino Lobo, Co-Founder & Managing Trustee, WOTR, Pune
10. David Hogg, Chief Regenerative Agriculture Advisor, Naandi Foundation, Hyderabad
11. Geetahalli, Deputy Director of Agriculture, REWARD, WDD, GoK
12. Gilles Boulet, Senior Researcher, University of Toulouse, France
13. Giovanni Ruta, Lead Environmental Economist, World Bank – East Asia & Pacific
14. Manoj Kumar, IFS, Principal Secretary (Forests), GoK
15. Mequanint Melesse, Senior Scientist, ICRISAT, Nairobi, Kenya
16. Million Alemayehu Gizaw, Senior Natural Resources Management Specialist, The World Bank
17. Mohammed Paravej Banthanal, Director, WDD, GoK
18. Muhammad Junaid, IAS, Director, WDSC, Government of Rajasthan
19. Murty J. V. R., Senior Water Resources Specialist & World Bank Representative
20. Nitin Khade, IAS, Joint Secretary, Department of Land Resources, Government of India
21. Obi Reddy G. P., Principal Scientist, ICAR–NBSS&LUP, Nagpur
22. Patil N. G., Director, NBSS&LUP, Nagpur
23. Patil P. L., Vice-Chancellor, University of Agricultural Sciences (UAS), Dharwad
24. Prabhakar L, Executive Vice-President, ITC Limited, Kolkata
25. Prakash N. B., Special Officer, CoE-WM, UAS, Bangalore
26. Priti Kumar, Task Team Lead, The World Bank
27. Rajeev Chawla, IAS(R), Strategic Advisor & Chief Knowledge Officer, MoAFW, Govt. of India
28. Sagar Bharat Khatkale, DBT Specialist, PoCRA, Mumbai
29. Stanford Blade, Deputy Director General, ICRISAT, Hyderabad
30. Suresha S. V., Vice-Chancellor, UAS, Bangalore
31. Tanay Joshi, Sector Lead-Agriculture and Social Sector Advisory, Ernst&Young, Bengaluru
32. Tanuja Thakur Khalkho, IAS, Joint Secretary & Financial Advisor, DoLR, GoI
33. Umakant, IFS(R), National Level Network Manager, NRAA, New Delhi
34. Upendra Pratap Singh, IFS, Commissioner, WDD, GoK
35. Victor Afari-Sefa, Research Program Director, ICRISAT, Kano, Nigeria
36. Virupaksha H. S., Scientist & Technical Expert, CoE-WM, UAS Bangalore
37. Vivek Madinur, Research Manager, IRMA, Anand, Gujarat

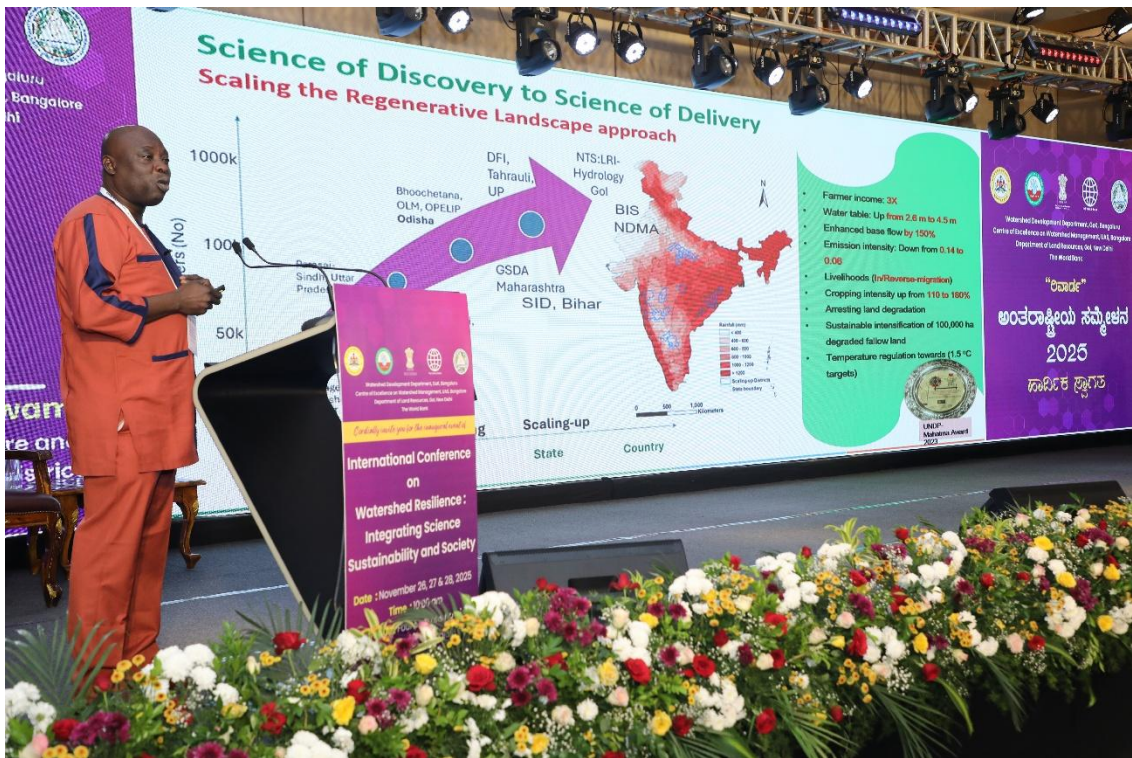
Selected Photos of Conference



Inauguration of the international conference



Conference participants view



Victor Afari-Sefa, Nigeria - Resource person's presentation



Gilles Boulet, France - Resource person's presentation



David Hogg, Hyderabad - Resource person's presentation



Mequanint Melesse, Kenya - Resource person's presentation



Panel discussion moderated by Nitin Khade, JS, DoLR



Panel discussion moderated by Andrew Goodland, The World Bank



Million Gizaw, Ethiopia - Answering delegates queries



Delegates seeking clarifications from the resource person



Presentation of recommendations in concluding session by Nitin Khade and Andrew Goodland



Cultural program artists with delegates



Delegates visit to watershed developed on LRI principles



Delegates visit to watershed developed on LRI principles