



Advanced Course for Asia & North Africa on CONSERVATION AGRICULTURE: Gateway for Sustainable Agrifood Systems

Training Report



09-24 DECEMBER 2023
NEW DELHI-KARNAL-JABALPUR (INDIA)



F2RCWANA
OneCGIAR Regional
Integrated Initiative on
Fragility to Resilience in
Central and West Asia
and North Africa



CA-Training Organised by CIMMYT-BISA-ICAR

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INTRODUCTION

The Conservation Agriculture (CA) practices with increased acceptance across the globe are being considered as harbinger for sustainable intensification of smallholder production systems. Its positive impact on natural resources, and resilience to climate change effects are widely acknowledged. In developing world and specially Asia and Africa, CA is a relatively new introduction and hence capacity development is vital for development, adaptation, and scaling CA based technologies for impact at scale on smallholder farmers in these regions. Therefore, an advanced and practical course on conservation agriculture was organized to offer a unique capacity development opportunity to the scientific community associated with natural resource management research for development (NRM4D). The advanced course on CA in Asia & North Africa was initiated during 2010 and 11th in the series was organized by CIMMYT- BISA-ICAR under the aegis of CGIAR Research Programs on WHEAT, MAIZE, TAFSSA and ICAR-CA and F2R CWANA. This course links the advances and multidisciplinary approach for sustainable intensification of maize and wheat-based systems and cereal & legume-based systems in general. The technologies and strategies for restoration of natural resource and climate resilient production systems with vast expertise of CIMMYT, ICAR & BISA researchers and partners across Asia, Africa, and Americas. Keeping in view the high response, the course has become a regular flagship activity wherein selected young men and women researchers from NARS as well as international organizations and NGOs across Asia and North Africa involved in CA based sustainable intensification can be benefited.



Participants in the CA Advanced Course

The Global South is predominantly occupied by rural areas where most of its population depends on natural resources – land, freshwater, and coastal fisheries – for everyday survival. The region needs to be doubling its food production and food security by 2050. However, the rising population, low environmental footprint, and changing climatic conditions pose a considerable challenge to the agriculture sector across the globe. The continuously increasing demand puts the agrifood system under tremendous pressure. Therefore, the scarcity of soil and water resources, exacerbated by soil degradation and environmental pollution, are the principal challenges to enhancing irrigated and dryland agriculture production in South Asia and Africa.

It is an ecosystem approach to agricultural land management based on three interrelated principles – minimal mechanical soil disturbance, permanent soil cover, and crop diversification through rotation or intercropping. It helps farmers boost yields, regenerate natural resources, reduce cultivation costs, create more resilient production systems to protect the environment and enhance the livelihoods of rural populations. Despite these benefits, farmers face some significant barriers to adopting the CA practices like lack of knowledge and skills, lack of access to a good variety of seeds, equipment, support from the policies, a proper value chain, and trust or acceptance of the fact that CA can yield results and long-term benefits. Thus, it hampers the effective implementation of the CA practices among the farmer communities. Hence, capacity development is vital for the development, adaptation, and scaling of CA-based technologies for impact at scale on smallholder farmers in these regions. To cater to these changing needs, the 'Advanced Course on Conservation Agriculture in Asia – a Gateway for Sustainable and Climate Resilient Agrifood Systems' was launched in 2010. Later, it was expanded to North Africa. This time, the 12th in the series was organized from December 09-24, jointly by CIMMYT, BISA, and ICAR in various parts of the country with support from One CGIAR Research Initiatives F2R-CWANA, EiA, & TAFSSA and the CRA project of the Bihar Government.

Objectives

- To develop an enhanced understanding of locally adapted conservation and climate resilient agriculture systems, applications of agricultural engineering sciences and new agricultural tools and techniques, and scaling appropriate CA machinery for diverse production systems, agro-ecologies and farm typologies.
- To synthesize and apply the information and knowledge related to CA and climate resilient based sustainable intensification (SI) in their own research environments.
- To develop a basic understanding of CA research and the interactions between CA management practices and increasing climate resilience in mixed smallholder farming systems.
- To understand the implications for CA of diversified cropping systems, precision water & nutrient management, weed and pest management strategies, crop residue management, and techniques including remote sensing and crop modelling.
- To acquire skills to plan and manage long-term basic and strategic research trials on CA and monitor soil, plant and environmental parameters under contrasting scenarios.
- To generate scientifically-sound hypotheses, data management strategies, and interpret data and summarize them into scientifically sound conclusions for linking to knowledge networks.
- To learn tools for farming systems analysis, typologies, innovation system, business models, targeting and scaling for impact.

Key Discussion Points

Conservation Agriculture (CA) based sustainable intensification (SI): principles and practices:

- Basic concepts of CA and climate-resilient SI systems
- Climate change and agriculture
- Hands-on training in the operation & maintenance of CA machinery
- The benefits of diversified and nutrition sensitive production systems
- Small holder precision agriculture: concepts and applications
- Increasing smallholder farmers' climate resilience and reducing risk
- In-field hands-on for CA based crop management technologies from planting to harvest, including decision support tools/sensors/crop modelling Crop-livestock interactions in relation to CA/SI Business models, impact assessment of CA/SI technologies.
- CA in dryland ecosystems: Opportunities and issues

- Farming Systems Analysis, targeting and typologies
- Soil health and nutrient management through efficient resource use
- Remote sensing/GIS/UAVs/modelling approaches
- Carbon farming vis-a-vis CA
- Interaction with farmers, stakeholders of public and private sector and CA machinery manufacturers
- Exposure visits to experiment station/research platforms/ innovations platforms
- Small group discussions, brainstorming, and group exercises to cement knowledge and build a collegiate and supportive learning environment.

Agenda

Time	Activity	Key persons
Day 0 – Saturday 09 December: Delhi		
All day	Participants arrive in Delhi	All
Day 1 – Sunday 10 December: NASC Complex, Delhi and BISA farm, Jabalpur		
0800-0840	Registration	All
0840-0855	Welcome address	Dr AK Joshi
0855-0915	Brief introductions	All
0915-0950	Genesis and background of CA course	Dr Mahesh K Gathala
0950-1005	Guest of Honor address	Dr HS Jat
1005-1020	Guest of Honor address	Dr RK Yadav
1020-1050	Chief Guest address	Dr SK Chaudhari
1050-1055	Vote of thanks	Dr Alison Laing
1055-1130	Photo session & tea break	All
1130 SHARP	Departure to airport	All
1350-1510	Fly Delhi to Jabalpur	All
1600-1730	Informal networking in Jabalpur	All
Day 2 – Monday 11 December: BISA farm, Jabalpur		
0930-1100	Introduction and global overview of CA	Dr Ravi Gopal Singh and Dr Mahesh K Gathala
1100-1130	Tea break	All
1130-1300	Climate-resilient sustainable intensification in irrigated systems	Dr Raj Kumar Jat
1300-1400	Lunch	All
1400-1700	Visit CA experiment at BISA farm	Dr Ravi Gopal Singh and Dr Raj Kumar Jat

Day 3 – Tuesday 12 December: BISA farm, Jabalpur		
0900-1030	CA based crop management technologies from planting to harvest	Dr Raj Kumar Jat and Dr Ravi Gopal Singh
1030-1050	Tea break	All
1050-1155	Coupling carbon credits with CA: what works, what does not?	Dr AG Adeeth Cariappa
1155-1300	Digital innovations for agrifood systems	Dr Satish Nagaraji
1300-1400	Lunch break	All
1400-1500	Gender and social behavioral change in modern agricultural practice	Dr Vijayalaxmi Khed
1500-1730	Farming systems design and typologies (including tea break)	Dr N Ravishankar and Dr A Prusty
Day 4 – Wednesday 13 December: BISA farm, Jabalpur		
0900-1300	Hands-on CA machinery training at BISA farm	Dr Raj Kumar Jat and Dr Ravi Gopal Singh
1300-1400	Lunch break	All
1400-1510	Weed management strategies in CA systems	Dr Ravi Gopal Singh
1510-1620	Water management in CA systems	Dr Shilp Verma
1620-1640	Tea break	All
1640-1730		
Day 5 – Thursday 14 December: BISA farm, Jabalpur and CSSRI, Karnal		
0900-1010	Role of legume systems in CA and soil regeneration	Dr Shiv Kumar
1010-1200	Role of drones in digital agriculture; hands-on training	Dr Sunil Kumar
1200-1300	Lunch break	All
1300	Departure to airport	All
1540-1705	Fly Jabalpur to Delhi	All
1730-2030	Drive Delhi to Karnal	All
Day 6 – Friday 15 December: CSSRI, Karnal		
0930-1300	Introduction to long-term CA experiment; site visit	Dr Madhu Choudhary, Dr Deepak Bijarniya, et al.
1300-1400	Lunch break	All
1400-1700	Introduction to cropping systems modelling	Dr Alison Laing

Day 7 – Saturday 16 December: CSSRI, Karnal		
0900-1020	Advances in CA machinery	Dr HS Sidhu
1020-1120	Impact of laser levelling on CA	Dr Manpreet Singh
1120-1140	Tea break	All
1140-1300	Spray techniques and applications of plant protection chemicals in weed management in CA	Dr RS Chhokar
1300-1400	Lunch break	All
1400-1510	Soil health & nutrient management through efficient resource use	Dr Yadvinder Singh
1510-1530	Tea break	All
1530-1700	Soil biology, soil health & sustainability in CA	Dr Madhu Choudhary
Day 8 – Sunday 17 December: CSSRI, Karnal		
0900-1700	Rest day – no scheduled activities	All
Day 9 – Monday 18 December: CSSRI, Karnal		
0900-1015	Global nitrogen management and dynamics, with a focus on CA	Dr JK Ladha
1015-1115	Benefits of diversified and nutrition sensitive production systems	Dr Mahesh Gathala
1115-1130	Tea break	All
1130-1300	Global carbon sequestration potential and greenhouse gas offsetting under CA	Dr Debashis Chakraborty
1300-1400	Lunch break	All
1400-1515	Decision support based irrigation and nutrient management in CA systems	Dr Yashpal Singh
1515-1615	Carbon credit markets	Dr Shanthi Jagadabhi
1615-1630	Tea break	All
1630-1730	Soil salinity management in relation to CA	Dr RK Yadav
Day 10 – Tuesday 19 December: CSSRI, Karnal		
0900-1010	Renewable energy for sustainable agriculture	Dr Pares Shirsath
1010-1120	Adapting to increasing climate variability and change through sustainable intensification	Dr Pramod Aggarwal
1120-1135	Tea break	All
1135-1300	Weed biology and dynamics under CA	Dr Bhagirath Chauhan
1300-1400	Lunch break	All
1400-1515	Maize based CA systems	Dr HS Jat

1515-1615	Insect pest and disease dynamics in CA	Dr Tarak Nath Goswami
1615-1630	Tea break	All
1630-1730	Specialty fertilizers for efficiency in sustainably intensified cropping systems	Dr NK Awasthi
Day 11 – Wednesday 20 December: CSSRI, Karnal and Haryana		
0830-0930	Global mixed farming systems	Dr Santiago Lopez Ridaura
0930-1030	Experiences of CA scaling and adoption across the Indian IGP	Dr RK Malik
0930-1730	Village visit to observe CA in practice and interact with farmers	All
Day 12 – Thursday 21 December: Haryana and Punjab		
0830-1100	Drive to Landforce, Amargath	All
1100-1300	Landforce factory tour and discussion	All
1300-1400	Lunch	All
1400-1600	Drive to National Agro, Ludhiana	All
1600-1730	National agro factory tour and discussion	All
1730-1800	Drive to hotel	All
Day 13 – Friday 22 December: Ludhiana, Punjab		
0900-1700	BISA farm Ludhiana visit, hands on activities	All
Day 14 – Saturday 23 December: Ludhiana, Punjab and CSSRI, Karnal		
0800-1300	Visit to CA village & farmers' fields	All
1300-1400	Lunch	All
1400-1700	Drive to CSSRI, Karnal	All
1830-2200	Workshop celebration dinner	All
Day 15 – Sunday 24 December: CSSRI, Karnal and onwards travel		
0900-1000	Conservation and regenerative agriculture in dryland systems	Dr ML Jat
1000-1100	Sustainable intensification business models for scaling CA	Dr Rajbir Singh
1100-1130	Tea break	All
1130-1215	Participants' feedback	Representatives from each country or region
1215-1245	Awarding certificates and photos	Dr Rajbir Singh and Dr ML Jat

1245-1330	Closing remarks	Dr Mahesh Gathala and Dr Ravi Gopal Singh
1330-1430	Lunch	All
1430	Departure to onward destinations	All

Inaugural Session

All the participants received a hearty welcome in New Delhi at NASC Complex with a welcome address from Dr. Arun Joshi, CCR CIMMYT & MD, BISA. Dr. Mahesh Gathala, Systems Agronomist, Sustainable Agrifood Systems Program, CIMMYT, briefly introduced them to the course's genesis, background, and objectives. Dr. Gathala also highlighted that through this course, about 220 researchers, development personnel, and policymakers have benefited from twenty countries since the inception of the course in 2010. The guest of honors, Dr. HS Jat, Director of ICAR-Indian Institute of Maize Research (IIMR), welcomed the participants and emphasized the importance of this course in personal development as he is also a beneficiary of this course and engaged in organizing the course in the past one decade while he was with CIMMYT and ICAR-CSSRI. The chief guest, Dr. SK Chaudhari, DDG (NRM), ICAR, highlighted that this is the true collaboration efforts of CGIAR and ICAR to jointly organize CA courses to achieve climate resilient agriculture in the global south. This course is a successful example of the conversion of information to knowledge through process by practices offered to the participants. He also talked about the importance of dryland agriculture, where CA can be a crucial strategy to address climate vulnerability issues, as a recent analysis indicated 310 districts of India fall under climate vulnerability. Finally, he assured the participants that they would receive ample knowledge of CA from this advanced course. In the end, Dr. Alison Laing proposed the vote of thanks.



Inaugural Session

After receiving a warm welcome in Delhi, participants visited the BISA farm in Jabalpur as a part of their 4-day visit program. Dr. Ravi Gopal Singh, Scientific Lead, BISA, and Dr. Mahesh Gathala gave an overview of CA with a global perspective. A series of sessions and hands-on training were organized at the CA experiment farm in BISA. Dr. Raj Kumar Jat, Senior Scientist, BISA, talked about the climate-resilient sustainable intensification in irrigated systems and the efficient use of permanent raised beds for CA-based crop management in irrigated and rainfed systems.

Descriptions

Participants also received an intriguing lecture by Adeeth Cariappa, Agricultural Economist, CIMMYT, where he spoke about coupling carbon credits with CA: what works, what does not? Carbon credits (Carbon sequestration through residue mulch, less emission of CO₂ due to fuel savings, reduction in irrigation input, etc.) from adopting CA present an ideal solution to combat climate change while enhancing farmers' income.

In this Digital era, it's critical to be aligned with digital systems; thus, Dr. Satish Nagaraj, ICT for Development Specialist, CIMMYT, presented some insights on 'Digital innovations for agrifood systems'. He explained developing and implement innovative digital applications for monitoring and service delivery of agricultural researchers in North Africa and South Asia. Adding to this digital landscape, Dr. Sunil Kumar, a BISA Scientist, explained how to utilize drones effectively in agriculture during the training session. The training aimed to empower participants with the tools and techniques needed to leverage modern technologies like drones for optimizing agricultural processes and improving crops. Dr. Sunil also gave hands-on training on deploying drones for various farm applications.

Additionally, the training covered high-throughput wheat phenotyping techniques, providing participants with the skills and knowledge to conduct efficient and accurate assessments of wheat crops. This included understanding the methodologies involved in high-throughput phenotyping and applying them to enhance agricultural practices, particularly wheat cultivation. The training aimed to empower participants with the tools and techniques needed to leverage modern technologies like drones for optimizing agricultural processes and improving crop management strategies.

Dr Vijayalaxmi Khed from CIMMYT delivered a lecture on Gender and social, behavioral change in modern agricultural practice. She discussed creating collaborations and opportunities to improve the conditions and agency of women, youth and Indigenous communities in the Global South. Dr. Khed explained how women manage excess workload (working inside and outside the house), a clear trade-off between productive and leisure time without change in domestic responsibilities. She concluded that rural women's nexus of time poverty and decision-making has "clear implications for the development and diffusion of laborsaving technologies in agriculture." despite playing a crucial role in wheat farming in central India, most women could not influence decisions.

Dr. N Ravishankar and A. Prusty from ICAR Indian Institute of Farming Systems Research explained the different farming systems designs and typologies for marginal farmers with less than one hectare of land. They discussed the prototype farms for redesigning current farming practices to help give these farmers sustainable livelihoods. They described a modeling approach (FarmDESIGN) for the ex-ante assessment of the current farming practices of marginal households in terms of economic, environmental, and nutritional indicators compared with those of experimental research farms to delineate an alternative scope of flexibility to optimize farming practices. To enhance profit, soil organic carbon balance, and nutritional system yield regarding dietary energy and reducing pesticide usage.

A permanent raised bed planting system with residue retention is another form of CA technology, which is highly economical and input- (machinery, nutrients, and water) use efficient. Dr. RK Jat elaborated on the principles of permanently raised beds under CA and provided hands-on training on using machinery (raised bed planter) to make permanently raised beds. He also provided practical training on the development and a live demonstration to explain the working of Turbo Happy Seeder and CA plot planter.

Dr. Ravi Gopal Singh also discussed the weed management strategies in CA systems. In detail, he analyzed the ecology and population dynamics of weeds under CA systems and effective management practices at CIMMYT-BISA. He explained how CA helps reduce weed pressure with time in all the cropping systems if the right weed management strategies are adopted during the adoption CA in initial years.

Dr. Florian Postel delivered a lecture on water management in CA: elements for optimizing efficiencies. She highlighted that the increasing demands of a growing global population and the impacts of climate change have led to water scarcity, especially in the agricultural sector. Therefore, sustainable agriculture practices prioritizing water conservation are essential to ensure food security, protect ecosystems, and build a resilient future. By implementing techniques such as drip irrigation, precision sprinklers, use of soil moisture sensors for accurately monitoring soil moisture content and adjusting irrigation schedules accordingly, and rainwater harvesting, farmers can reduce water waste, improve water-use efficiency, and preserve valuable water resources. Choosing crops better adapted to local climatic conditions and soil types can optimize water use. Water conservation in agriculture is essential for environmental sustainability.

During the BISA Jabalpur farm visit, participants met and interacted with Dr. Shiv Kumar, CCR, ICARDA & Dr. Arun K Joshi as they talked about the role of legume systems in Conservation Agriculture and Soil Regeneration. Dr Kumar explained that legumes fix the atmospheric N, facilitate the rebuilding of soil organic matter, restrict pests and pathogens, and facilitate soil nutrients' circulation and water retention. Based on these multiple functions, legume crops have a high potential for conservation agriculture, being functional either as growing crops or as crop residue. These manifold abilities of legumes make them potential candidates for the management of agriculture in a sustainable way. Introducing legumes in the cropping systems is imperative to achieve the goal of agricultural sustainability and soil security in the diverse agroecosystems.

Participants then moved to Karnal in Haryana and started the following schedule on January 15, where Dr. R.K. Yadav, Director ICAR-CSSRI, warmly welcomed the participants and enlightened the importance of the international and national collaboration activities at CSSRI and how long-term experiments on CA are managing and contributing to generate science-based evidence to inform policy and capacity building.

Dr. Madhu Choudhary and Dr. Deepak Bijarniya conducted the visit of the trainees to the long-term CA experiment at ICAR-CSSRI Karnal, where Dr. Kailash Prajapati provided a detailed explanation and showcased the results of the 12-year CA trial. Additionally, during the visit, a Ph.D. student elucidated the findings of the TAFSSA (Transforming Agri Food System for South Asia) research platform.

Dr. H.S. Sidhu delivered a lecture and conducted hands-on training on recent advances in scale-appropriate CA machinery. He described the supporting elements and the challenges of mechanization and CA. He introduced CA machinery developments for small, medium, and large farmers. Dr. H.S. Sidhu explained the calibration and operations of CA machinery. Turbo Happy Seeder has been developed in India for zero till seeding all crops into heavy loads of crop residue, particularly in combined harvested rice fields without residue burning. The use of this machine is highly economical as it replaces many field operations for straw management and seedbed

preparation. He also explained the development and need to attach a super straw management system (SMS) to combine harvesters that chop the crop residue and spread it uniformly in the field. The attachment of super SMS on combine harvesters facilitates the chopping and even spread of loose rice residue and is essential for the smooth and efficient working of Turbo Happy Seeder. Dr. Sidhu explained the new machine called the CA plot planter developed by BISA, Ludhiana, which is very efficient for evaluating different genotypes under CA.

Dr. Manpreet provided basic concepts and field training of laser land-leveling techniques in another lecture. After introducing various components, they explained the basic principles and workings of the laser land leveler. They explained the costs and benefits of adopting laser land leveling under CA for saving irrigation water and increasing nutrient use efficiency. Hands-on training of laser land leveler setting up in the field with all three components of receiver, transmitter, and control box and their functions; with this, all participants enhanced their knowledge of laser land leveling, the most successful broadly adopted technology in India.

Dr. Allison Liang introduced the cropping systems modelling regarding CA. The lecture provided theory and practice on the APSIM (Agriculture Production System sIMulator) model user interface and how to manage data on soils, weather, and soil dynamics, such as residue decomposition and moisture levels. Dr Allison explained that the model could accurately quantify the impacts of long-term CA practices on the crop yields and water use patterns of irrigated and rainfed rotational cropping systems under global climate change. APSIM model can simulate long-term system variability and region-wide out scaling of CA options from one farm or village, including the effects of different options on sustainability or greenhouse gas emissions, which can be difficult or expensive to measure in the field. She also conducted a practical session on interpreting the simulation outcomes and understanding the modeling.

Dr. RS Chhokar conducted a practical session and gave participants essential insights into weed and insecticide application techniques. Emphasizing precision, participants were explained the optimal stages for weed spraying, nozzle selection based on droplet size, and effective insecticide dosage calculations. The hands-on experience included operating spray pumps, adjusting nozzles, and understanding the correlation between dosage and water volume. He equipped participants with practical skills, empowering them to implement accurate and efficient weed and insecticide management practices in their agricultural activities.

Dr. Yadvinder Singh delivered a lecture on soil health & nutrient management through efficient resource use efficiency. He explained how CA practices impact nutrient dynamics and availability in soils. He elaborated on the different methods (e.g., deep placement, precision nutrient management, fertigation, etc.) for increasing nutrient use efficiency in various crops and cropping systems under CA. Adding to this, Dr Madhu Choudhary delivered a lecture on changes in soil biology and sustainability in CA. She demonstrated the impact of CA on soil, particularly soil biological health. Improving soil health will help increase the cropping system's sustainability.

Dr. Gathala conducted the practical session on the measurements of the physical properties in the field, soil sampling, and process methods and demonstrated the field equipment of physiological and physical measurements with the latest instruments; each participant collected the data and used the instruments in the field.

Dr. Debashis Chakraborty delivered a seminar on global carbon sequestration potential and greenhouse gas offsetting under CA. Agricultural production with intensive farming practices favored the loss of carbon (C) from soil. CA offers significant potential to help lower greenhouse gas emissions and reduce atmospheric carbon dioxide. Dr Chakraborty explained how CA can help sequester soil carbon (C), reduce greenhouse gas emissions, and minimize climate change. Due to reduced GHG emissions, CA also reduces global warming potential (GWP). He suggested

an urgent need for their scaling and accelerated adoption to increase soil C-sequestration. Policies and programs must be devised to incentivize farmers to adopt more C-neutral or C-positive agricultural practices.

Dr. Yash Saharawat, International Fertilizer Development Corporation, delivered a lecture on Decision support-based irrigation and nutrient management in CA systems. The CA practices are highly site-specific; it's worthwhile to study precision irrigation and nutrient management under different cropping systems, soil types, and agro-climatic zones. Drip irrigation and fertigation significantly improve irrigation and nutrient management. Decision Support Systems (DSSs) and simulation models process large and diverse amounts of information to provide irrigation and nutrient recommendations specific to individual crops and sites. Dr. Saharawat presented several general aspects regarding using DSSs/models in crop production, such as how to enhance user-friendliness. Subsequently, he described DSSs/models developed or used to assist with irrigation or nutrient management, particularly concerning CA. He also highlighted the new slow-releasing products and specialty fertilizers for higher-use efficiencies. He gave the example of super granule ureas with deep placement attached with new devices in upland crops and mechanical rice transplanters, which showed prominent results in cereal-based crops and vegetables.

Dr Shanthi Jagadabhi from Grow Indigo shared her knowledge and views on Carbon credit markets. She described that a carbon credit represents ownership of the equivalent of one metric ton of carbon dioxide that can be traded, sold, or retired. A credit becomes tradeable because of a genuine reduction in emissions, but the reduction is from an activity such as CA. Dr. Shanti explained the monitoring, reporting, and verification (MRV) process, challenges, and auditing by third parties. She explained that carbon markets aim to reduce greenhouse gas emissions, enabling emission units (carbon credits) trading and certificates representing emission reductions. Carbon trading allows entities that can reduce emissions at a lower cost to be paid by higher-cost emitters. By putting a price on carbon emissions, carbon market mechanisms raise awareness of carbon pollution's environmental and social costs, encouraging investors and consumers to choose lower-carbon paths. She discussed voluntary carbon marketplace, which includes all transactions of carbon offsets not purchased with the intent to surrender them into an active regulated carbon market and offsets purchased with the intent to re-sell or retire them to meet carbon neutral or other environmental claims.

Dr. RK Yadav shared his views and knowledge on soil salinity management with CA. He discussed the present status of saline and sodic soils and the role of CA in reducing the pH and salinity of salt-affected soils. Improving soil organic matter and health indicators, particularly infiltration rate CA, can minimize soil salinity stress and increase productivity.



Participants engaged in training activities

Dr Paresh Shirsath, climate scientist at BISA, discussed using renewable energy for sustainable agriculture. He talked about launching the ambitious Solar Mission as a significant initiative of the Government of India. With the steep decline in the prices of photovoltaic (PV) panels, they have become one of the most viable and cleanest energy sources available, realizing several applications in agriculture. The Government of India and several state governments vigorously promote solar irrigation pumps by offering heavy capital subsidies. The Government of India's initiative of further 'greening' the agriculture sector of India, the Ministry of New and Renewable Energy formulated a scheme called 'Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM)' to promote solarisation of irrigation. Solar PV technology allows professionals to select different degrees of decentralization of power generation and distribution per their requirements. The use of solar energy interventions is aimed towards the common goal of achieving a climate-resilient and sustainable future for energy-water use for irrigation. However, different experiments and pilots have different approaches to achieving that future.

Dr. JK Ladha, adjunct professor at UC-Davis, USA, spoke on global nitrogen management and dynamics, focusing on CA. He addressed the issues of concern that range from an excess of fixed N resulting in environmental pressures for some regions. In contrast, insufficient fixed N affects food security in other regions and may lead to health risks. Achieving synchrony between N supply and crop demand without excess or deficiency is the key to optimizing tradeoffs amongst yield, profit, and environmental protection in both large-scale systems in developed countries and small-scale systems in developing countries. Dr. Ladha highlighted that N needs to be managed in an integrated fashion at various scales as both sources of reactive nitrogen are released into the environment, and its effects require an integrated assessment of N dynamics both spatially and temporally. He spoke about the challenges for N management, specifically in the context of food production and its impacts on human and ecosystem health.

Dr. Bhagirath Chauhan, a Professor from the University of Queensland, shared his experiences on weed biology and dynamics under CA. He explained that weed ecology and management under CA and conventional agriculture differ considerably. In CA systems, crop residues on the soil surface may influence soil temperature and moisture regimes that affect weed seed germination and emergence patterns over the growing seasons. The weed shift in CA is being realized mainly due to the adoption of no-tillage, crop residue retention, and crop rotation. Adopting no-tillage practices increases the infestation of small-seeded and perennial weeds and concentrates weed seeds in upper soil layers, decreasing the infestation of *Phalaris minor* in wheat. He discussed the effect of ZT directly on the abundance of water-logging sensitive weeds, which are virtually not observed in transplanted puddled rice. The success of the CA system depends on efficient weed management with the usage of herbicides as pre-planting (non-selective) and post-emergence (selective) options.

Dr. M. Gathala shared his knowledge of maize-based CA systems. He suggested several maize-based systems (such as maize-wheat-mungbean and maize-mustard-mungbean) that can replace rice-based cropping systems. The maize-based cropping system leads to a large saving in irrigation water, low input costs, higher profits, and lower global warming potential than the traditional rice-wheat system.

Dr. RK Malik, CIMMYT consultant, shared his experiences of CA scaling and adoption across the Indian IGP. He explained the reasons for the low adoption of CA in IGP and suggested steps for scaling CA in the region. After these theory and practical sessions, participants were taken to the farmer's fields to interact with the farmers and observe the impact first-hand. They met a progressive farmer group at Karnal who shared their experiences practicing CA from the last few years in Haryana.



Concluding day interaction

Special visits were organized to the leading farm machinery manufacturers in the region for the benefit of the participants so that industry-participant interaction could be enhanced. Firstly, the participant visited the Landforce factory at Amargarh, a leading manufacturer of all types of farm equipment, from seeding to harvesting and processing.

All the participants were warmly received by the Managing Director and owner of the Landforce with all his R&D and marketing team, and later, they gave a brief overview of the factory vision and background and followed the factory tour. This firm has the latest manufacturing facilities and techniques with robotic welding, assembling, and automated paint. Mr. Sarbjeet also discussed with participants the possibilities of collaboration in North Africa and other parts of the global south. In the afternoon, the group visited the National Agro-industry at Ludhiana, a leading plant manufacturer, including bed planters, zero till drills, Happy Seeders, pneumatic, and precise planters. Mr. Rajdeep, the owner of the National Agro, highlighted the importance of good planters and also expressed to extend the business possibility in the Global South.

Dense fog & chilly mornings could not stop our participants from visiting the BISA farm in Ludhiana, Punjab. They visited different farm facilities like the farm machinery section to discuss the various types of machinery and, later, a practical session on calibrating the planters and seeders led by Dr. Manpreet Singh, Engineer from PAU. Participants also benefited by seeing the breeding trials and phenotyping of the wheat lines and shared the experience of conducting and screening the advanced wheat lines. Participants were surprised to be visiting the whole farm under CA for seed production and wheat crop health—the long-term experiments coupled with CA and sub-surface drip irrigation and fertigation for precise nutrient and water management. In the end, participants benefited from the experiences of Dr. HS Jat, Director of ICAR-IIMR at their research farm. Dr. Jat conducted a hands-on training and live demonstration on installing sub-surface drip lines with the newly designed machines. He also explained how sub-surface drip lines can be maintained under conservation agriculture plots and how they are essential to improve input use efficiencies further.

At the end of the training, Dr. ML Jat, Director of the Global Research Program, Resilient Farms and Food Systems, ICRISAT, and Chief Guest of the Closing Ceremony, shared his views and experiences on Conservation and regenerative agriculture in dryland systems. He highlighted that the growing climate crisis, rapidly degenerating soils, extinction of agro-biodiversity, and highly volatile markets have raised stern fears about achieving sustainable development goals related to agriculture. The climate risks in the recent past have been persistent, leading to significant yield losses, especially in the drylands. This has seriously threatened food & nutritional security and livelihoods of billions. Without long-term corrective measures, the challenge will further compound given the agrifood systems' contribution of a third of global anthropogenic greenhouse gases and rapidly deteriorating soil health and drying aquifers. CA is an ecosystem approach to regenerative agriculture and land management systems, environmentally and socially adapted rotations including legumes and cover crops, and other complementary good agronomic management practices. CA aims to achieve sustainable, resilient, and profitable agriculture and subsequently leads to improved livelihoods for farmers by applying three CA principles. He highlighted that the capacity development of stakeholders is vital for the development, adaptation, refinement, and scaling of CA-based technologies for impact at scale on smallholder farmers in these regions.



One of the participants receiving certificate

Dr. Rajbir Brar, ADG, ICAR, shared his views on different business models for scaling CA. He explained that the affordability of CA machinery is a limitation for the adoption of CA by small farmers. He suggested the establishment of chains of custom hiring centers for the timely availability of CA machinery at affordable hiring costs to small farmers.

After these visits and learning sessions, a closing ceremony was organized at CSSRI, Karnal. Dr. R.K. Yadav, Director ICAR-CSSRI, chaired the closing ceremony; Special Guests were Dr. Rajbir,

ADG-ICAR, and Dr. HS Jat, Director ICAR-IIMR and the Chief guest was Dr. ML Jat, Global Director RFFS, ICRISAT. All the dignitaries expressed their satisfaction and views. Participants received certificates and gave their feedback on this advanced course. One of the participants shared that "Session on CA machinery was beneficial and learning about carbon credit was again a significant part of our learning. We also got an opportunity to exchange our ideas and experiences with researchers from Morocco, Egypt, and Bangladesh, which was again very useful. In addition, all participants also provided the Google feedback form for further improvements and suggestions. We sincerely thank the organizers for making us confident and technically smart CA personnel".

Attendance list and sex-disaggregate

The 12th course saw the participation of early mid career researchers and development officers from **Morocco, Egypt, Bangladesh, and India**. In this course, 19 participants joined, with eight female participants.

S No.	Name	Project Name	Nationality	Gender
1	Daoudi Imane	CIMMYT EiA	Morocco	Female
2	Ouhemi Hanane	CIMMYT EiA	Morocco	Female
3	Mr. Atmane Ben Said	CIMMYT EiA	Morocco	Male
4	Miss. Ibtissam Haouari	CIMMYT EiA	Morocco	Female
5	Dr. Ayoub Maalem	CIMMYT EiA	Morocco	Male
6	Dr. Ahmed Hessein Ahmed Hussein	CIMMYT EiA	Egypt	Male
7	Dr. Mahmoud Shawky Abdellatif Abdellatif Mohamed	CIMMYT EiA	Egypt	Male
8	Dr. Ahmed Gamaleldin Abdelkhalek Abdallah Baddour	CIMMYT, EiA	Egypt	Male
9	Mr. Maruf Hossen Shanto		Bangladesh	Male
10	Dr. Vinod Kumar	BISA, CRA	India	Male
11	Dr. Ramakant Singh	BISA, CRA	India	Male
12	Dr. Manisha Tamta	BISA, CRA	India	Female
13	Dr. Sonaka Ghosh	CIMMYT, ICAR-CA	India	Female
14	Dr. (Ms.) Khushboo Rani	CIMMYT, ICAR-CA	India	Female
15	Dr. David Camus	CIMMYT, ICAR-CA	India	Male
16	Dr. Sumanta Kundu	CIMMYT, ICAR-CA	India	Male
17	Dr. (Mrs.) Aliza Pradhan	CIMMYT, ICAR-CA	India	Female
18	Dr. Amrit Lal Meena	CIMMYT, ICAR-CA	India	Male
19	Nisha Choudhary	CIMMYT, ICAR-CA	India	Female