Resilient and efficient agro-ecosystems under changing climate and demography

Innovation, Investment, Intervention and Impact

Chandrashekar Biradar, PhD
Principal Scientist (Agro-Ecosystems)
Head-Geoinformatics Unit
c.biradar@cgiar.org

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Spurring Geospatial Opportunities in Inclusive Agricultural Development
Drought in middle east is worst of past 900 years

Conflicts and migration

Source: NASA, 2016
Water Stress Around the World

(Source: World Resources Institute)
Land and Soil Degradation

Chemical deterioration severity
- low
- medium
- high
- very high

Wind erosion severity
- low
- medium
- high
- very high

Physical deterioration severity
- low
- medium
- high
- very high

Water erosion severity
- low
- medium
- high
- very high
Impact of climate change on agriculture

Crop yields under climate change

Impact of climate change on agriculture

World bank Development report 2010
http://wdronline.worldbank.org/

Wheeler and Baum, 2013.
Global Drylands and CGIAR

tropical and non-tropical drylands

Area (km²)
- Tropical Drylands: 29.33 million
- Non-tropical Drylands: 95.52 million

Population
- Tropical Drylands: 1.89 billion
- Non-tropical Drylands: 2.68 billion

Institutions:
- CIMMYT, Texcoco, Mexico
- CIAT, Cali, Colombia
- IITA, Ibadan, Nigeria
- CIAP, Lima, Peru
- Bioversity International, Rome, Italy
- ICRISAT, Hyderabad, India
- IRRI, Los Banos, Philippines
- IFPRI, Washington D.C., USA
- WARDA, Africa Rice, Bouake, Ivory Coast
- ICRISAT, Ibadan, Nigeria
- World Agroforestry, Nairobi, Kenya
- World Fish, Penang, Malaysia
- Bioversity International, Rome, Italy
- ICARDA, Beirut/Amman, Lebanon/Jordan
- CGIAR Research Program on Wheat
- CGIAR Research Program on Rice
- CGIAR Research Program on Sesbania
Two-thirds of the global population (4.0 b) live under severe water scarcity and all most all of population in non-tropical dry areas.
Changing Water Balance

- Large fluctuation in water balance
- Climate variability and extreme events
- Crop rotation and economic drive
- Depleted soil organic carbon

Increasing deviation from long-term averages

Comparison of years:
- Good Year: 2014-2015
- Bad Year: 2015-2016
Inclusive-Integrated Agro-Ecosystems

Increased land and water productivity while safe guarding the environmental flows and ecosystem services

- more **crop** per **drop** -water is foci
- in a **inch of land** and a **bunch of crop**

Knowledge based prioritization (space & time) better strategy for intervention, implementation and impact

Eco-Crop Zoning
Water Use Efficacy
Conservation Practices
Adoption/Adaptation
Scaling Technology

- food and environmental security
- cooperative and collective actions
- trade, social security and stability
Water, Nutrition, Ecology and Climate Change

Why dryland crops and crop diversification?

• Economically-Nutritious
• Ecological-Soil Health
• Improved Productivity
• More Climate Resilient
• Reduce Virtual Water Trade

Water-Efficient-Ecological Food Production

- Daal/Falafel (1kg) 1,250 liters
- Chicken (1kg) 4,325 liters
- Mutton (1kg) 5,520 liters
- Beef (1kg) 13,000 liters

http://www.soyfoods.org/
EOS in Agricultural RDO

Scaling Trade-on/offs
Farmscapes to Landscapes

Big-Data Analytics
Citizen Science
Precision Decisions

Vegetation Dynamics
Pest and Diseases Risk
Crop Modeling (Physio)
Ag hydrology

Agro-ecosystems
L&W Productivity
Land Use Change

Cropping Systems Dy
Ag Water Productivity
Yield Gap Analysis

Moderate Resolution Imaging Spectroradiometer (MODIS)
SPOT Vegetation

Landsat 7
IRS

WorldView series
RapidEye/QuickBird
Cartosat

WVs/DG/UAVs

MODIS AWiFS

Clouds
Vegetation
Desert
Waterbodies

Figures/VarImpacts
HyRS
Crop Fallows
Intensification
Feedstock

Varieties/Landraces

Crops/Forage

Farmlands/Grasslands

Agro-ecosystems
Digital Agriculture Platform

On the fly demand driven query and cluster analysis

Cadastral, Object & Pixel based
Biophysical and socio-ecological

Machine Learning
Crop types, crop intensity, pattern, fallows, crop stress, AET-I8, soil moisture-SMAP

Citizen-Science Cellphone feedback

Direct Access and Markets/Trade

Precision-Delivery

Image Based, Open Source Precision Decision at Farm scales

Timely-Access-Application-Trading (TAAT)

On the fly demand driven query and cluster analysis

Precision decision delivery at farm scales and feedback

Farming Stakeholders

Landsat AWS

Crowdsourced, OA, Cloud Computing at Farm Scale

Citizen Science Community of Practices
Existing Agricultural Production Systems

Where are they and what is going?

Biradar et al., 2009, 2015  Drylands of Developing World
Dynamics of Cropping Intensity and Pattern

- Integrated Agro-Ecosystems
- Sustainable Intensification and Diversification
- Input Use Efficiency - Conservation Agriculture
- Thematic Land-Water-Climate Resilience

How can we track and link?

Agricultural Intensification

Increase in Arable Land 72%

Length of the crop fallows, start-date, end-date

(Biradar et al., 2015)

Biradar and Xiao, 2009
Quantification of its dynamics
Under changing Climate and Demography

Remote Sensing
MODIS
LANDSAT
SENTINEL
MICROS

GeoStats
AgCensus
Climate, Soils
Demography

Open Source Cloud Computing Algorithms

Biradar, 2016*
EOS in Precision Decisions

Automated workflow for operational mapping, monitoring and rural advisory

Inter and intra-annual dynamics of cropping systems – pattern, rotation, shift

Loss

Gain

Between Farms

Within farms
Ag Intensification & Diversification

Better use of crop fallows for sustainable future

Near real-time farm analytics at pixel to landscape scales

Cropping System
Crop Intensity
Crop Calendar
Crop Rotation
Cropped Area
Fallow Dynamics
- Fallow area
- Duration
- Start date
- End date
Yield Potential
- Current
- Achievable
Suitable Crop/Variety
- Legumes
- Oil Seeds
Soils
Soil Health (SHC)
Soil Moisture (SMAP)
Water use
Evapotranspiration Allocation/Irri. Sch.
Markets
-ePlatform
-Ag Supply Chain
-Access (I/O)
Monitoring
-Pest/Diseases
-Crop Stress
Citizen Science
Cropping Intensity and land use dynamics

(Biradar et al., 2015)
Length of crop fallows

(Biradar et al., 2015)
Inter and Intra Annual Dynamics over Decades

15 years cycle

Length of Crop Fallows (LCP): 2000-2015

Cropping Intensity and land cover: 2000-2014

(Biradar et al., 2015)

Start and End Dates of Inter-annual Fallows

Start and End Dates of Intra-annual Fallows
Crop-fallows for intensification
On-farm water management

Fallow from July to January (7 months)

March

December
Static Maps
to see JPG maps showing the regional similarity of IP sites and variety-specific maps

Interactive Mapping based on user-defined queries to find suitable varieties and extent of suitability
Water productivity of the dryland crops are much higher than any production systems.

Water productivity (WP) is defined as the kg of yield produced/m$^3$ of water used or, alternatively, as value in $ of yield produced/m$^3$ of water used.

**Water Productivity (WP)**

<table>
<thead>
<tr>
<th>Crop</th>
<th>WP (kg/m$^3$)</th>
<th>Value ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>0.42</td>
<td>0.50</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.60</td>
<td>0.33</td>
</tr>
<tr>
<td>Rice paddy</td>
<td>0.50</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Biradar et al., 2013

*Inter and Intra Field Variability*

*Where are those Yield Gaps?*

Within the fields

Biradar et al., 2013
Adoption and out scaling of Innovative Technologies: e.g., Conservation Agriculture

- productivity
- employment
- enterprise

<table>
<thead>
<tr>
<th>Suitability class</th>
<th>Area (km²)</th>
<th>Population</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly suitable</td>
<td>40,956</td>
<td>10,021,600</td>
<td>243</td>
</tr>
<tr>
<td>Medium suitable</td>
<td>28,870</td>
<td>5,081,674</td>
<td>174</td>
</tr>
<tr>
<td>Low suitable</td>
<td>24,083</td>
<td>2,929,224</td>
<td>122</td>
</tr>
<tr>
<td>Not suitable</td>
<td>576,076</td>
<td>9,471,688</td>
<td>16</td>
</tr>
</tbody>
</table>

Legend:
- High
- Medium
- Low
- Region
- District
- Unsuitable
Agroforestry systems: Trees in farm lands

Area under agroforestry in India: 7.4 million ha
(Zomer et al., 2007)

Length of farm bunds available for tree planting: 6.6 m km

Its role in carbon sequestration 18-38 Mg C ha⁻¹
(Various studies and estimates)
Measuring Impact of Successful interventions

Soil Salinity, Dujaila, Iraq

Salinity Maps

1958

- < 4 dS/m
- 4 - 8 dS/m
- 8 - 16 dS/m
- 16 - 32 dS/m
- > 32 dS/m

MoA, Iraq

Pre-Reclamation Period

2010

Satellite Images

April 1984

April 2013

Post-Reclamation Period

Yield Increase
1.92 to 4.0 t/h
Average yield in saline lands for five major crops:

1.92 t/h

which is about 52% less than non-saline lands.
Measuring Impact of Successful interventions
Soil Salinity, Dujaila, Iraq

Dujaila, Iraq

Post-salinity reclamation period
Landsat April 2013

Average yield in non-saline lands for five major crops

4.0 t/h

which is about 52% more than saline lands
Irrigation Infrastructure and land reclamation

Agricultural Intensification and Expansion

Land Use Map 2004/05 (Pre-Project)

Irrigation Induced Salinity Control and Reclamation Project

(World Bank Report, Biradar et al., 2012)
Irrigation Infrastructure and land reclamation

Agricultural Intensification and Expansion

Land Use Map 2008/09 (Post-Project)

(World Bank Reports, Biradar et al., 2012)
Location specific Investment, Interventions and Impacts

Current: 0% gain
32 m tons

S-1 : 72% Gain
61 m tons

S-2 : 26% Gain
35 m tons

S-3 : 18% Gain
40 m tons

Grain Yield (kg/ha, '1000)

ICARDA
Biradar, et al., 2016*
We have heavily compromised sustainable food production and health of the lives and the planet Earth by neglecting minor crops (dryland cereals and legumes)

Go back to the future
Integrated farming systems with better soil and water management for nutritious food for a sustainable future
in an inch of land and bunch of crop

Where much gain is expected?
Is that from genetic? 15-20
Is that from agronomy? 50-60
Is that from socio-economy? 20-35 (policy)

avoid the unmanageable and manage the unavoidable

-IPCC Confronting Climate Change:

Thank You

c.biradar@cgiar.org
geoagro.icarda.org

- Ag-Intensification
- Digital Agriculture
- Wheat out-scaling
- CA Adoption
- Thematic Research
- Cereals-Legume System
- Pests & Disease Risks
- Land Degradation
- Crop modelling
- Watershed management
- Climate Change
- System Modelling
- Big-data Analytics
Integrated Observation Systems

Agro-ecosystems

Weather Station

PhenoCam

CO₂, H₂O, CH₄, & N₂O
Eddy Flux Tower

Spectroradiometer

FLIR Thermal Camera

Airborne & Space-borne RS

UAV

COSMOS Rover

Solar Power

Airborne & Space-borne RS

COSMOS Soil Moisture

Agro-ecosystems