

# CROP ROTATION & INTERCROPPING IN INDIA

This summary document provides an overview of the state of crop rotation and intercropping in India. And also covers a literature review of impact studies conducted on crop rotation and intercropping in India. **It is a part of the larger CEEW study, *Sustainable Agriculture in India 2021: What We Know and How to Scale Up*.**

*Sustainable Agriculture in India 2021: What We Know and How to Scale Up*, is a handbook on the prevalence, practices and state of affairs of the 16 most promising sustainable agriculture practices in the country. It presents the economic, social and environmental impacts of these practices with recommendations on their potential to scale-up sustainable agriculture in India.

The study is available at:  
<https://www.ceew.in/publications/sustainable-agriculture-india-2021>



Crop rotation and intercropping are two different types of cropping patterns followed on a farm to diversify crops and enhance cropping intensity (Refer below). Temporal crop diversification includes crop rotation, while spatial crop diversification is achieved through

intercropping.<sup>1</sup> Crop rotation is undertaken to maximise profit without large investments and without impeding soil fertility. It can also break the cycle of pests and diseases. Intercropping is practised to produce more crop from a unit of land by efficient utilisation of resources while providing insurance against total crop failure due to weather aberrations, particularly under rainfed conditions.

### Terminology: Crop rotation and Intercropping

Crop rotation is the practice of planting two or more crops sequentially on the same plot of land to improve soil health, optimise nutrients, and combat pest and weed pressure. Simple rotation may involve two or three crops, while a complex rotation may incorporate a dozen or more.<sup>2</sup> Crops can be rotated on a field within the same year, or over two years, or more extended periods. Crop rotation requires the succeeding crops to be of a different species or subspecies (variety) than the previous crop, such as legumes grown after wheat and cereals, however, cereal-cereal crop rotations are predominant in the country with farmers growing green manure before sowing rice for building soil health (stakeholders consulted at ICAR-IFSMR).

Intercropping is the growing of two or more crops simultaneously in the same field. Sowing of the base and intercrop is either done simultaneously or in phases. It involves the practical application of ecological principles such as diversity, crop interaction and other natural regulation mechanisms. Intercropping can be classified into the following types:<sup>3</sup>

- *Mixed intercropping*: When two or more crops are grown simultaneously with no distinct row arrangement.
- *Row intercropping*: When two or more crops are grown simultaneously on the same piece of land with distinct row arrangement.
- *Strip intercropping*: When two or more crops are grown simultaneously in alternate strips of uniform width and on the same field.
- *Relay intercropping*: When two or more crops are grown simultaneously but with overlapping life cycles, such that a second crop is planted before the first crop matures.

## Crop rotation and intercropping's linkages to FAO's agroecological elements

In principle, crop rotation and intercropping adheres to and promotes most agroecological elements as defined by the FAO

Elements	Description of agroecological linkages
<i>Diversity</i>	Increasing the diversity of cultivated crops helps preserve biodiversity and enhance ecosystem services in the agricultural landscape.
<i>Co-creation and sharing of knowledge</i>	Crop rotations and intercropping are knowledge-intensive practices. To achieve significant yields requires knowledge that farmers often attain by experimenting with different crop combinations over the years and/or by sharing knowledge within the farming community.
<i>Synergies</i>	It promotes diversified systems by selectively combining annual and perennial crops to enhance synergies and complementarities in terms of nutrient and water and requirements. It also enhances biological and ecological synergies, contributing to human and livestock nutrition and multiple other benefits.
<i>Efficiency</i>	Rotation and intercropping strategies allow for efficient use of water, nutrients, and solar energy. The approach reduces the need for organic and inorganic fertilizers, thus saving costs.
<i>Recycling</i>	Rotating crops serves an essential function of exploiting nutrients at deeper levels of the soil and recycling them to make them available for crops, thus acting as biological pumps. Intercropping also leads to better nutrient recycling (FAO 2020b).
<i>Resilience</i>	Crop rotation and intercropping have the potential to lead to higher and more stable yields, as well as increase profitability. Intercropping ensures a regular income from a field, helping to make a farmer more economically resilient. Further, these practices are essential for weed, pest, disease control and contributing to the resilience of the agroecosystems in the long term.
<i>Human and social values</i>	Crop diversification through rotation, intercropping, and mixed cropping is vital to improve incomes, provide employment, and enhance rural livelihoods. It also allows for the development of value chains for minor crops that contribute to socio-economic benefits too.
<i>Culture and food traditions</i>	Rotating crops and intercropping are an essential strategy to improve food and nutritional security. Traditionally, farmers have experimented with intercropping, mixed cropping, and rotations in their cropping systems to stabilize yields through trial and error.

### A brief context in India

India's tropical and subtropical climate offers scope for growing two or more crops per year. However, **Crop rotations** are location-specific depending on their economic utility, which varies under diverse socio-economic and agroecological conditions. **Intercropping** is known to be a feasible solution as a hedge against crop failure, especially in rainfed regions, as it minimises the risk for farmers and ensures equitable returns.

Both practices are mentioned in several policy documents and schemes at a national and state level. At the national level, the Soil Health Management (SHM) programme under the *National Mission for Sustainable Agriculture (NMSA)* has provisions for field level demonstrations on organic farm packages



that include crop rotation. The programme promotes legume intercropping through self-help groups.<sup>4</sup> Crop rotation with commercial crops is one of the main objectives of the *National Food Security Mission-Commercial Crops (NFSM-CC)* for increasing soil fertility.<sup>5</sup> Crop rotation and mixed farming are also part of the Research and Technology Development component of *Rajasthan Organic Farming Policy*.<sup>6</sup>

Intercropping of oilseed crops with other trees and crops is promoted by the *Submission on Agroforestry* to make current practices more sustainable.<sup>7</sup> The *National Mission on Oilseeds and Oil Palm (NMOOP)* has provisions to financially assist farmers with intercropping of oilseeds with cereals, pulses and sugarcane.<sup>8</sup> The *Policy Note of the Agriculture Department, Tamil Nadu (2020-2021)* promotes and assists with intercropping of pulses in cotton. The state agricultural policy for Odisha focuses on crop rotation techniques to reduce salinity levels and encourages intercropping of oilseed and pulse crops with paddy and sugarcane.<sup>9</sup> ICAR has demonstrated the use of intercropping for livelihood security and resilience to climate variability under the NICRA<sup>1</sup> project.<sup>10</sup>



### Crop rotation and intercropping: acreage, geographies, and cultivation details

**How much area in India is under crop rotation and intercropping?** Stakeholders consulted at the ICAR-Indian Institute of Farming Systems Research (Modipuram), estimate the area under crop rotation to be around 30 million ha, which includes cereal-cereal cropping systems and the area under intercropping to be around 1 million ha, however this excludes intercropping in horticultural crops.

**At what farm size is crop rotation and intercropping practised?** Crop rotation is followed by both small and large farmers in irrigated and rainfed regions alike, except in canal irrigated areas and areas with climatic limitations, according to stakeholders at NRRI. Despite the mechanisation constraints, intercropping is practised by smallholder farmers because it offers flexibility in planting and sowing, minimises risk, and helps meet their nutritional needs.<sup>11</sup>

**How many farmers in India are practising crop rotation and intercropping?** Stakeholders consulted at the ICAR-IIFSR estimate the number of farmers who are practising crop rotation to be between 12 and 15 million and those practising intercropping to be between 0.70 and 0.90 million.

**Where in India is crop rotation and intercropping prevalent?** Crop rotation is a vital traditional farming system of the Indian semi-arid tropics,<sup>12</sup> but it is practiced in almost every state in the country. Intercropping is mostly practised in India's semi-arid and arid tropical areas.<sup>13</sup> It is more common in southern (Karnataka, Telangana, Tamil Nadu, Maharashtra); and western (Gujarat) regions and Madhya Pradesh (Figure 1), though it is also adopted in many more states.

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<sup>1</sup> See NICRA: <http://www.nicra-icar.in/nicarevised/>

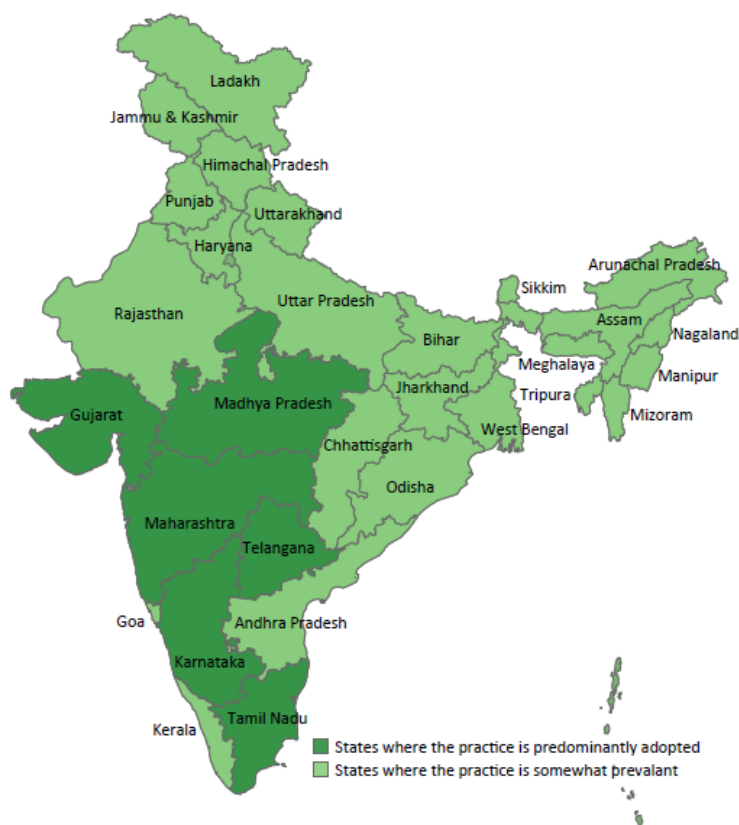
## Which are the major crops cultivated under crop rotation and intercropping in India?

Stakeholders consulted at the ICAR-IIFSR mention the predominant crop rotations being cereal-cereal based like rice-rice, rice-wheat and maize-wheat which comprise about 74 per cent of the calories of the Indian diet. Many of the farmers usually grow green manure crop (leguminous crop) before planting rice for building soil health purposes. Legumes are essential in any rotation and should comprise 30 to 50 per cent of the crop land.<sup>14</sup>

Though intercropping is practised in various crops (cereals, pulses, horticulture) and agricultural production systems (agroforestry, integrated farming systems), it is suitable<sup>2</sup> for wide-spaced crops like maize, cotton, sugarcane, etc (NRRI stakeholder). Pigeonpea is commonly intercropped with cereal crops (sorghum, pearl millet, maize, finger millet, etc.) as well as with short-duration pulse crops (green gram, black gram, chickpea).<sup>15</sup>

Pulses are intercropped with oilseeds, cereals, coarse grains, and commercial crops. A few of the crops grown under both practices are shown in Table 1.

Figure 1. Intercropping is more predominant in the southern and western regions of the country



Source: Authors compilation from literature reviews and stakeholder consultations

Table 1. Major crops used in crop rotations and intercropping

Crop rotation	Main regions where it is practised
Rice-pulses, bajra-pulses, sorghum-pulses, groundnut-wheat, soybean-mustard, maize-pulses or clovers	Across the country
Rice – wheat; rice – maize; maize – wheat	Irrigated areas
Rice – pulses; rice – oilseeds; maize - pulses or oilseeds	Rainfed regions
Rice-green gram/black gram	Eastern India (Odisha, West Bengal)
Rice-mustard	Eastern UP, Bihar and northern West Bengal
Rice-vegetable, sugarcane-wheat, wheat-vegetable, wheat-pulses, wheat-fallow, sorghum-berseem, maize-mustard, mustard-vegetable, maize-wheat	Indo-Gangetic plains

<sup>2</sup> Competition between crops can be harmful sometimes if combinations are not chosen carefully (Maitra et al. 2020).

Intercropping	Main regions where it is practised
Wheat + mustard	Northern India
Maize with rice/soybean; cereals + legumes	Drylands
Maize + beans, maize + peas, peas + radish, maize + ginger, maize + cabbage	Higher altitudes (Sikkim)
Elephant foot yam grown as intercrops in litchi, coconut, banana orchards	Across the country

Source: Compiled from (Rana and Rana 2011; Srivastava et al. 2012a; Murthy et al. 2017; ICAR-CCARI 2020; Maitra et al. 2020; Stakeholders consulted at NRRI and Department of Agriculture, Sikkim)



## Impact of crop rotation and intercropping

This section considers the economic, social, and environmental impacts of crop rotation and intercropping.

### ECONOMIC IMPACT

#### 1. Yields

According to the literature, crop yield improvements are one of the immediate economic benefits of both crop rotation and intercropping. As continuous monocropping on the same area of land tends to deplete soil health and reduce yields, these practices – alongside other measures (weed control, applying secondary and micronutrients) – are said to bridge yield gaps mostly in dryland rainfed areas with low productivity. For example, an analysis done in Karnataka's dryland zone indicates over 50 per cent of the yield could be increased by following crop rotation and intercropping for major crops (finger millet, pigeon pea, maize, cowpea, horse gram, groundnut, sunflower).<sup>16</sup>

An experiment was conducted to observe crop rotation performance in leguminous and non-leguminous crops in Rajasthan. In the winter, cumin and psyllium were grown in rotation with sesame and cluster beans. Results showed that yields of 566 kgs/hectare for cumin and 808 kgs/hectare for psyllium were obtained in the treatments of organic inputs and cluster beans in rotation. Here the legumes were found to play a key role, contributing 20-25 per cent in yield growth for the next crop of cumin.<sup>17</sup> Another study that evaluated the gross productivity across several locations showed that rice rotations with oilseed, wheat, pulse and maize gave a rice equivalent yield (REY)<sup>3</sup> of between 7.0 to 10.2 tonnes/ hectare.<sup>18</sup>

In intercropping, various factors affect its performance, including solar radiation, water, nutrients, the maturity of the crop, growth rate, root systems, allelopathic effect, planting pattern, etc.<sup>19</sup> Most studies indicate the benefits of intercropping over monocropping to be yield stability and enhanced crop productivity.<sup>20</sup> For instance, cereal + legume intercropping has reported higher yield stability and lower probability of failure than crops grown alone in rainfed areas. In a few instances, although yields in vegetables grown as intercrops under a fruit canopy were reduced due to shading, the yield potential of

<sup>3</sup> Yields of different crops are converted into equivalent yield of any one crop such as rice equivalent yield.

shallow-rooted and short-duration intercrops was not affected by perennial trees.<sup>21</sup> Under the NICRA project, intercropping demonstrated in locations across the country reported yield advantages that ranged from 10.5 to 85.2 per cent for crops that included maize, cowpea, pigeonpea, pearl millet, etc.<sup>22</sup>

However, the success of intercropping lies in the crop choices, environmental and locational factors and availability of proper sowing implements. Often yield advantages are prominent when crops do not compete for similar ecological niches, and when component crops have different growing periods.<sup>23</sup>

## 2. Income

The literature on income for crop rotation and intercropping practices suggests the practices offer much potential to enhance farmers' income and profitability by diversifying crops over time or space. Crop rotation provides a steady and assured income in times of crop failure, as the next harvest can yield some of the income. A study conducted to determine gross return of different rice-based cropping systems across the country found that rice rotations with oilseed, wheat, pulse and maize gave returns of between INR 40,472/ hectare (USD 548/ha) and 59,110/ hectare (USD 800/ hectare).<sup>24</sup>

Intercropping of fruit trees with short duration crops (pulses, spices, vegetables) is found to offer considerable potential for farmers to gain income before the fruit trees become productive, and can double farmers' incomes once the fruit trees start producing.<sup>25</sup> In particular, several studies mention the high potential of horticulture-based intercropping for giving additional returns to farm families. For example, vegetable-based intercropping gave additional income in a study of fruit orchards, for instance, the intercropping of coconut + black pepper + pineapple was profitable, with a high net return of INR 45600 per hectare (USD 619).<sup>26</sup> Growing cotton, pigeonpea and millets is a coping strategy in low rainfall areas, allowing farmers to make a profit.<sup>27</sup> The NICRA project found that across the country where crops like cotton, soybean, pigeonpea, cowpea, millets, etc. were intercropped, the perceived benefit-cost ratio was in the range of 1.3 to 4.2 compared to conventional practices. In places where maize+cowpea was intercropped, the higher returns for cowpea observed were due to the fact that almost no inputs were required other than seed.<sup>28</sup>

Intercropping is also more remunerative than sole cropping in delayed monsoon situations.<sup>29</sup> But a challenge of the practice is its labour-intensive nature, which can boost employment generation in terms of more days of on-farm employment. This can be beneficial when family members are involved in farming, as in the case of small and marginal sugarcane growers.<sup>30</sup> However, it can pose a problem where labour is scarce. Another significant caveat is the difficulty of operating farm machinery in intercropped fields, that requires the use of manual labour for sowing, removing weeds. This involves additional expenses which can be a deterrent for resource-limited farmers.



### SOCIAL IMPACT

#### 1. Human health

We did not find any relevant evidence on the impact of crop rotation on human health; more in-depth studies are required.

Studies of intercropping found a higher demand for intercropping vegetables due to their contribution to improved diets.<sup>31</sup> Legumes grown on marginal lands in intercropping systems are mentioned as an essential source of protein for people's diets, offering the potential to end malnutrition in the country.<sup>32</sup> However, we found no other significant studies on intercropping impacting human health so further research is needed.

## 2. Gender

There is little research on the impact of crop rotations and intercropping on women. However, a study conducted of crop rotation in a Central Himalayan ecosystem village (Garhwal Himalayas) found it increased women's contribution in terms of working hours, accounting for over 75 per cent of total labour (farm and off-farm activities).<sup>33</sup> This shows the increasing role of women in the practice which is encouraging, but simultaneously it also increases the workload for women farmers. Nonetheless, the topic is still under research and more experimental studies could enhance the understanding of its impact on women.



### ENVIRONMENTAL IMPACTS

#### 1. Soil and nutrients

**Crop rotation** mitigates soil health problems by controlling weeds and insect pests, decreasing soil run-off, and building soil health and structure through root systems and plants that have different nutrient demands. In general, sowing restorative crops that build soil health has immense importance in crop rotation practices. Crops' different rooting systems absorb essential nutrients from various soil depths utilizing nutrients more efficiently than sole cropping. Mainly, alternating shallow and deep-rooted crops restores soils.<sup>34</sup> Generally, crop which demand high nutrient should both precede and follow legume-dominated crop combination. Topographical features also affect crop selection; for instance, alternate cropping of erosion-promoting crops (millet) and erosion-resistant crops (legumes) can be adopted on erosion-prone sloping lands.<sup>35</sup>

Similar to crop rotation, **intercropping** plays a vital role in reducing pests and diseases. It also prevents erosion by covering more ground area than monocropping; for instance, intercropped maize-cowpea reduces soil erosion, and tall crops like maize play an essential role as a windbreak.<sup>36</sup> In rainfed, salt-affected, problematic soil areas, alternative cropping systems like inter, mixed and alley cropping are beneficial.<sup>37</sup>

The literature widely mentions the significant advantage of legumes (the 'legume effect') in both crop rotation and intercropping for fixing atmospheric nitrogen, reducing the need for nitrogen fertilizers.<sup>38,39,40,41,42,43</sup>

## 2. Water

With proper planning, resources like water, space, and land are used efficiently in both practices. The crop types rotated tend to depend on the availability of water and usually two or three crops are taken on the similar field in a year under irrigated conditions. But, one of the crops rotated should be a dry one or one



that requires lesser water to avoid damage to the soil by continuous watering. In rainfed areas, after the harvest of Kharif crops, crops requiring less moisture are sown like pulses and cereals. This crop rotation involving less water-intensive successive crops helps balance water requirements.<sup>44</sup>

When rotated, crops with different root depths tend to use soil moisture more efficiently. For example, sunflower extracts water from deeper soil layers, while shallow-rooted crops (cabbage) draw it from nearer the surface. Greater water percolation occurs in these systems due to the varied root structure. Both crop rotation and intercropping reduce water and wind erosion.

Relay intercropping systems has the potential to increase water productivity considerably. A concept known as 'complementary intensive intercropping systems' that involves raising morphologically and physiologically different crops that complement each other and succeeding crops has immense potential under declining water conditions, but more studies need to be done on this strategy.

### 3. Energy

We found no relevant studies on the impact of crop rotations on energy.

Intercropping is considered to be an energy-efficient and sustainable practice in the rainfed regions,<sup>45</sup> there are limited studies on the impact of intercropping on energy use. In the literature energy is mentioned in the context of the ability of a few intercrop species (elephant foot yam, colocasia, turmeric and ginger, growing tuber) to transfer solar energy efficiently.<sup>46</sup>

Second, certain crop combinations in intercropping have proved to be more energy-efficient, such as cereal+legumes, due to the nitrogen-fixing ability of legumes.<sup>47</sup> Maize+groundnut intercropped in a row ratio of 1:5 resulted in a better energy performance than solo maize in terms of energy input and output efficiency in the Eastern Himalayas (Arunachal Pradesh).<sup>48</sup>

### 4. Emissions

Although the studies are few, it seems that certain crop rotations tend to reduce emissions more than monocropping. For example, field experiments in the Indo-Gangetic plains found lower average annual CO<sub>2</sub> emissions in wheat crop rotations (wheat-fallow-paddy, wheat-fallow, wheat-maize, wheat-pulses, wheat-sugarcane, wheat-sorghum, and wheat-vegetable) than from vegetable crops, which showed higher emission rates. In a similar study, compared to sole wheat (0.71 grams per m<sup>2</sup> per hour), sorghum-berseem rotation (fodder crops) had the highest rate of CO<sub>2</sub> emissions (0.75 grams per m<sup>2</sup> per hour), followed by vegetables grown alone (0.72 grams per m<sup>2</sup> per hour) and vegetables in rotation with mustard (0.72 grams per m<sup>2</sup> per hour). In these crops, the moisture seemed to be responsible for higher emissions rates.<sup>49</sup>

No other systematic studies were found on the impact on emissions or carbon sequestration.

### 5. Biodiversity

Introducing a range of varieties to an agroecosystem leads to an increase in natural biodiversity and strengthens the agroecosystem's ability to respond to the stresses created by monocropping.<sup>50</sup> Rotating crops leads to diverse soil biodiversity (flora and fauna) as the leguminous roots excrete organic substances

attracting bacteria and fungi. Intercropping and mixed cropping can promote on-farm biodiversity by supporting more organisms than is possible in a single-crop environment.<sup>51</sup> However, no systematic studies were found probing deeper into these impacts on biodiversity.

Despite the known advantages, there is a lack of systematic studies on the impact on biodiversity.

## Impact evidence

State of available research discussing the impact of crop rotation and intercropping on various outcomes.

### Crop rotation

Evidence Type	Yield	Income	Health	Gender	Soil and nutrients	Water	Energy	GHG emissions	Bio-diversity
Journals	9	7	0	1	17	5	0	2	2
Reports	2	2	0	0	10	0	0	0	0
Articles/ case-studies	0	0	0	0	0	0	0	0	0
Others **	0	0	0	0	0	0	0	0	0
<b>Total</b>	<b>11</b>	<b>9</b>	<b>0</b>	<b>1</b>	<b>27</b>	<b>5</b>	<b>0</b>	<b>2</b>	<b>2</b>

\*\* Thesis, guidelines, conference papers, etc

Source: Authors' compilation

### Intercropping

Evidence Type	Yield	Income	Health	Gender	Soil and nutrients	Water	Energy	GHG emissions	Bio-diversity
Journals	18	20	2	0	18	5	5	0	1
Reports	1	4	0	0	0	0	0	0	0
Articles/ case-studies	0	0	0	0	0	0	0	0	0
Others **	0	0	0	0	0	0	0	0	0
<b>Total</b>	<b>19</b>	<b>24</b>	<b>2</b>	<b>0</b>	<b>18</b>	<b>5</b>	<b>5</b>	<b>0</b>	<b>1</b>

\*\* Thesis, guidelines, conference papers, etc

Source: Authors' compilation

Note – The evidence is from the first 75 results examined in Google Scholar Advanced search and the first 30 results from Google Advanced Search. Only those papers which clearly established the evidence for different indicators were selected.

## Stakeholder mapping

The following institutions are involved in the research and promotion of crop rotation and intercropping; a few were consulted for this research:

Government institutions	Research/implementation institutions	NGOs/Civil society organisations
ICAR - Indian Agricultural Research Institute	Indian Head Agricultural Research Foundation	bioRe Association India
ICAR - National Rice Research Institute (NRRI)	The National Academy of Sciences India	Natural Capital
Central Research Institute for Dryland Agriculture (CRIDA)	Punjab Agricultural University, Ludhiana	Living Farms
ICAR - Indian Institute of Farming Systems Research (IIFSR)	University of Agricultural Sciences, Bangalore	Centre for Dignity
Central Arid Zone Research Institute (CAZRI)		Manjari Foundation

Source: Authors' compilation

Note – The stakeholders list is indicative and not exhaustive

## Endnotes

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