Genetic Enhancement and Natural Resources Management for Enhancing Productivity, Sustainability and Resilience in Drylands

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Indian Agriculture at a Glance

- 17.74% of world human population
- 4.2% of the World’s water
- 2.4% of the world’s area
- 140.1 m ha net sown area
- 52% of net sown area is rainfed
- 142% cropping intensity
- 52% of workforce in agriculture
- 15.4% contribution to GDP
- 10.6% earning of total exports

- Large country with diverse biophysical and socioeconomic settings with diverse agroecologies- climates, seasons, soil types, production systems, farming systems
- Increase in frequency of extreme weather events
- Small & marginal land holdings (86.2%), poor coping mechanisms

Ranifed agriculture practiced arid, semi-arid and sub-humid regions and accounts for 52% of the net cultivated area
Contributes about 40% of food production
- Coarse cereals: 83%
- Pulses: 81%
- Oil seeds: 72%
- Cotton: 67%
- Rice: 40%
<table>
<thead>
<tr>
<th>Item</th>
<th>1950-51 Production (million tonnes)</th>
<th>2019-20 Production (million tonnes)</th>
<th>Times Increase (X)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food grains¹</td>
<td>50.83</td>
<td>295.67</td>
<td>5.82</td>
</tr>
<tr>
<td>Pulses¹</td>
<td>8.41</td>
<td>23.01</td>
<td>2.74</td>
</tr>
<tr>
<td>Oilseeds¹</td>
<td>5.16</td>
<td>33.50</td>
<td>6.49</td>
</tr>
<tr>
<td>Cotton¹</td>
<td>0.52</td>
<td>6.13</td>
<td>11.79</td>
</tr>
<tr>
<td>Sugarcane¹</td>
<td>57.05</td>
<td>358.14</td>
<td>6.28</td>
</tr>
<tr>
<td>Horticulture@</td>
<td>96.56 (1991-92 level)</td>
<td>313.35</td>
<td>3.25</td>
</tr>
<tr>
<td>Milk#</td>
<td>17.00</td>
<td>187.70</td>
<td>11.04</td>
</tr>
<tr>
<td>Fish#</td>
<td>0.75</td>
<td>13.42</td>
<td>17.89</td>
</tr>
<tr>
<td>Egg (no. in billion)#</td>
<td>16.1 (1985-86 level)</td>
<td>103.30</td>
<td>6.42</td>
</tr>
<tr>
<td>Meat#</td>
<td>1.9 (1998-99 level)</td>
<td>8.11</td>
<td>4.27</td>
</tr>
</tbody>
</table>

¹ III Advance Estimates of 2019-20,  @ I Advance Estimates of 2019-20,  # Figures for 2018-19
Diversification and Integration

Field Crops (85)
- Cereals (4), Millets (10), Pulses (12), Oilseeds (15), Commercial Crops (11), Forage Crops (17), Potential Crops (16)

Horticultural Crops (134)
- Fruits (28), Vegetables (48), Spices (12), Seed spices (10), Tuber Crops (11), Temperate fruits (10), Plantation crops (3), Flowers (8), Mushroom (4)

Animal breeds (199) & Fish Species (111)
- Buffalo, cattle, small ruminants
- 61 food fish and shellfish, 50 ornamental fish

NRM and Farm Mechanization
- Climate resilient agriculture
- Saline/alkaline/sodic soils, Arsenic affected, waterlogged/water stressed areas and cropping
- Small smart machines and agro-processing

Farmers Outreach
- 716 KVKs, all rural districts
## Crop Varieties: 1969 - 2019

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>2626</td>
<td>645</td>
<td>446</td>
<td>42</td>
<td>45</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>864</td>
<td>183</td>
<td>183</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Pulses</td>
<td>966</td>
<td>187</td>
<td>187</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Fibre crops</td>
<td>364</td>
<td>92</td>
<td>89</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Forage crops</td>
<td>187</td>
<td>81</td>
<td>81</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Sugar crops</td>
<td>122</td>
<td>44</td>
<td>32</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Others</td>
<td>35</td>
<td>2</td>
<td>2</td>
<td>Hort. 4</td>
<td>-</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>5164</strong></td>
<td><strong>1234</strong></td>
<td><strong>1020</strong></td>
<td><strong>53</strong></td>
<td><strong>48</strong></td>
</tr>
</tbody>
</table>
Field crop varieties for drought/moisture stress tolerant/water stress/low rainfall condition released since 2014

<table>
<thead>
<tr>
<th>Total: 137</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CEREALS 75</strong></td>
</tr>
<tr>
<td>Rice (32)</td>
</tr>
<tr>
<td>Wheat (19)</td>
</tr>
<tr>
<td>Maize (8)</td>
</tr>
<tr>
<td>Sorghum (4)</td>
</tr>
<tr>
<td>Pearl M. (7)</td>
</tr>
<tr>
<td>Little millet (2)</td>
</tr>
<tr>
<td>Kodo millet (1)</td>
</tr>
<tr>
<td>Finger Millet (2)</td>
</tr>
<tr>
<td><strong>OILSEEDS 10</strong></td>
</tr>
<tr>
<td>Soybean (2)</td>
</tr>
<tr>
<td>Groundnut (3)</td>
</tr>
<tr>
<td>Sesame (1)</td>
</tr>
<tr>
<td>Indian Mustard (2)</td>
</tr>
<tr>
<td><strong>PULSES 18</strong></td>
</tr>
<tr>
<td>Urdbean/ blackgram (1)</td>
</tr>
<tr>
<td>Pigeonpea/ Red gram (9)</td>
</tr>
<tr>
<td>Horse gram (2)</td>
</tr>
<tr>
<td>Cluster bean (Guar) (1)</td>
</tr>
<tr>
<td>Chickpea (3)</td>
</tr>
<tr>
<td>Lentil (2)</td>
</tr>
<tr>
<td><strong>COMMERCIAL CROPS (6)</strong></td>
</tr>
<tr>
<td>Cotton</td>
</tr>
<tr>
<td>Roselle</td>
</tr>
<tr>
<td><strong>FORAGES (11)</strong></td>
</tr>
<tr>
<td>Pearl Millet</td>
</tr>
<tr>
<td>Forage Sorghum</td>
</tr>
<tr>
<td>Cowpea</td>
</tr>
<tr>
<td>Fescue</td>
</tr>
<tr>
<td>Guinea Grass</td>
</tr>
<tr>
<td>Rice bean</td>
</tr>
<tr>
<td>Marvel Grass</td>
</tr>
<tr>
<td>Anjan Grass</td>
</tr>
<tr>
<td>Forage Sewan Grass</td>
</tr>
</tbody>
</table>
Resilience of technology to withstand stresses (food grain production)
ICAR Varieties/Technologies Making Impact 
(A Few Examples)

• Pusa Basmati 1121 – 1.5 lakh Crores of Rupees during (2008-2016); Net Export: Rs. 33000 Cr.; Net Profit Rs. 16700 Cr. per year

• Sugarcane CO 238 (12% sugar recovery) – Rs. 28,795 crores gross value every year

• Wheat HD 2967 and HD 3086 Area: 10 million ha contributing to 50 mt production (50% of total wheat production in India). Licensed to 204 seed companies

• Potato Varieties - Rs. 57,512 crores gross value every year

• Biocontrol – Papaya mealybug affected 1500 ha; Saved about Rs. 1300 Cr.

• CRRI Rice: 133 varieties covering 18-20% of rice area of the country; Total Value worth Rs. 48000 Crore per year
# Pulses Revolution:
## Breakthroughs in Pulses Research and Seed Production

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Years</th>
<th>Million tons</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2016-17</td>
<td>2017-18</td>
</tr>
<tr>
<td>Production</td>
<td>23.13</td>
<td>25.42</td>
</tr>
<tr>
<td>Total Imports</td>
<td>6.61</td>
<td>5.61</td>
</tr>
<tr>
<td>Availability</td>
<td>29.74</td>
<td>31.03</td>
</tr>
<tr>
<td>Total Exports</td>
<td>0.14</td>
<td>0.20</td>
</tr>
<tr>
<td>Total availability for domestic consumption</td>
<td>29.60</td>
<td>30.83</td>
</tr>
</tbody>
</table>

DES: Directorate of Economics and Statistics; DoC: Department of Commerce; * 3rd Advance estimate of DES

1. **Development of > 900 HYV in pulses**
2. **Released 4 landmark varieties with unique characteristic:** (Fe, Zn fortified lentil), IPA 15-03 (early maturity pigeonpea hybrid), Mungbean IPM 205-7 (Virat, a Super early mungbean variety), IPFD 10-12 (green seeded fieldpea varieties).
3. **Reduction in** duration (Mung; 55/70D, lentil to 120/150 D & chickpea to 100/140 days.
4. **Increase in seed size** Kabuli chickpea (to 55/25 gram)  
5. **Development of Diagnostic Kits** (*LYMVs PCR Diagnostic Kit* and Multiplex-PCR *LYMVs Mplex*) for virus identification causing the most widespread YMV in pulses.
6. **Development of** Trichoderma based formulations (*Dalhanderma 1,2*)
Millets grown in India

Major millets
- Pearl millet (*Pennisetum americanum*)
- Great millet / sorghum (*Sorghum bicolor*)
- Finger millet (*Eleusine coracana*)

Small millets
- Little millet (*Panicum sumatrense*)
- Kodo millet (*Paspalum scrobiculatum*)
- Proso millet (*Panicum miliaceum*)
- Barnyard millet (*Echinochloa frumentacea*)
Indian Council of Agricultural Research

Pulses
Cotton
Sorghum
Maize
Pearl millet
Finger millet
Ground nut
Rice
Sugarcane

Water requirement of millets & other crops (in mm)

Water Requirement of Millets

Up- Millets Production (32%) & Millets Productivity (159%)

Millets Area down by 50%
Biofortified Varieties: Sustainable Way to Alleviate Malnutrition

- Zinc
- Iron
- Protein
- Lysine
- Tryptophan
- Anthocyanin
- Glucosinolate
- Trypsin inhibitor
- Erucic acid
- Vitamin-A
- Vitamin-C
- 53

- Rice (7)
- Wheat (17)
- Maize (9)
- Pearl millet (9)
- Sorghum (1)
- Lentil (2)
- Mustard (2)
- Linseed (1)
- Soybean (1)
- Horticultural crops (4)
Total 48 of MAS-derived cultivars released in India

Number of cultivars improved for various traits using molecular breeding
<table>
<thead>
<tr>
<th>Crop/Crop Group</th>
<th>Total Specie(s)</th>
<th>Total acc. conserved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>136</td>
<td>165966</td>
</tr>
<tr>
<td>Millets</td>
<td>28</td>
<td>59434</td>
</tr>
<tr>
<td>Forages</td>
<td>200</td>
<td>7261</td>
</tr>
<tr>
<td>Pseudo-cereals</td>
<td>55</td>
<td>7791</td>
</tr>
<tr>
<td>Legumes</td>
<td>109</td>
<td>66927</td>
</tr>
<tr>
<td>Oilseeds</td>
<td>84</td>
<td>60386</td>
</tr>
<tr>
<td>Fibre crops</td>
<td>77</td>
<td>15877</td>
</tr>
<tr>
<td>Vegetables</td>
<td>212</td>
<td>27082</td>
</tr>
<tr>
<td>Fruits &amp; Nuts</td>
<td>68</td>
<td>289</td>
</tr>
<tr>
<td>M&amp;AP &amp; Narcotics</td>
<td>681</td>
<td>268</td>
</tr>
<tr>
<td>Ornamental</td>
<td>122</td>
<td>668</td>
</tr>
<tr>
<td>Spices and Condiments</td>
<td>28</td>
<td>3254</td>
</tr>
<tr>
<td>Agroforestry</td>
<td>191</td>
<td>1653</td>
</tr>
<tr>
<td>Duplicate safety Samples (Lentil, Pigeonpea)</td>
<td>-</td>
<td>10235</td>
</tr>
<tr>
<td>Total Material (W&amp;B)</td>
<td></td>
<td>10771</td>
</tr>
</tbody>
</table>
Early vigor
- Early leaf growth in seedling stage increases land shading and minimises water loss from the soil

Tillering inhibition
- Tillering inhibition (Tin gene) reduces unproductive tillers under drought

Deep roots
- Deep root system extracts soil from deeper soil layer

Alternative dwarfing genes
- Increased coleoptile length helps in emergence from deeper soil layer
Shri. Narendra Modi, Hon’ble Prime Minister of India, inaugurating the “Nanaji Deshmukh Plant Phenomics Centre” on 11th October 2017 at IARI, Pusa, New Delhi.
Indian Seed Network

- ICAR Institutes (51), SAUs/CAUs (60/73), KVKs (717), Seed Hubs (218) (Pulses-150, Oilseeds-35, Millets-25, FPSPP, Seed Village Scheme)
- One national level organization viz. NSC (SFCI merged)
- 17 State Seed Corporations
- 25 State Seed Certification Agencies
- 132 Notified Seed Testing Labs (6 ISTA accredited and 16 have ISTA membership)
- ~500 large and medium size private seed companies

Indian Council of Agricultural Research (ICAR)

ICAR-Indian Institute of Seed Science

AICRP-NSP (Crop)

- BSP centres-41
- STR Centres-24
- Total Breeder seed production (2018-19)=1.17 lakh quintals

ICAR Seed Project

- Cooperating centres- 63
- Total quality seed production (2018-19)= 4.69 lakh quintals
- Infrastructure- seed production, processing and storage
1740 lakhs of Quality Planting Materials in the Last 5 years

~14 lakhs of Tissue Culture Raised Seedlings in the Last 5 years

2019-20
Total crops: 51 (33 kharif+18 rabi)
Varieties: 1330 (865 Kh+ 465 Rabi)
Rainfed Agriculture: Key Challenges

- Managing risks
- Resource poor operational land resource base
- Bridging yield gaps
- Enhancing water productivity
- Changing cropping patterns
- Maintaining soil health and productivity
- Low and skewed farm mechanization

Shift in Climate: 27 % of TGA

Source: Raju et. al. 2013, CRIDA
Climate Resilient Villages for Drought Proofing: Technological & Institutional Options

**WEATHER**
- Documentation of aberrant weather conditions
- Weather monitoring using AWS
- Weather based agro-advisory
- Real time contingency planning

**WATER**
- In Situ rainwater management
- Efficient application techniques
- Flash flood management
- Flood diversions
- Community water sharing

**CROP**
- Stress tolerant varieties (Drought, Flood/Heat/Nutrient use efficient)
- Short Duration varieties
- Intercrop/systems
- Crop Diversification
- Efficient rice systems

**NUTRIENT**
- Soil Health Card based SSNM
- Neem Coated Urea
- Precision Farming
- Green Manuring

**CARBON**
- Village organic resource inventory
- Residue recycling
- Conservation agriculture
- Tank silt
- Agro forestry
- Livestock management

**INSTITUTIONAL**
- Village Climate Risk Management Committee
- Custom Hiring Centers
- Contingency Seed and fodder systems
- Field Information Facilitator
- Commodity groups
- Capacity building
CRVs can bring in Drought Proofing in even in Regions with 500 mm rainfall

Access to water for critical irrigation was provided to the majority of the households

**In-situ conservation in uplands** (Trench Cum Bund, Ridge and Furrow, Conservation Furrow)

Harvested water used for life saving irrigation during the dry spell during July 2015 improved yields in ground nut (40%), paddy (31%) and finger millet (56%)

Area under rabi increased by 21%

Water Storage Created (Cu m)

- 760 Community tank constructed/renovated
- 600 Farm pond constructed/renovated
- 32560 Check dam constructed/renovated
- 40100 Water storage structure
- 151075 Water storage structure

172 water harvesting structures created

(Tumkuru, Karnataka, India)
Scaling up Climate Resilient Villages

- Better Crop Management
- Conserving Natural Resources
- Livestock Production
- Integrated Farming Systems
- Agro-Advisories
- Adaptation to Weather Aberration & Extreme Events
- Household/ Village Food Security/ Sustainable Development
- Climate Change Mitigation

Source: NICRA-TDC
Systems Linkage in Drought Affected areas: Connecting the Dots

Agricultural Systems

- Irrigated systems
  - Horticulture systems
    - Tree based systems
    - Vegetables
    - Commercial crops
  - Fodder crops
  - Drinking water
  - Livestock systems
- Completely rainfed
- Supplemental Irrigation

Sources of Water

- Rainfall
- Moisture based
- Groundwater
- Tank Based
- Canal (assured?) - External source
Water Saving Technologies

- Laser levelling helps in saving water and nutrients. It also avoids waterlogging.
- Promote water saving planting techniques (timely planting in residual moisture, zero tillage, raised beds)
- Promote surface mulching
- Promotion of micro irrigation techniques: sprinkler/drip
- Focus on water use efficient genotypes
- Seed priming
**Conservation Agriculture** for Sustainable Crop Production

### Tillage Crop establishment

<table>
<thead>
<tr>
<th>Conventional</th>
<th>Rotary till</th>
<th>Bed planting</th>
<th>Zero till</th>
<th>Surface residue</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
</tr>
</tbody>
</table>

### Need based nitrogen application using NDVI sensor

Using NDVI sensors 15-20% nitrogen can be saved in wheat and rice without any yield penalty. All these technologies put together can increase the profit margins of the farmers by more than 20% along with being environmentally friendly.

### New Machine for CA: Improved Rotary Disc Drill

![Image](image6.png) ![Image](image7.png) ![Image](image8.png)
Success Stories (Climate Smart Village & Wheat Village)

Source: CIMMYT

- Taraori, Karnal
- **Research Focus:** Identify potential donors for IUE

- Wheat varieties sown under CA and CT at Rambha village, Karnal (Haryana)
- Wheat seeding in rice residue using Turbo Happy Seeder and Rotary Disc Drill at farmers’ field
- High yielding wheat varieties released for various zones showed similar performance under CA and CT system
District Agriculture Contingency Plans (DACPs)

- DACPs available for 650 districts
- Plans for delay in monsoon and early, mid-season and terminal droughts
- Implemented through State Govt with technical backstopping by Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs)
- Saving on input cost, time of spraying, irrigation scheduling and crop harvesting
- Effectively used to cope with droughts and other climatic risks

http://www.crida.in:82/contingencyplanning/
EcoDRR (Ecosystem based Drought Risk Reduction)

Points to Ponder

- If available rainfall is more than the systems requirement
  Management of available resource is the main option

- If available resource is less than the systems requirement
  Management of all resources becomes important

Need to consider

- Agroecosystem perspective - Climate, soils, biodiversity, production systems
- Priority for systems – Resilient farming systems (crop, animal, tree based for climate adaptation)
- Enhancing soil quality, water productivity and energy use efficiency, Biodiversity and crop improvement
- Governance issues
- Participatory management
Areas of collaborations

- Exchange of plant genetic resources
- Sharing suitable varietal technologies
- Seed production systems
- Collaborations in research
- Scaling up of Climate Resilient Village Models
- Precision irrigation technology
- Human resource development (Scientists and students)
Thanks