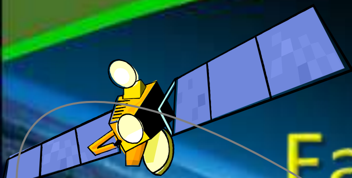

Earth observation and big-data analytics for building resilient agro-ecosystems

Innovation, Investment, Intervention and Impact

Chandrashekhar Biradar, PhD
Principal Scientist (Agro-Ecosystems)
Head-Geoinformatics Unit
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Nov 21-23, 2016
Hyderabad, India

International Conference on Statistics & Big Data Bioinformatics in Agricultural Research

CGIAR

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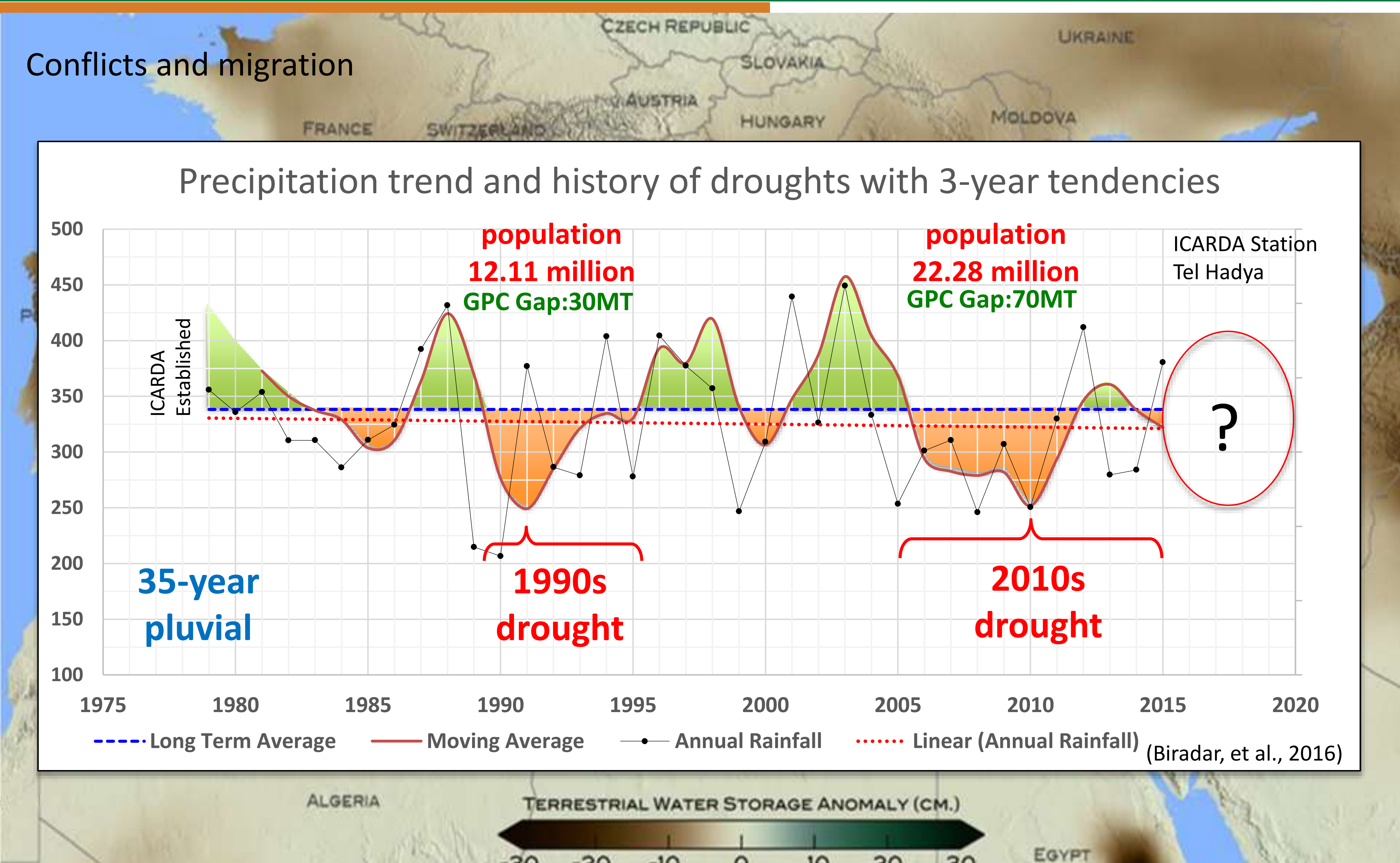
Science for Better Livelihoods in Dry Areas

Droughts in Drylands
and the consequences and conflicts

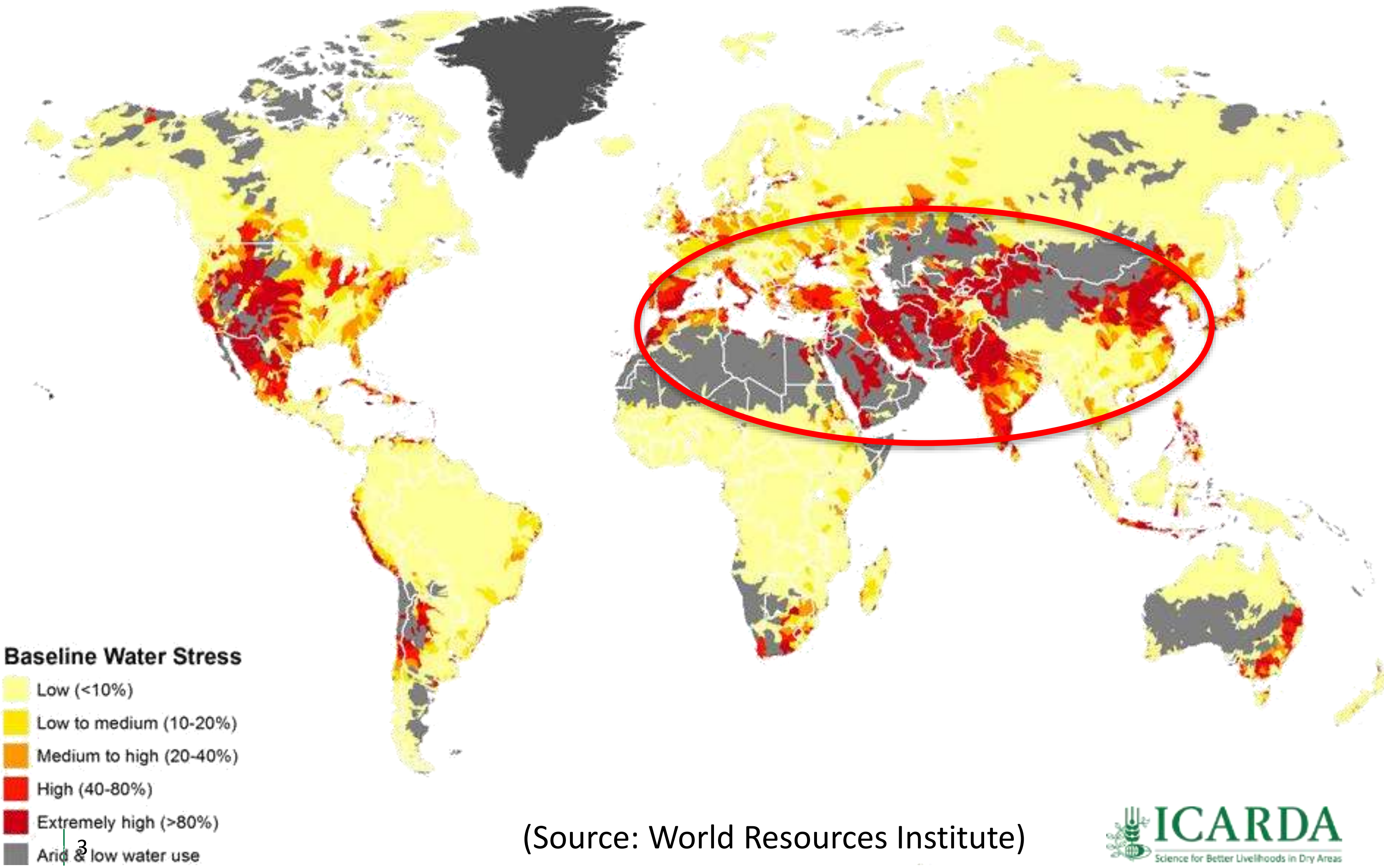
Drought in middle east is worst of past 900 years

Conflicts and migration



Source: NASA, 2016

Water Stress Around the World



(Source: World Resources Institute)

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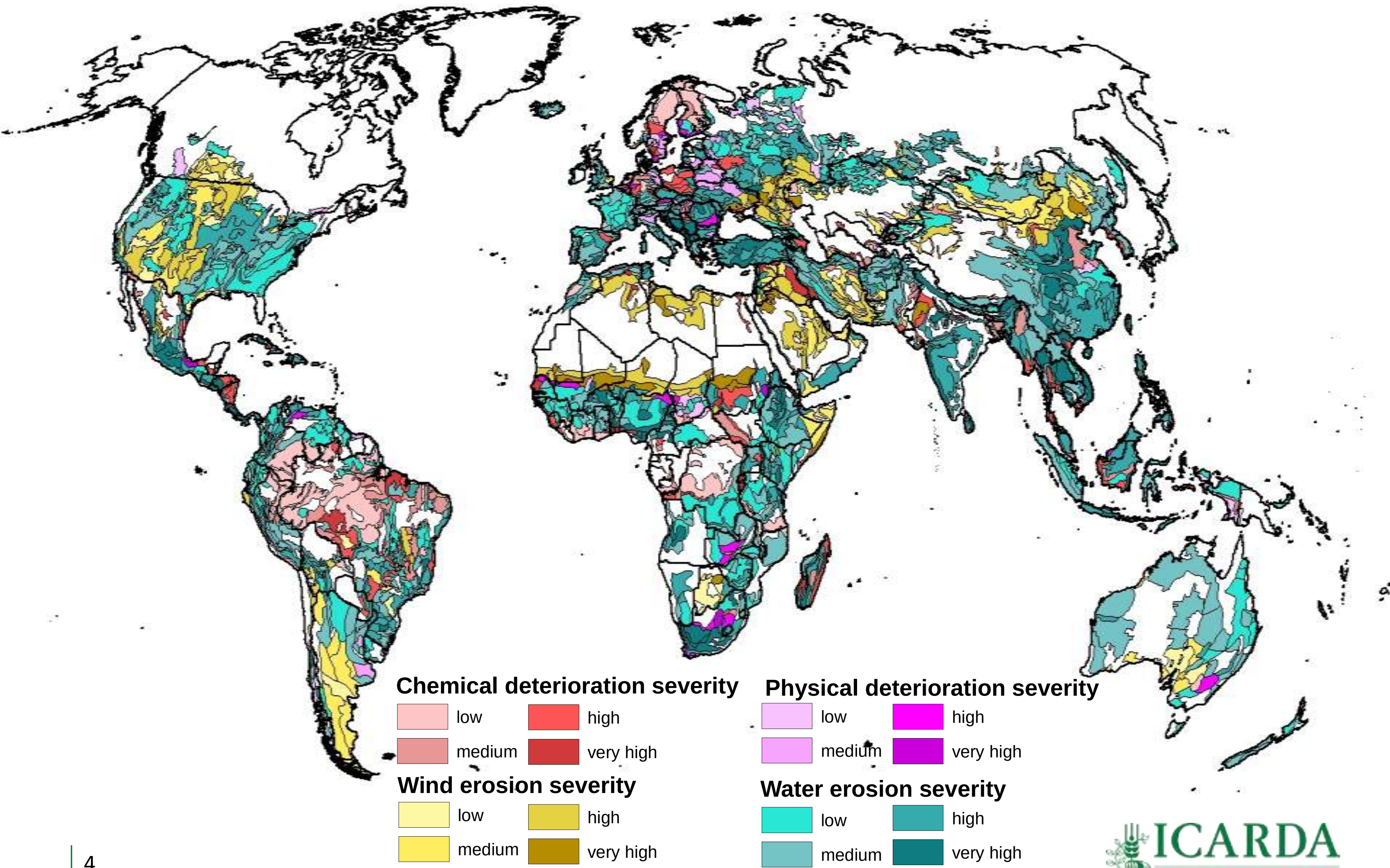
Land and Soil Degradation



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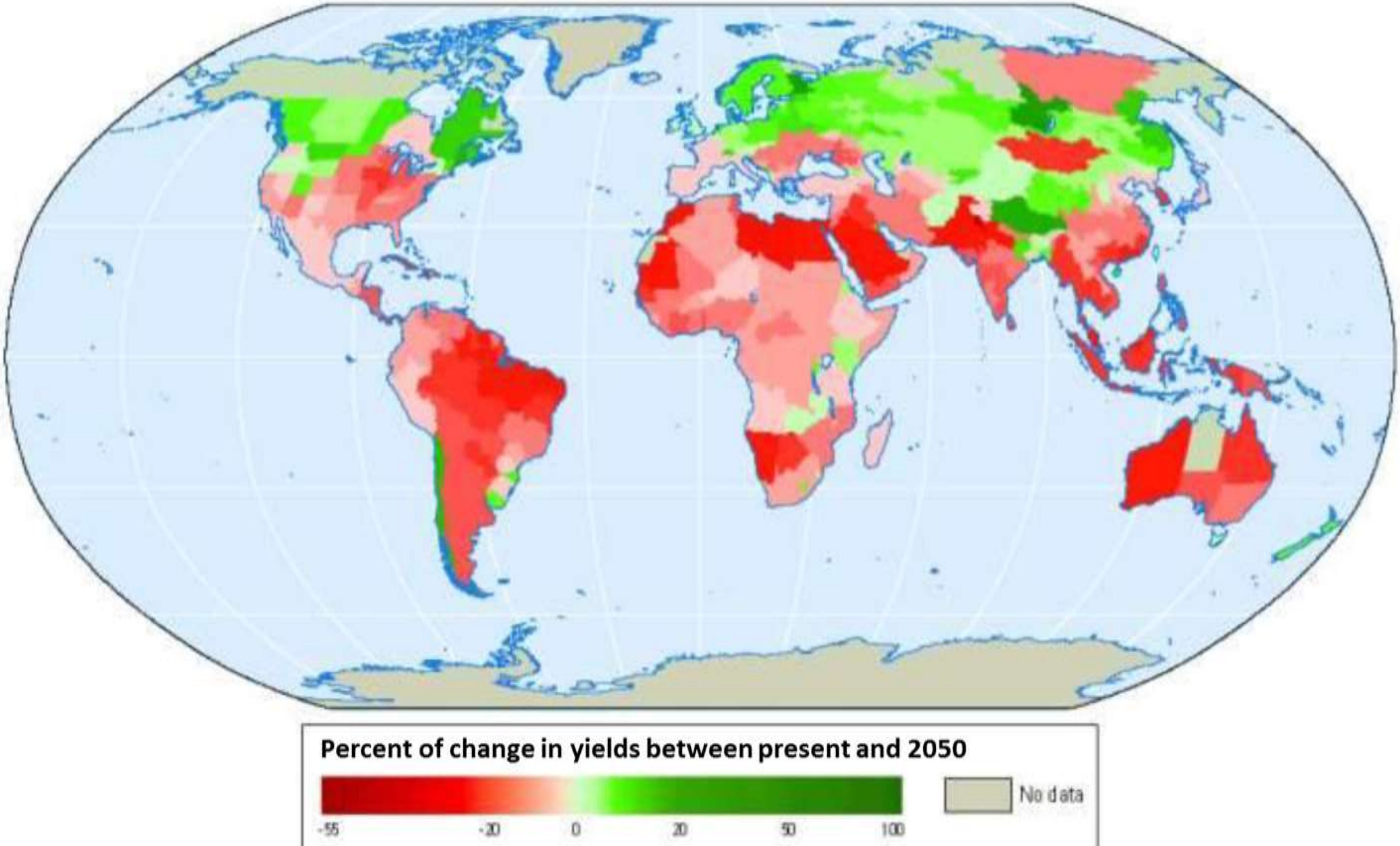
Impact of on agriculture

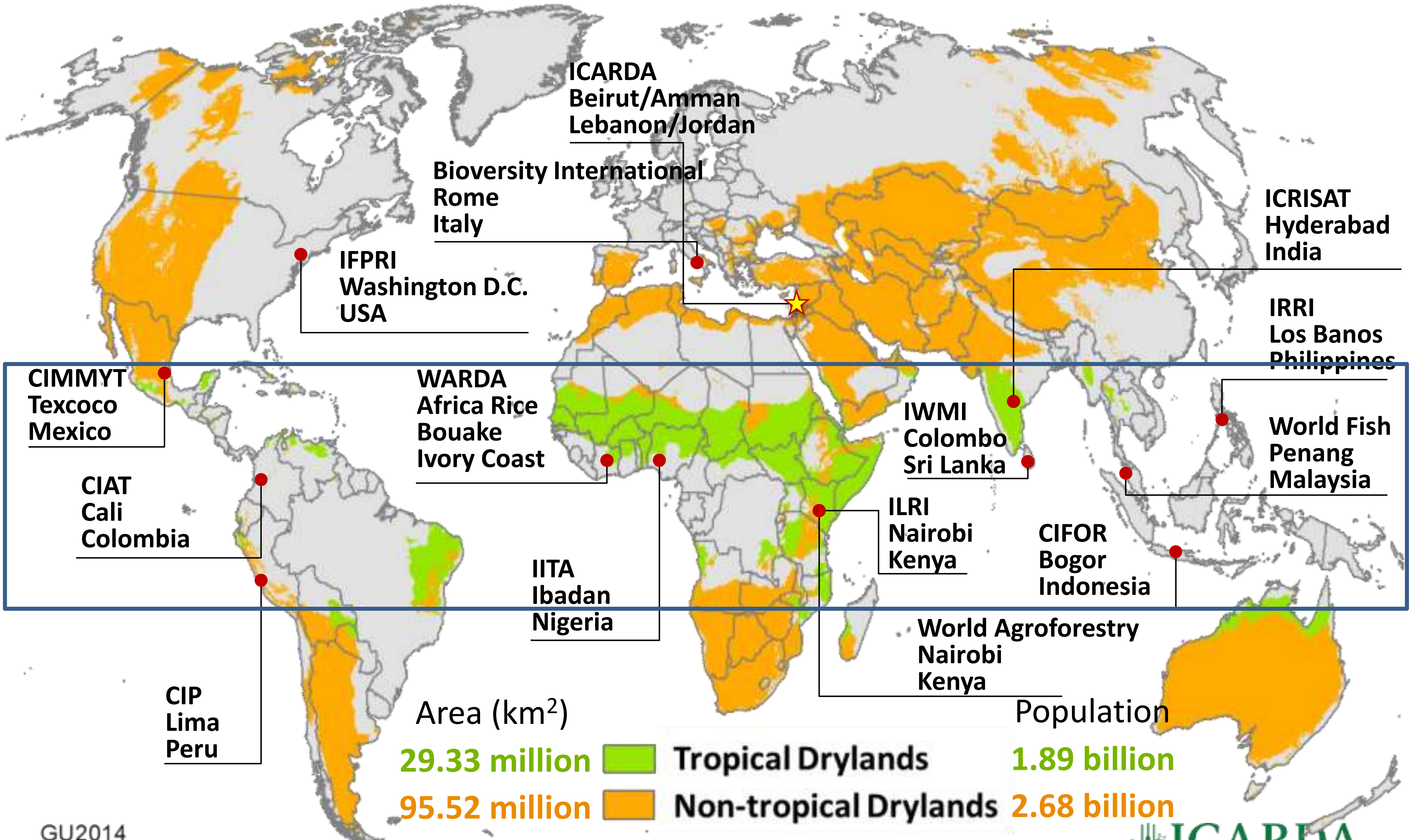


World bank Development report 2010
http://wdronline.worldbank.org/

Wheeler and Baum, 2013.

Global Drylands and CGIAR

tropical and non-tropical drylands



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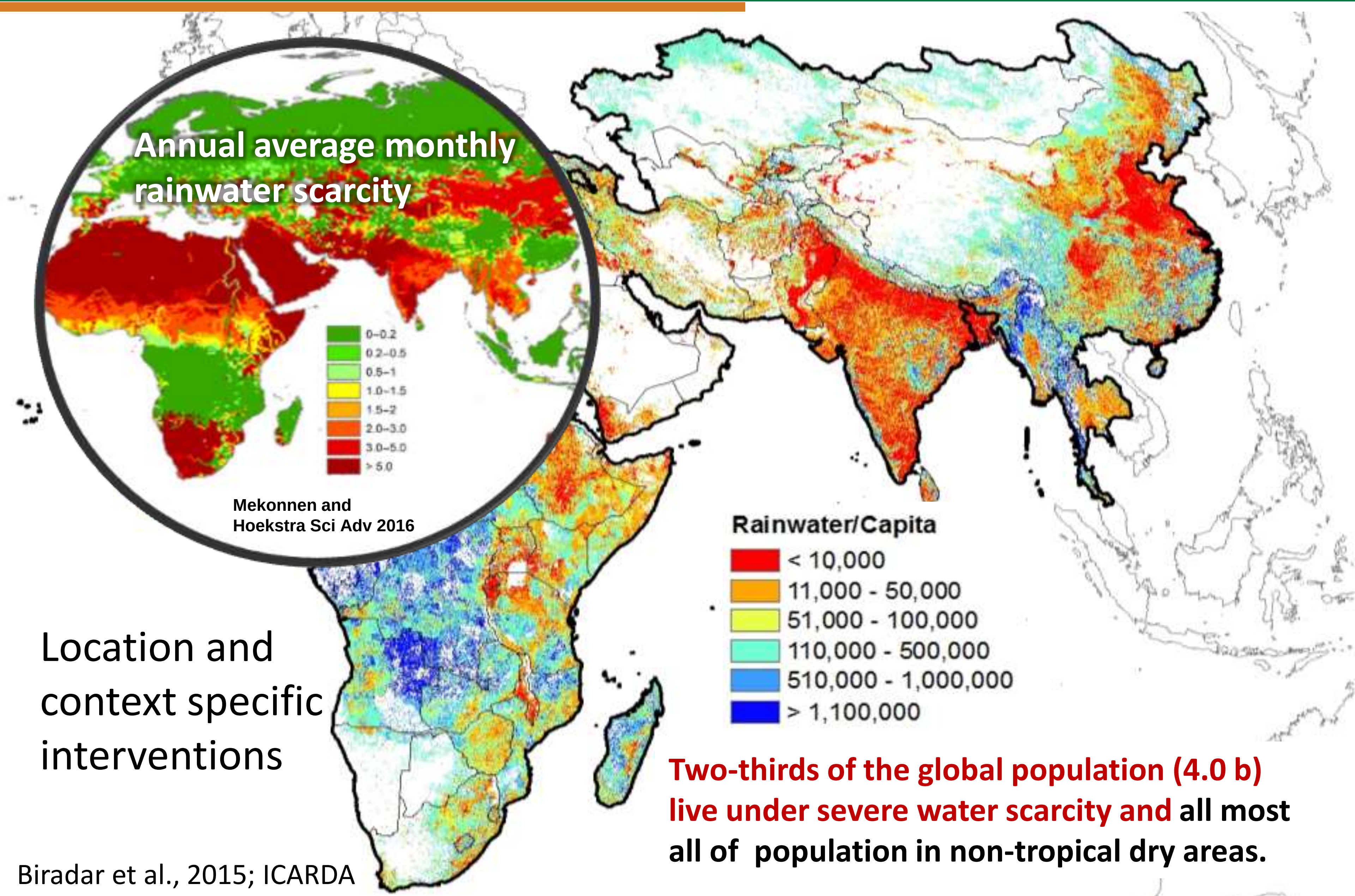
Green Water Resources

rainwater per capita (m^3/person/year)



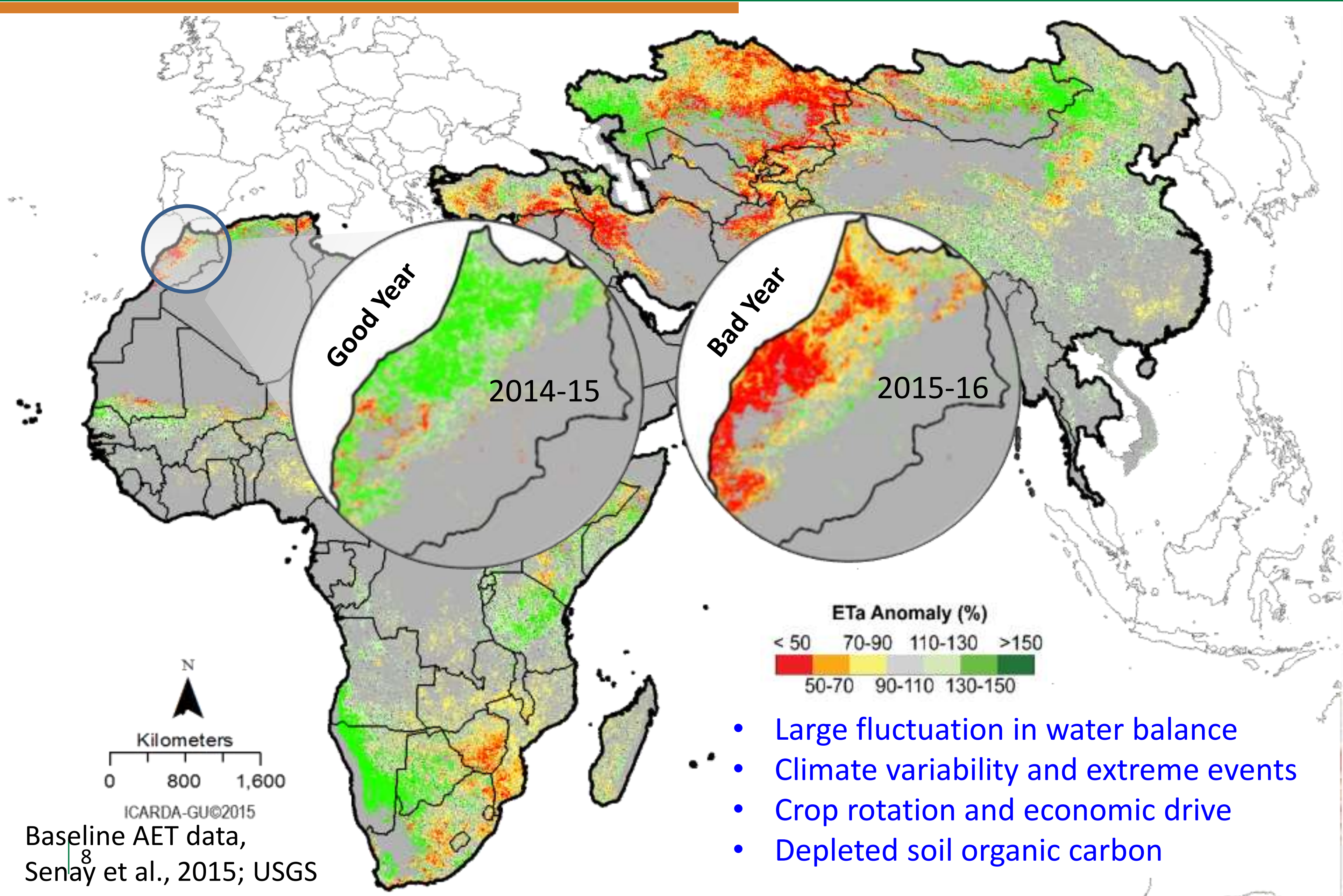
Location and context specific interventions

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.

Biradar et al., 2015; ICARDA

Changing Water Balance

Increasing deviation from long-term averages



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

Baseline AET data,
Senay et al., 2015; USGS

Towards Resilient Agro-Ecosystems

Pastoral Agropastoral Rainfed Tree-based Irrigated

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

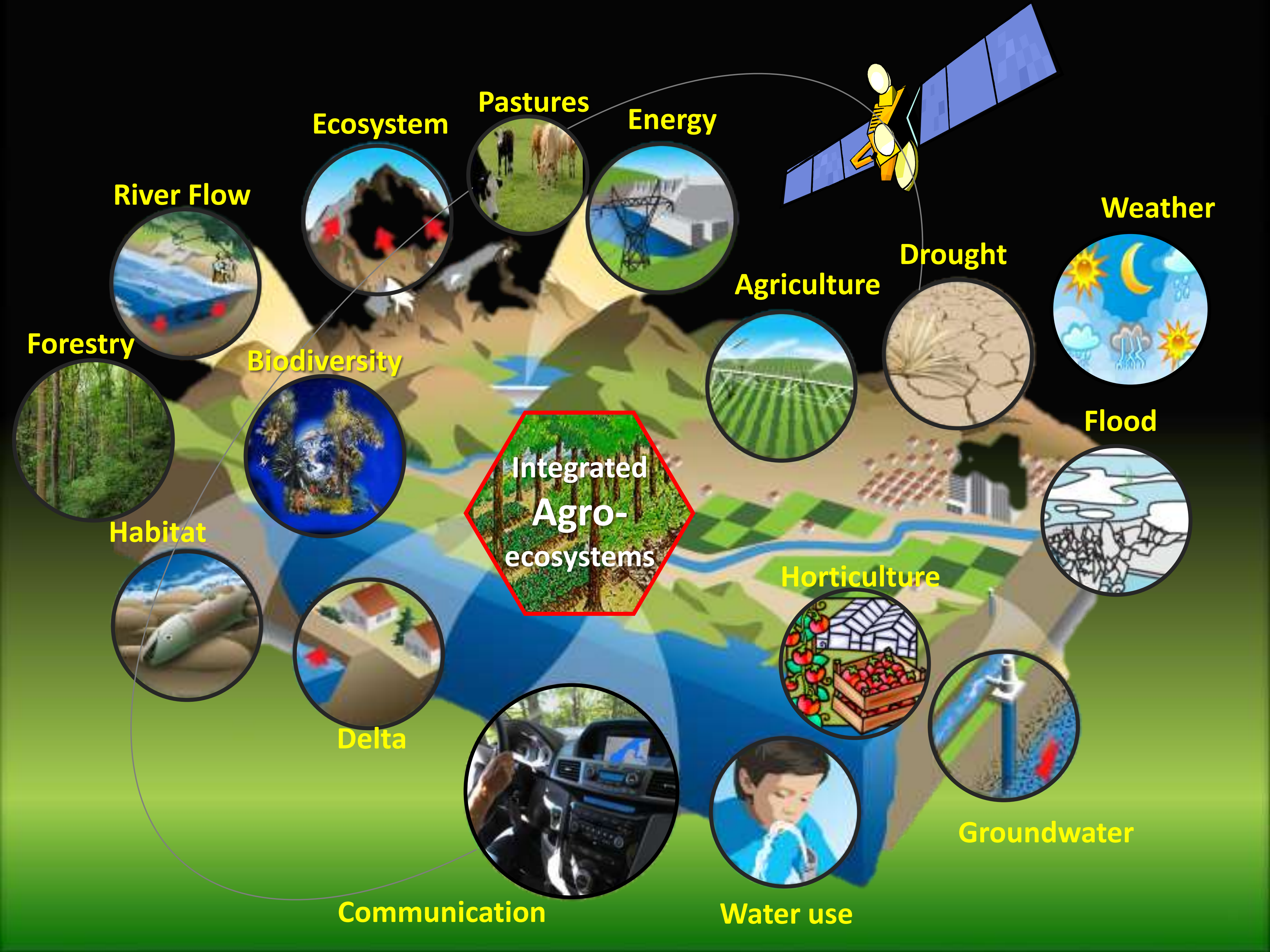
- more **crop** per **drop** -water focus
- in a **inch of land** and a **bunch of crop** -multi dimensions -integrated systems

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

Genes and Gains
Eco-Crop Zoning
Input Use Efficiency
Bridging Yield Gaps
Conservation Practices
Carbon Sequestration
Land Degradation
Technology Scaling

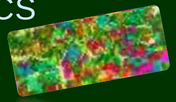
- food and environmental security
- resilience and risk reduction
- adaption and mitigation
- citizen science and collective actions
- trade, social security and stability


Role of Geospatial Science, Technology and Applications (GeSTA) in Dryland Systems
Youth
Engaging and empowering young gen. by creating opportunities
156 Remote sensing missions in orbit°
>12 Sensors potential in CRPs/IRPs, etc.
>6 are free
5
1) Ecological intensification, 2) Bridging yield gaps, 3) Input use efficiency, 4) Reduced land degradation, and 5) Location specific interventions.
Ensuring Food Security
Specific mutual-interaction & synergies between plant and animal species and management practices
Integrated agro-ecosystems: innovative approaches and methods for sustainable agriculture, while safeguarding the environment
Mapping present, Emerging, future land use /land cover dynamics, land degradation and desertification, changing demographics, climate change adaptation and impacts
Quantification of dryland agricultural production and livelihood systems
Characterization of vulnerable areas for increasing resilience and assist in identifying mitigation pathways with biophysical, socioeconomic and stakeholder feedback as well as specific needs & constraints
Safeguarding Environmental Flows and ESs
Cooperative Research and Partnerships
Innovations & Integration
Reducing Vulnerability
Measuring Impacts
Sustainable Intensification
Current status, trends, extent, characteristics of crops, pattern, productivity, water use, livestock, biodiversity, soils, & climate
Gender
Address social inequities, greater roles and priorities
Drylands 41% Earth's land area
Red. Vul.
A/Ss
TAs
Sus. Int.
A/Ss
TAs
Drylands
Integrated Production Systems for Improving Food Security and Livelihoods in Dry Areas
Biodiversity
Spatial enrichment and its role in food security, risk mitigation, & sustainability
increased Food production potential sources
Cropping Intensity
21%
7%
72%
Agricultural Intensification
Increase in Arable Land
Measuring the impact at spatial scales, rate, magnitude, synergy among the systems, CRPs, cross-regional synthesis
Mapping the extent of existing & traditional practices, indigenous knowledge, diversity, potential areas for modern & improved, productive, profitable, and diversified dryland agriculture, & linkages to markets
Geospatial commons , KM sharing, stakeholder feedback
Farmers, stakeholders, policymakers, mobilization, & marketing
Assessing the impact of outcomes in Action Sites, post-project implementation, & M&E
Location specific and ecological intensification
Delineation of potential, suitable areas for sustainable intensification, diversification of production systems
People 2.5b Live in Drylands
Assessment of present, emerging & future droughts, floods, pests & diseases, extreme events, infrastructure, migration
Nutrition
Changing diet patterns, nutrition and health
Efficiency
Productivity
ICARDA
Science for Better Livelihoods in Dry Areas
Improved Livelihoods
geoagro.icarda.org
Livestock
1.5b Depend on Drylands


Pastures
Energy
Ecosystem
River Flow
Weather
Drought
Agriculture
Forestry
Biodiversity
Flood
Integrated
Agro-
ecosystems
Habitat
Horticulture
Delta
Groundwater
Communication
Water use

Earth Observation Systems for Agro-Ecosystem Research

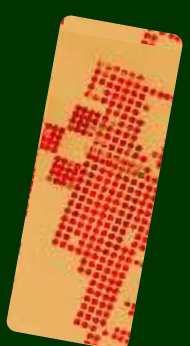
ACTIVE SATELLITE SENSORS AND CHARACTERSTICS

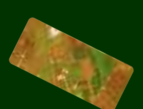


Very High Resolution (Up to - 1 m)

Satellite Sensors	Resolution			Swath (km)
	Spatial (m)*	Temporal (days)	Spectral (Bands)	
GEOEYE-1	1.65 (0.41)	1	B, G, R, IR, P	15.2
IKONOS	3.2 (0.82)	14	B, G, R, IR, P	11.3
PLEIADES-1A	2 (0.5)	1	B, G, R, IR, P	20
PLEIADES-1B	3 (0.5)	1	B, G, R, IR, P	20
Quick Bird	2.4 (0.6)	3.5	B, G, R, IR, P	16.5
WorldView-1	(0.4)	1.2	P	17.6
WorldView-2	1.8 (0.4)	1.2	P, C, B, G, Y, R, RE, IR (2)	16.4
CARTOSAT-2	1	5	P	9.6
CARTOSAT-2a	<1	4	P	9.6
CARTOSAT-2B	<1	4	P	9.6
SKYSAT-1	2 (0.9)	<1 (hourly)	B, G, R, IR, P	8
KOMPSAT-3	2.8 (0.7)	14	B, G, R, IR, P	16.8
KOMPSAT-2	4 (1)	14	B, G, R, IR, P	15
OrbView-3	4 (1)	3	B, G, R, IR, P	14

High Resolution (1 to 5 m)



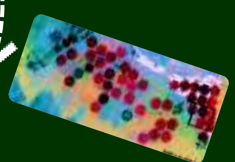


Satellite Sensors	Resolution			Swath (km)
	Spatial (m)*	Temporal (days)	Spectral (Bands)	
CARTOSAT-1	(2.5)	5	P	30
FORMOSAT-2	8 (2)	1	B, G, R , IR, P	24
SPOT-5	5, 20 (2.5, 5)	2-3	G, R, IR, SW, P	60 to 80
SPOT-6 (1.5)	6 (1.5)	2-3	B, G, R , IR, P	60
RapidEye	5	1	B, G, R, RE, IR	77
RESOURCESAT-1	5.8	5	G, R, IR	23, 70
GOKTURK-2	10, 20 (2.5)	2.5	B, G, R, IR, SW, P	20
TH-2	10 (2)		B, G, R, IR,P	60
EROS-A	(1.8)	2.1	P	14
Theos	15 (2)	3	B, G, R, IR	96
BEIJING-1	32 (4)	1	R G, IR	600
PROBA/HRC	18, 34 (5)	7	18	15

Medium resolution (5 - 30 m)

Satellite	Multispectral resolution (m)	B, s	Swath width (km)
ASTER (15m)			
VNIR (Visible Near Infrared)	15	VIR (4)	60
SWIR (Shortwave Infrared)	30	SW (6)	60
TIR (Thermal Infrared)	60	TIR (5)	60
CBERS - 2			
WFI	260	R, IR	890
CCD	20	B, G, R, IR	113
IRMSS	(2.7)	P-	27
LANDSAT 5TM -7ETM	30 (14.8)	B, G, R, IR, SW1, TIR, SW2, P	185
Nigeriasat-X	22	G, R, IR	-
Resourcesat-2/Liss-III	23.5	R, G, IR, SW	141
Deimos-1	22	G, R, IR	600
UK-DMC-2/SLIM6	22	G, R, IR	638
BILSAT-1	26 (12)	R, B, G, IR, P	640
Nigeriasat-1	32	G, R, IR	640
ALSAT-1	32	G, R, IR	640
UK-DMC/EC (DMC)	32	G, R, IR	600
EO-1/ALI-MS	30	B (2), G, R, IR (3), SW (2), P	37
EO-1/ Hyperion	30	220 bands	7,7
ASTER (15m)	15, 30, 90	G, R, IR (2) SW(6), TIR (4)	60
LANDSAT 7ETM+	30m (14.5)	B, G, R, IR, SW (2), TIR, P	185
SPOT-4	20 (10)	G, R, IR, SW, P	60
SPOT-3	20 (10)	G, R, IR+P	60
JERS-1	24 (18)	G, R, IR, IR	75
SPOT-2	20 (10)	G, R, IR	60
SPOT-1	20 (10)	G, R, IR	60
Landsat 5/MSS	80	G, R, IR, IR	185
Landsat 5/TM	30, 120	B, G, R, IR, SW, SW, TIR	185
RESURS-01-1	45	G, R, IR	600

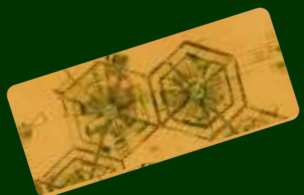
Low or Medium resolution



Satellite	Multispectral resolution (m)	B, s	Swath width (km)
Landsat 8	30 (14.8)	P, C, B, G, R, IR, SW (3)	185
VIIRS	375, 750	22b, s	3000
ASAR	(12.5)	VV 1	5 - 406
MERIS	300	15 b, s	1150
Metosat MSG			
GERB	40000	7	-
SEVIRI	1000, 3000	12	-
SPOT5/VEGETATION 2	1000	B, R, IR, SW (4)	2250
MODIS	250, 500, 1000	36	2330
SPOT4/VEGETATION 1	1000	B, R, IR, SW (4)	60
IRS-1D/ WiFS	188	R, IR (2)	774
Orbview-2/ SeaWiFS	1130	B(2), G (3), IR (8)	2800
IRS-1C/ WiFS	188	R, IR (2)	810
RESURS-01-1/ MSU-S	240	G, R, IR (3)	600
RESURS-01-1/ MSU-SK	170, 600	R, G, IR(2), TIR	600
ResourceSat/AWiFS	56	R, G, IR, SW	740
Landsat 2/ MSS	80	G, R, IR, IR	183
Landsat 2/ RBV	80	G, R, IR	183
Landsat 1/ MSS	80	G, R, IR, IR	183
Landsat 1/ RBV	80	G, R, IR	183

Radar Satellites

Satellite	Bands	Band (Polarity)	Swath width (km)
Sentinel-1			
COSMO-SKYMED 4	1, 5, 15, 30, 100	X-B (HH, VV, HV, VH)	10, 40, 30, 100, 200
TanDEM-X	1, 3, 16	X-B (HH, VV, HV, VH)	1500
COSMO_SKYMED 2	1, 5, 15, 30, 100	X-B (HH, VV, HV, VH)	10, 40, 30, 100, 200
RADARSAT 2	3, 8, 12, 18, 25, 30, 40, 50, 100	C-B (HH, HV, VH, VV)	5 - 500
COSMO-SKYMED 1	1, 5, 15, 30, 100	X-B (HH, VV, HV, VH)	10, 40, 30, 100, 200
Terra SAR-X	1, 3, 16	X-B (HH, VV, HV, VH)	1500
ALOS (PALSAR)	10, 20, 30, 100	L-B (HH, VV, HH, HV, VH)	70
ENVISAT (ASAR)	12.5	C-B (VV)	5 - 406
RADARSAT 1 (SAR)	8,25, 30, 35, 50, 100	C-B (HH)	50 - 500
ERS 2 (AMI)	25	C-B (VV)	100
ERS 1 (AMI)	25	C-B (VV)	100



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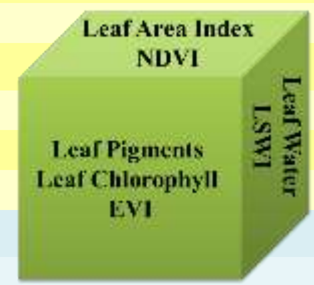
*=Resolution in parenthesis is panchromatic
+=Bands: B-Blue, G-Green, R-Red, IR-Infra Red, C-Coastal blue, Y-Yellow, SW-Shortwave Infrared, M-Mid infrared, P-Panchromatic, H-Horizonal, V-vertcial

EO Matrix at Farmscape to Landscape

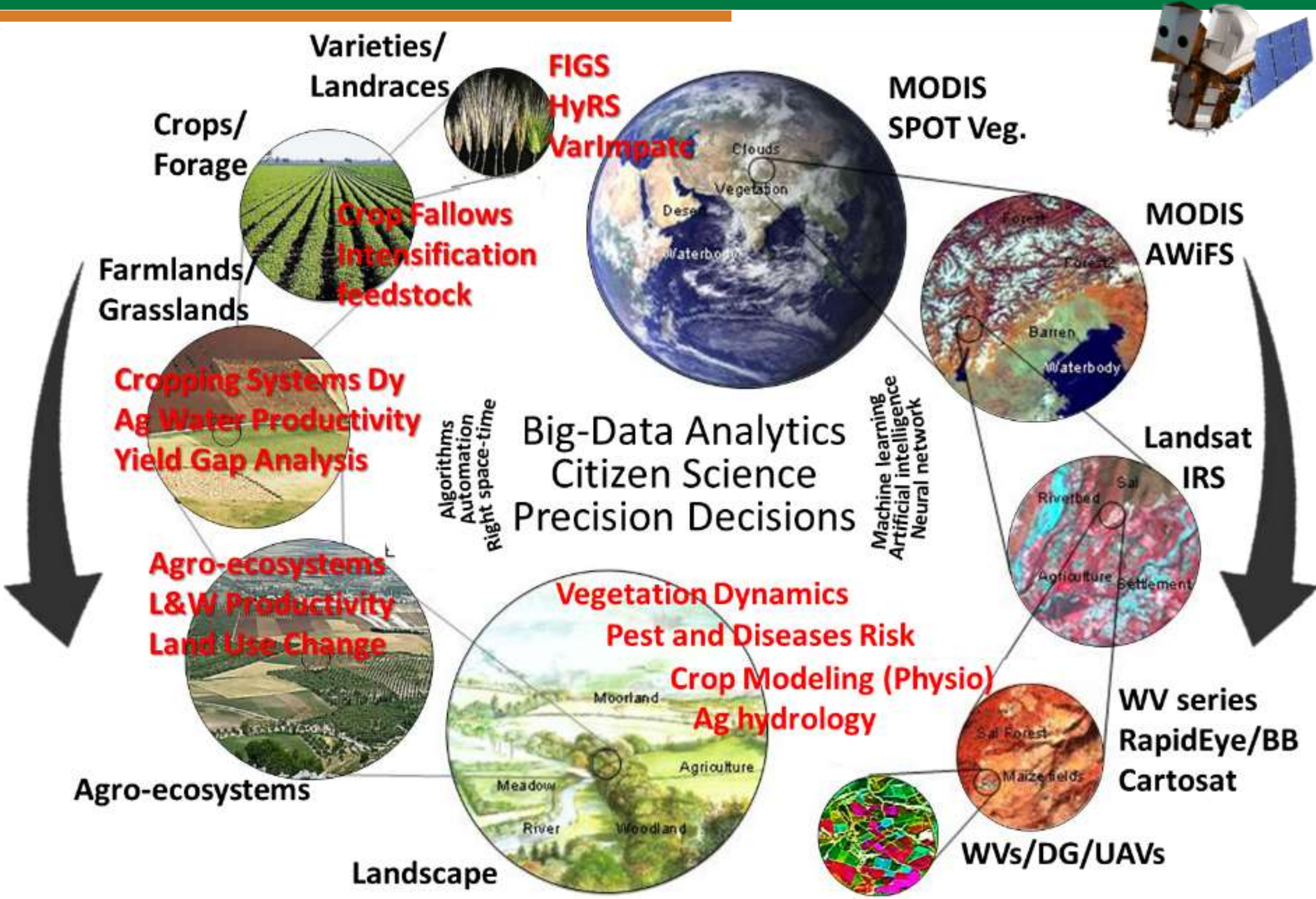
Example of One Sensor in each Platform/Scale

	Platforms	Ground/*in-situ*		Airborne		Spaceborne				
	Mode	**Hyperspectral**	**Multispectral**	**Optical**	**LiDAR**	**Optical**			LiDAR	**SAR**
RS data characteristics	**Sensor**	ASD FieldSpec	M× Camera	APs/UAVs	Lidar	WorldView-2	Landsat	MODIS	ICESat*	PALSAR
	Spectral	350-2500nm	4 bands	3-4 bands	1264nm	8 bands	7 bands	7/36 bands*	1264 & 532nm	L band
	Spatial resolution	0.1-1.5m	0.1-0.2m	1-m	20 - 80cm	0.46m Pan; 1.84m MS	15m Pan; 30m MS	250m, 500m, 1000m MS	70m	10m, 20m, 100m
	Swath	1-4m	2-10m	--	1-2km	16.4km	185km	2330km		35-250km
	Revisit	--	--	3-year	--	1.1 days	16 days	1 day	91 days	46 days
Biophysical	Plant biomass	×	×		×	×	×	×		×
	Plant height				×				×	×
	LAI, fPAR, LST	×	×			×	×	×		
	NDVI, EVI, LSWI	×	×	×		×	×	×		
Biochemical	Erosion, Salinity	×	×	×	×	×	×	×		
	Soil moisture	×	×	×		×	×			×
	Chlolophyll	×	×	×		×	×	×		
	Nitrogen	×	×	×		×	×			
	Phosphorous	×	×			×				
	Plant water	×	×			×		×		
Produc tion	GPP	×	×	×		×		×		
	NPP	×				×	×	×		
LULC	land cover/use	×	×	×		×	×	×		×
	phenology	×	×				×	×		×
	Irrigation	×	×	×		×	×	×		×
Terrain	DEM		×	×	×	×			×	×
	Derivatives		×	×	×				×	×
Scale	Tier 1 AOIs	×	×	×	×	×	×	×	×	×
	Tier 2 action sites	×	×	×			×	×	×	×
	Tier 3 AEZs	×	×	×				×	×	×
	Tier 4 Target			×				×		×



Across the scales

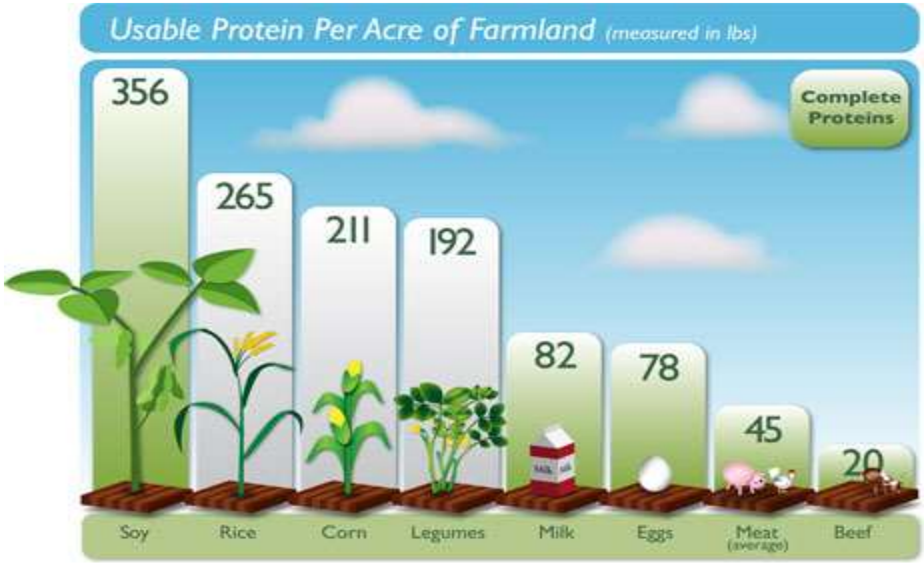
Scaling Trade-on/offs
Farmscapes to Landscapes



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



http://www.soyfoods.org/

USDA; FAO/WHO/UNICEF Protein Advisory Group (2004)

Reduce Loss and Produce More

Water-Efficient-Ecological Food Production

Daal/Falafel (1kg)
1,250 liters

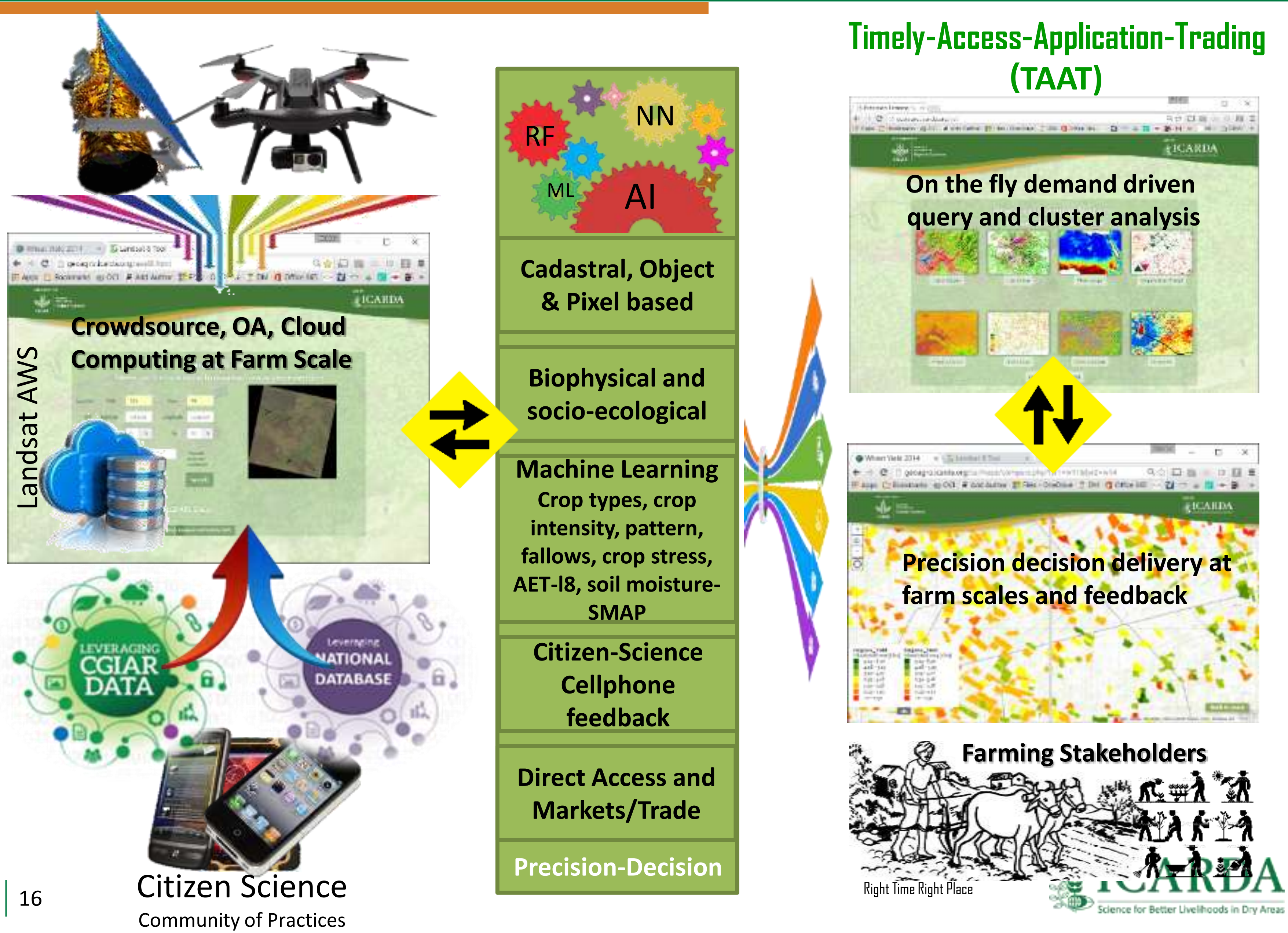
Chicken (1kg)
4,325 liters

Mutton (1kg)
5,520 liters

Beef (1kg)
13,000 liters

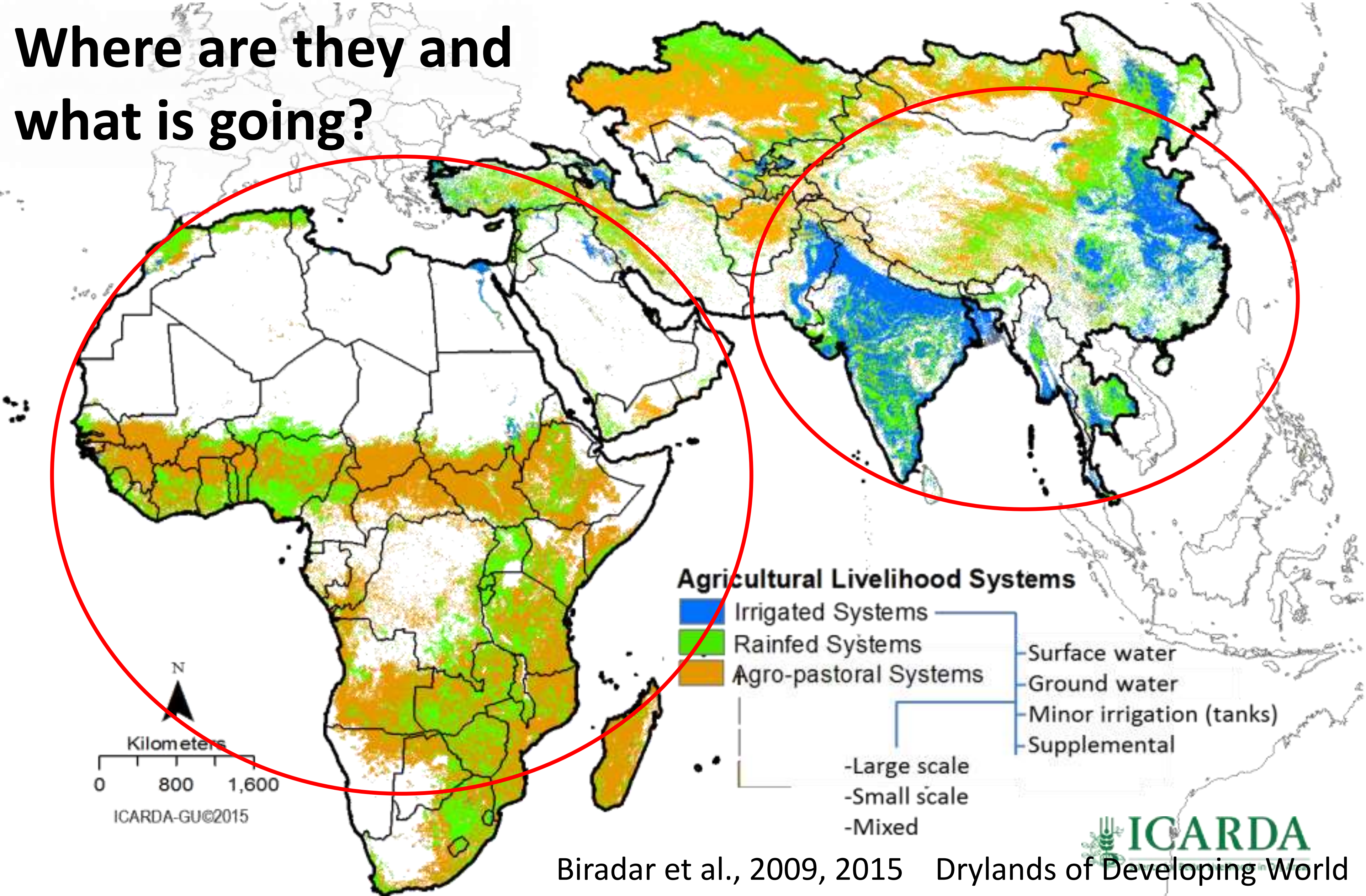
Digital Agriculture Platform

Image Based, Open Source Precision Decision at Farm scales



Existing Agricultural Production Systems

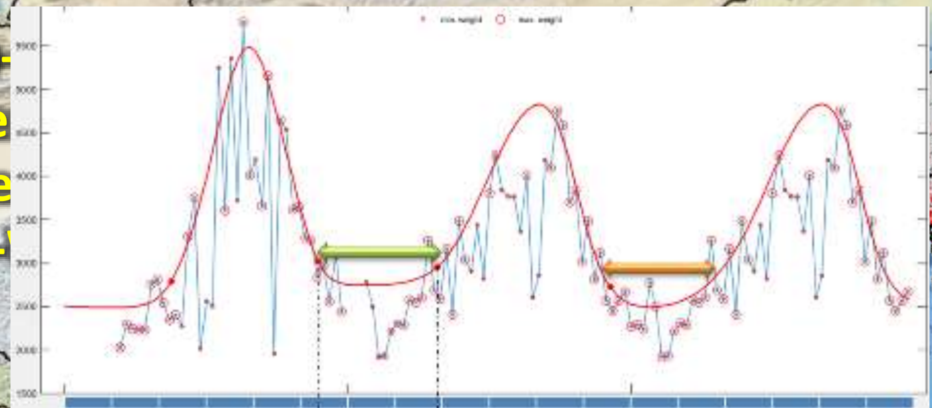
Where are they and what is going?



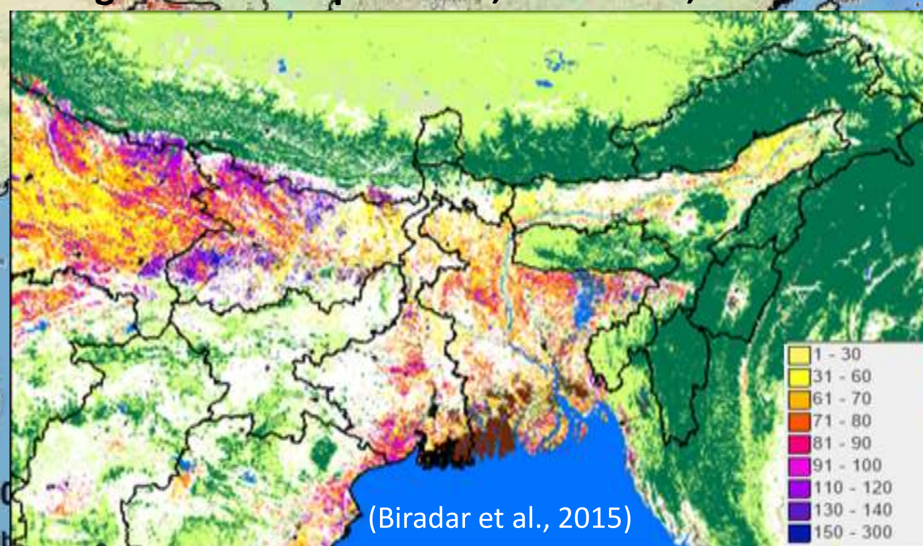
Biradar et al., 2009, 2015 Drylands of Developing World

Dynamics of Cropping Intensity and Pattern

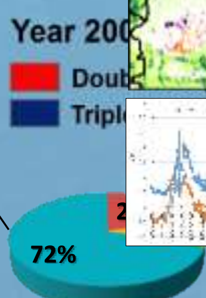
- Integrated Agro-
- Sustainable Inte
- Input Use Efficie
- Thematic Land-



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

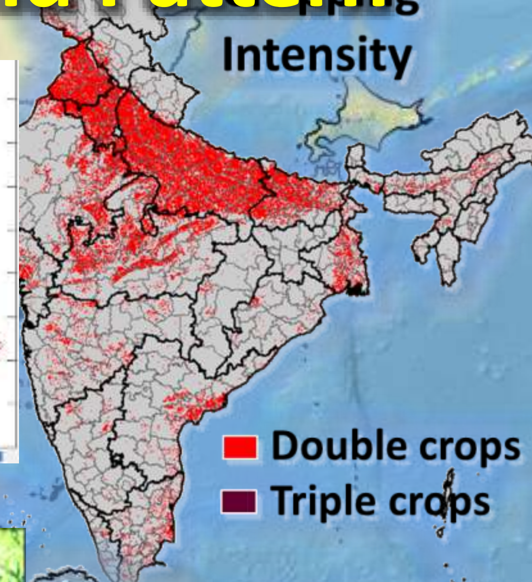


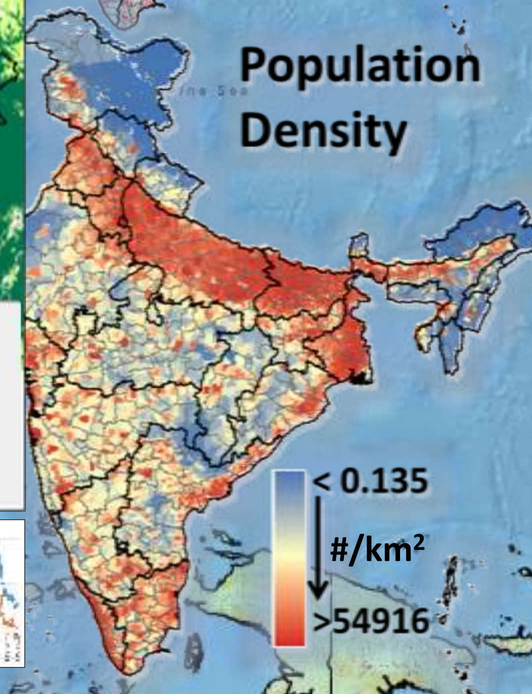
How can we track and link?



Agricultural Intensification

Increase in Arable Land



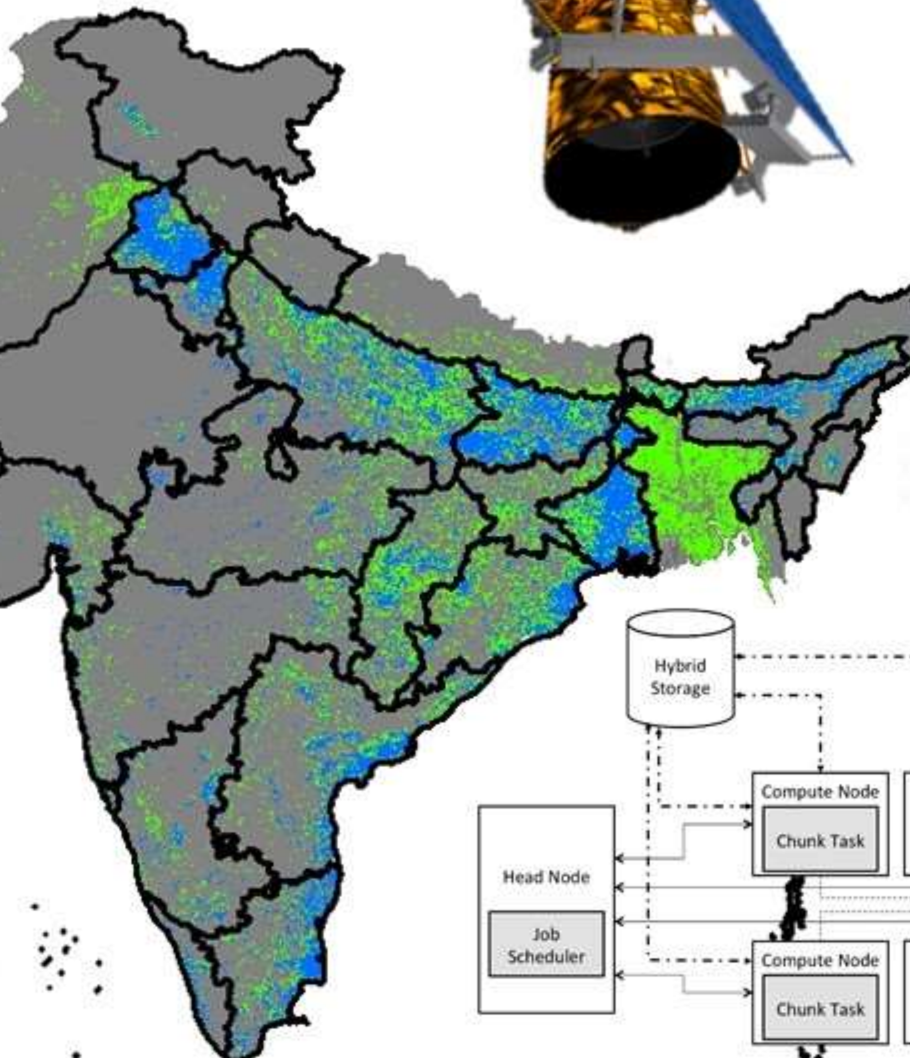


Biradar and Xiao, 2009

Quantification of its dynamics

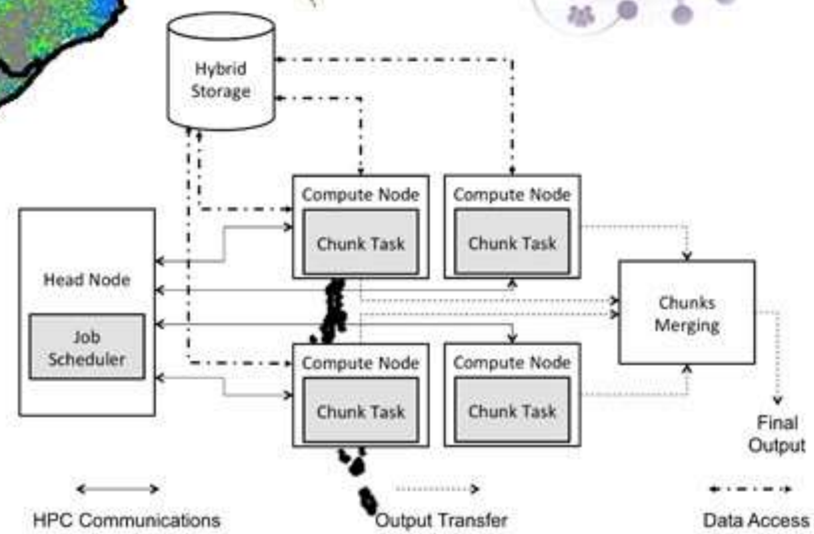
Under changing Climate and Demography

Remote Sensing
- MODIS
- LANDSAT
- SENTINEL
- MICROS



GeoStats
AgCensus
Climate, Soils
Demography

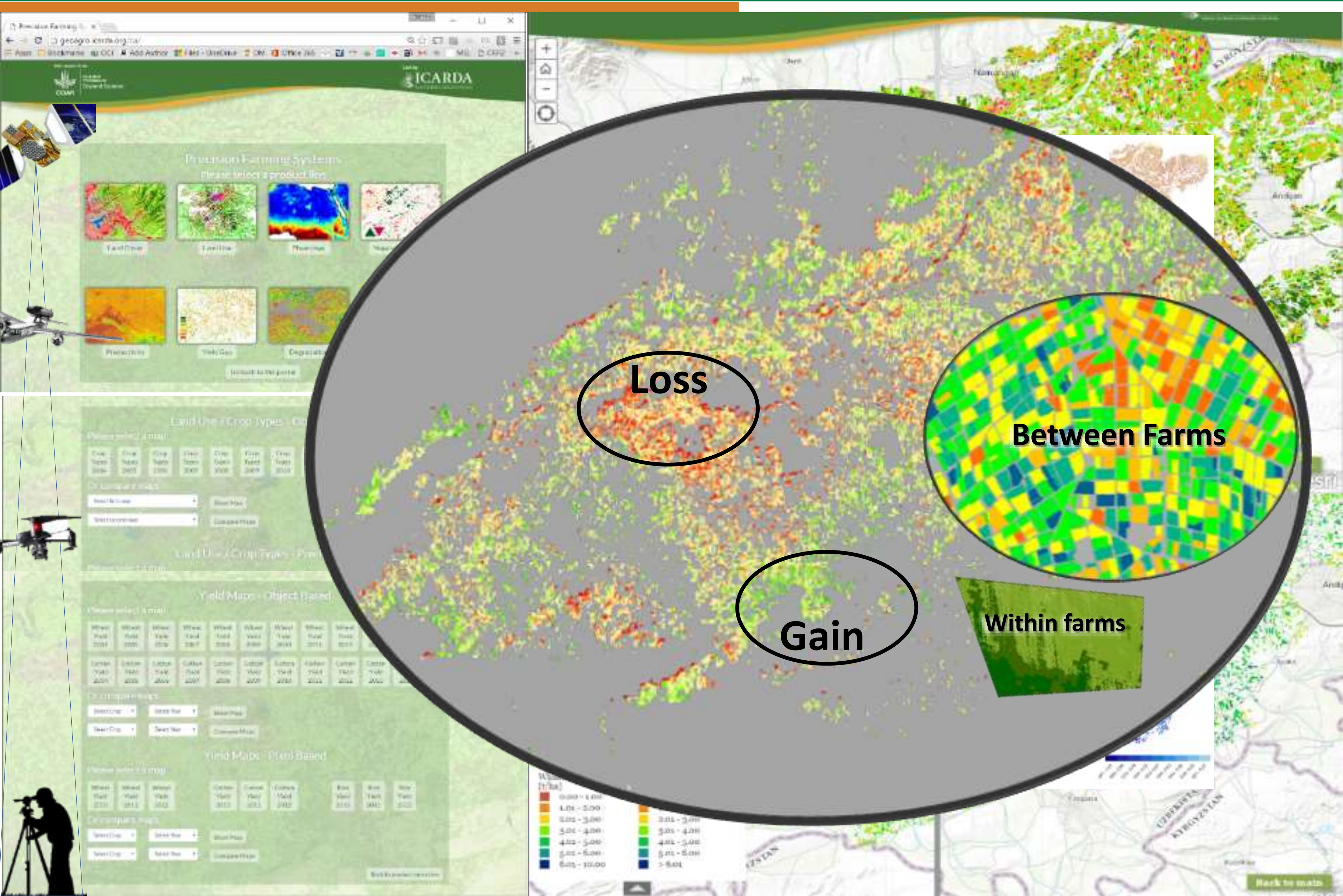
Open Source
Cloud Computing
Algorithms



Biradar, 2016*

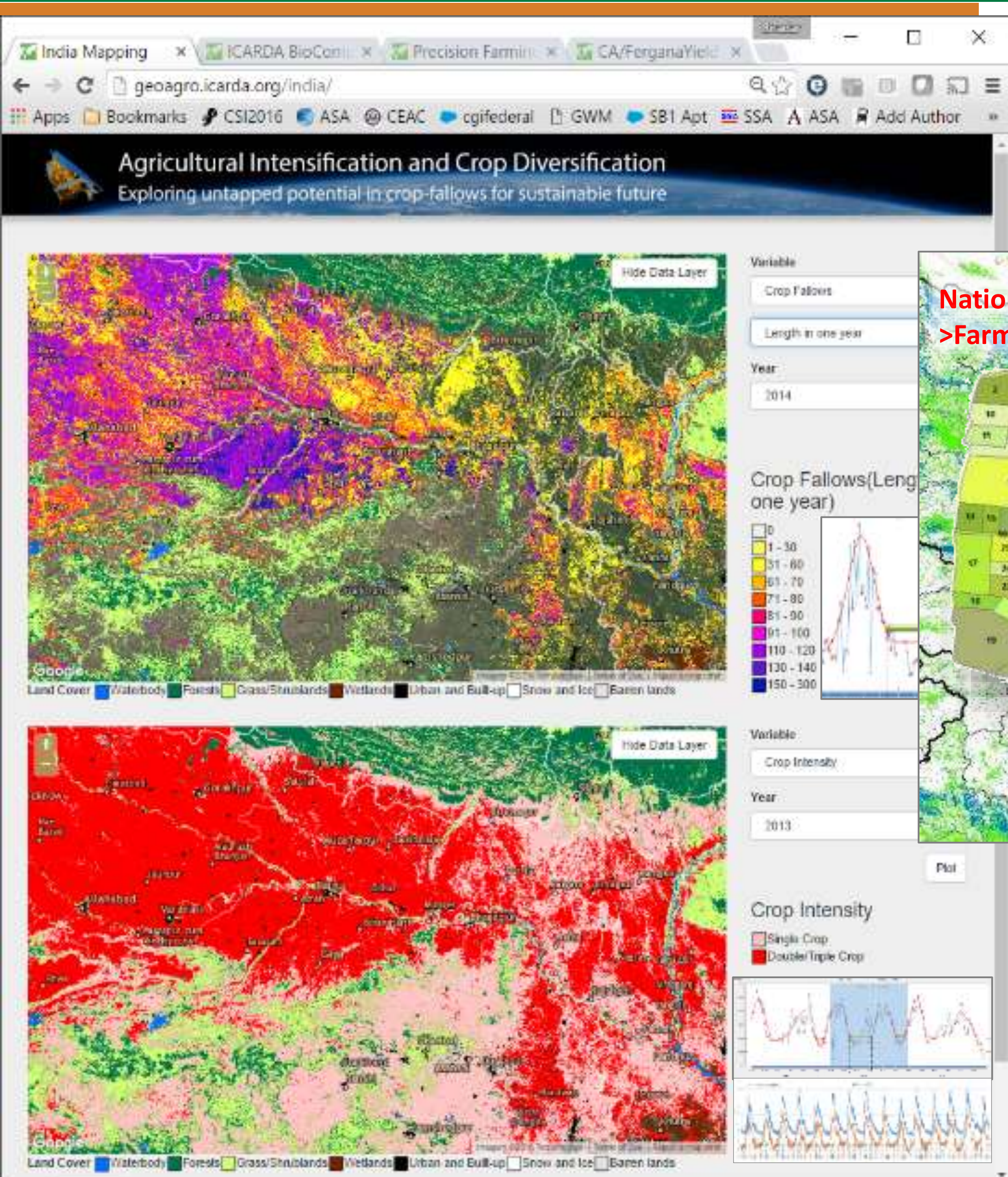
EOS in Precision Decisions

Automated workflow for operational mapping, monitoring and rural advisory



Ag Intensification & Diversification

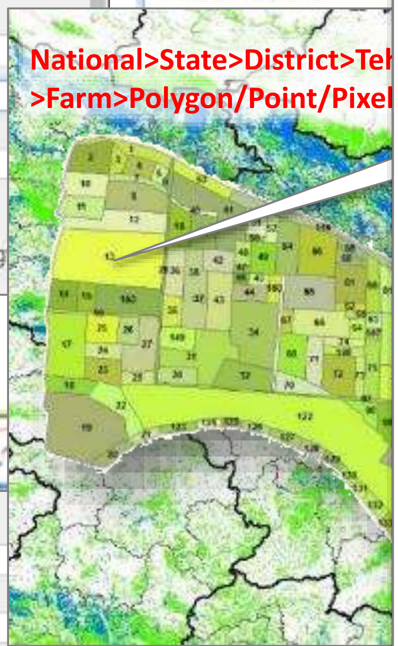
Bet... ws
for ...



Near real-ti...
pixel to lanc...

Variable

Crop Fallows



Lentil in Rice-b...

Irrigated

Rice – EE Lentil ...

Rice – Relay E Lent...

[**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)

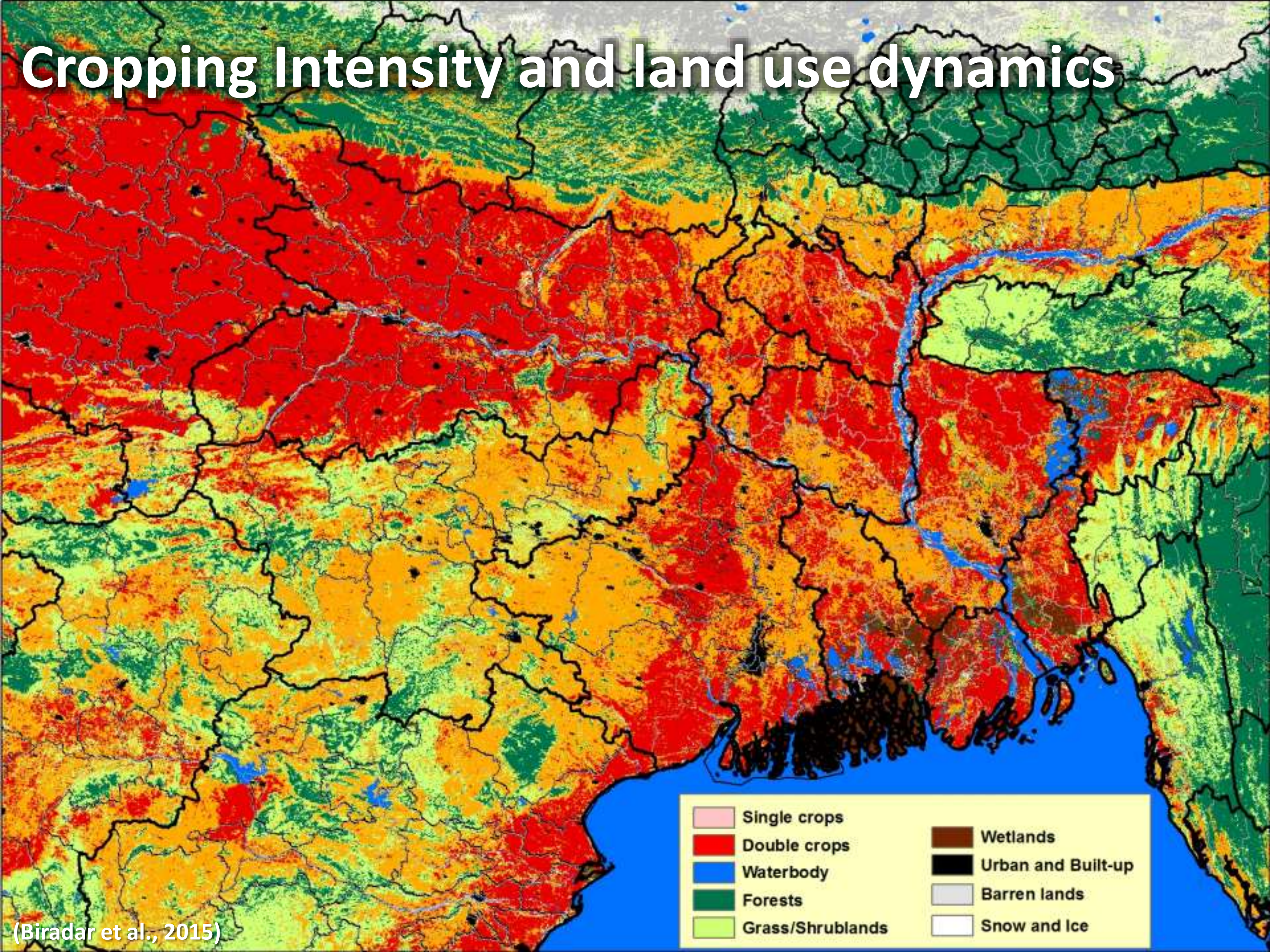
Water use
Evapotranspiration
Allocation/Irri. Sch.

Markets
-ePlatform
-Ag Supply Chain
-Access (I/O)

Monitoring
-Pest/Diseases
-Crop Stress

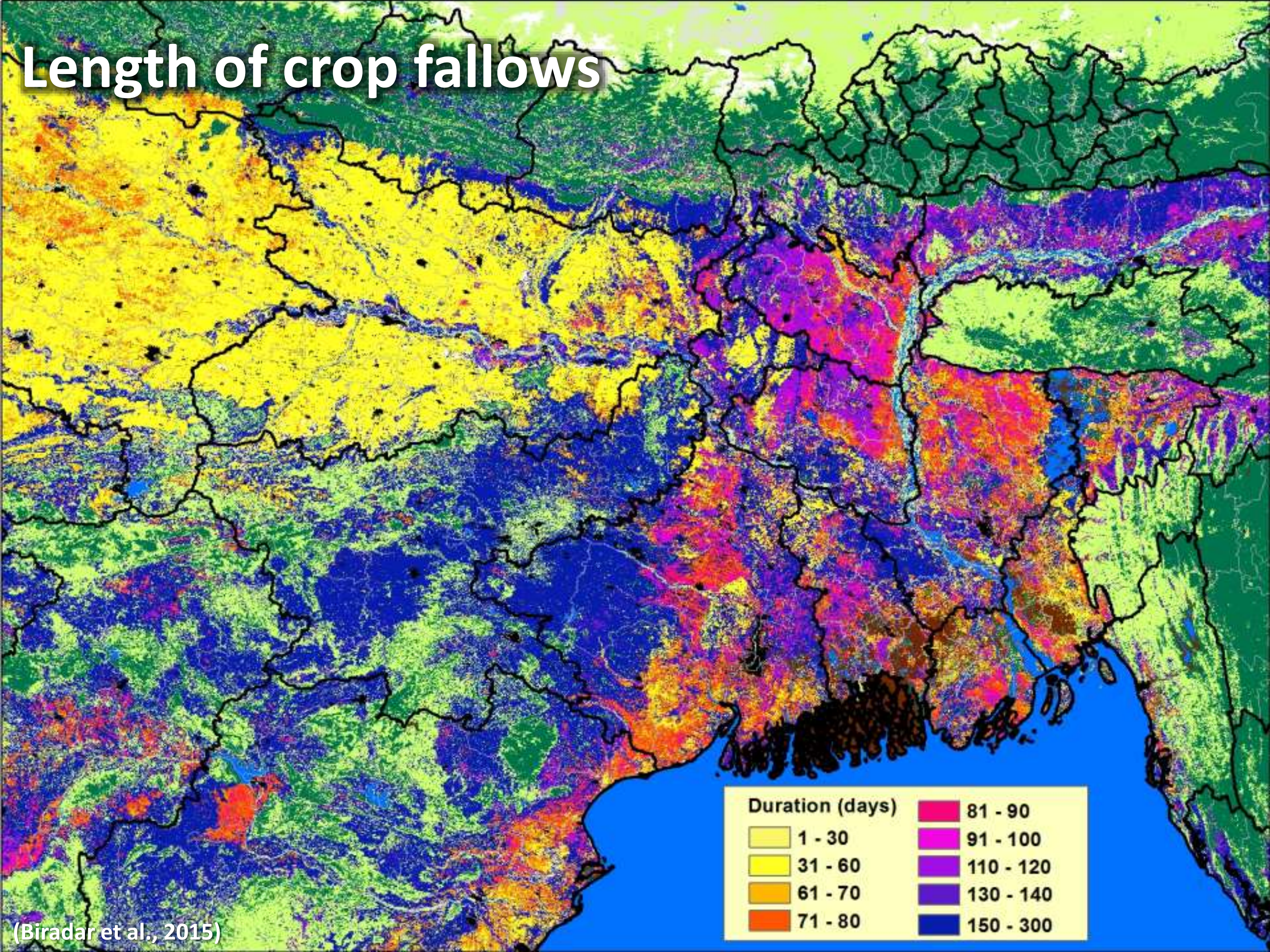
Citizen Science

Cropping Intensity and land use dynamics



(Biradar et al., 2015)

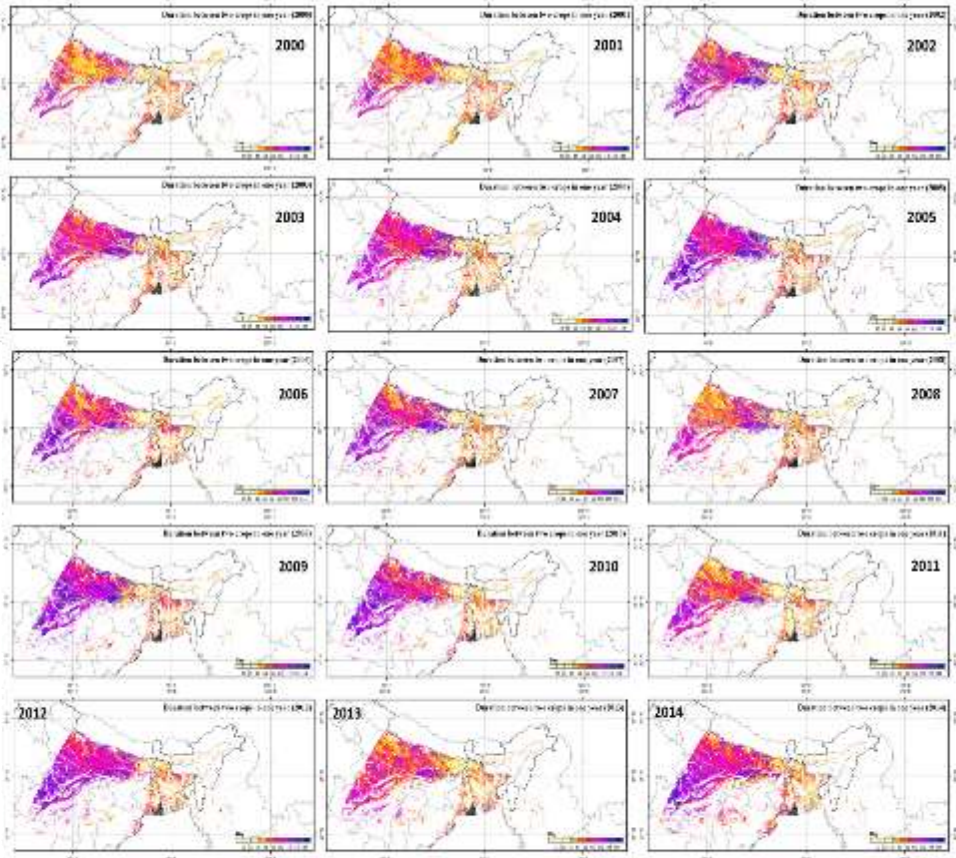
Length of crop fallows



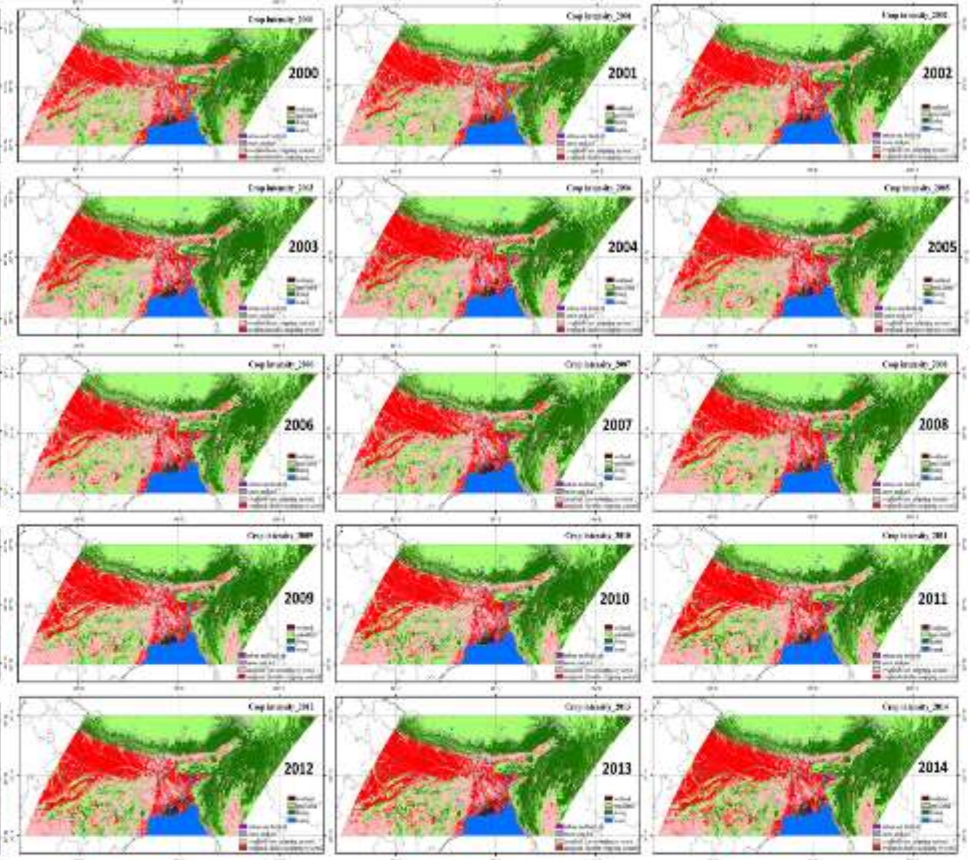
(Biradar et al., 2015)

Inter and Intra Annual Dynamics over Decades

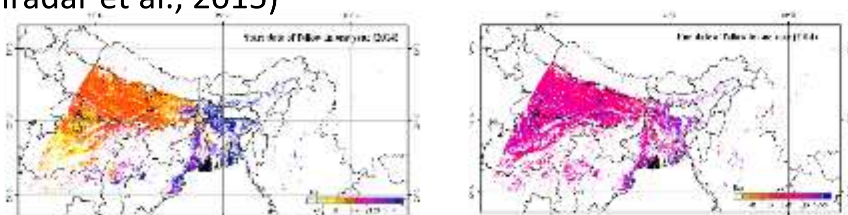
Length of Crop Fallows (LCP): 2000-2015



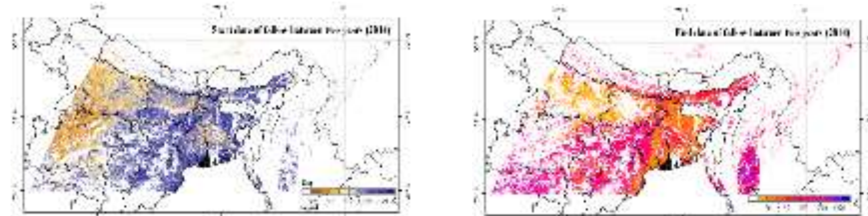
Cropping Intensity and land cover: 2000-2014



(Biradar et al., 2015)



Start and End Dates of Inter-annual Fallows



Start and End Dates of Intra-annual Fallows

CGIAR

Crop-fallows for intensification

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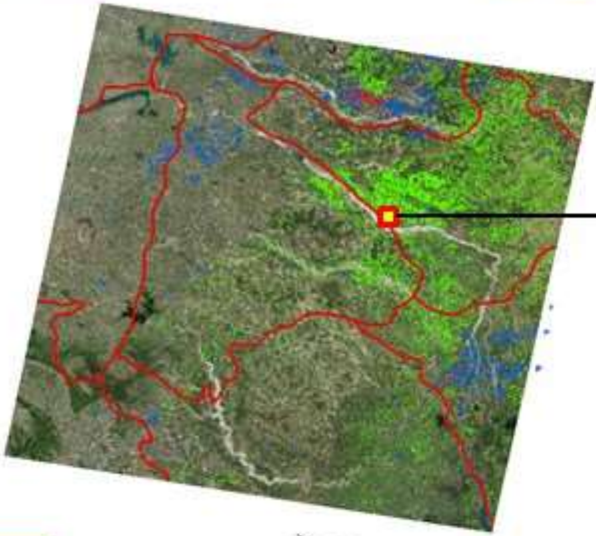
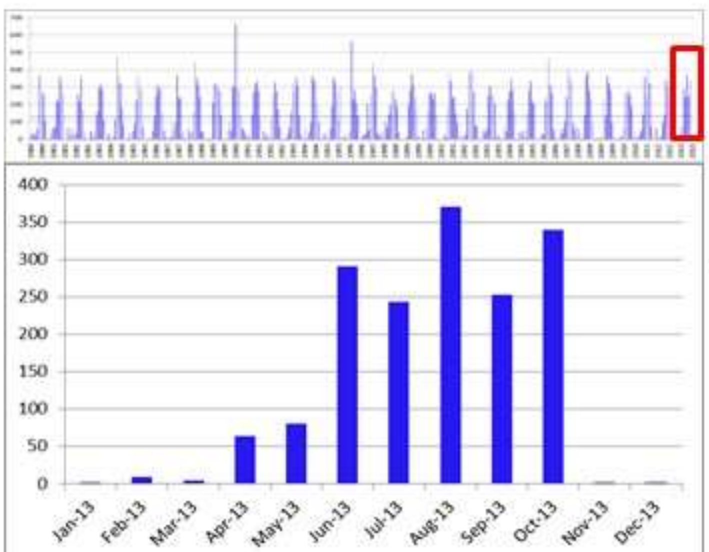
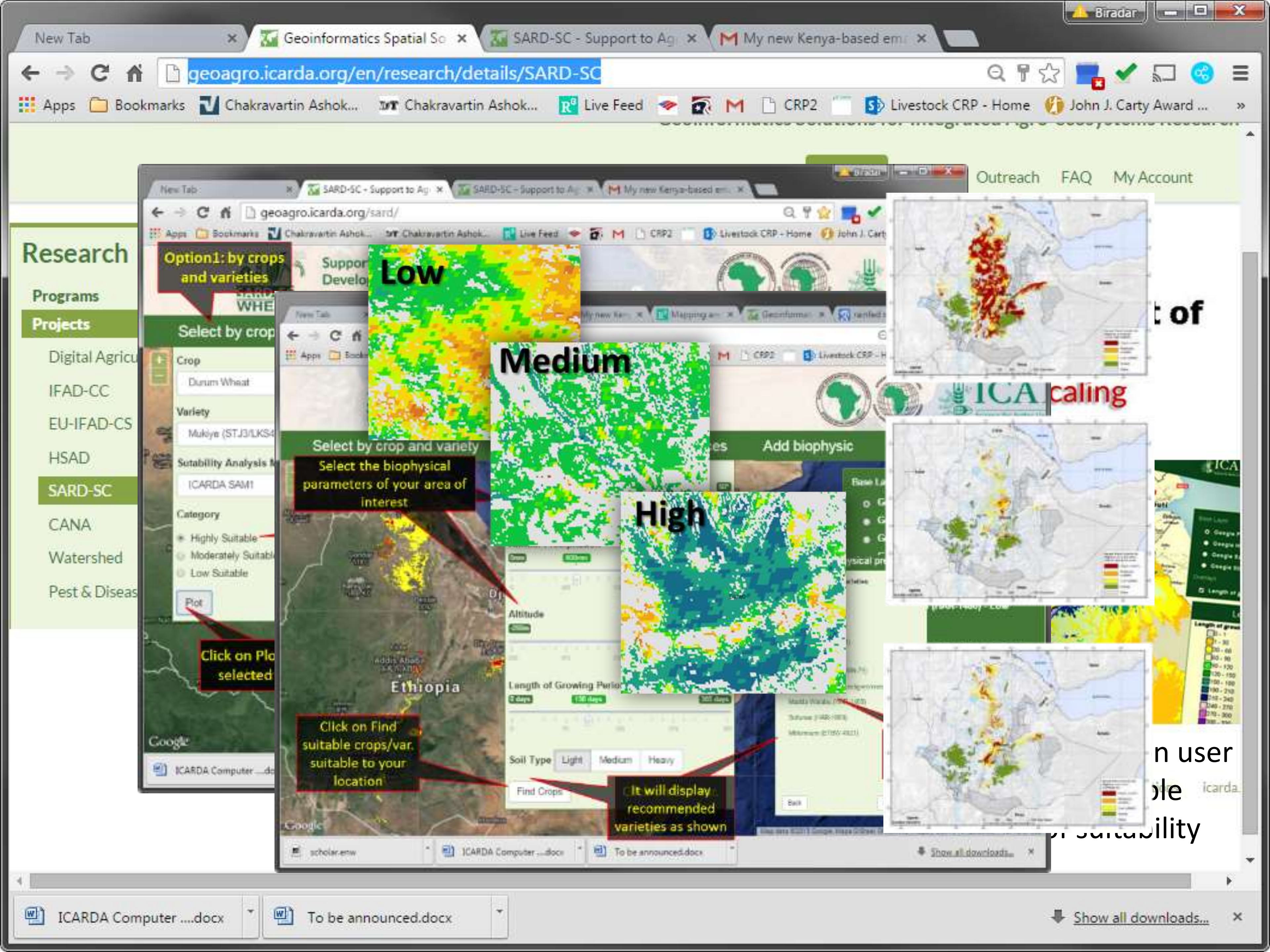
On-farm water management



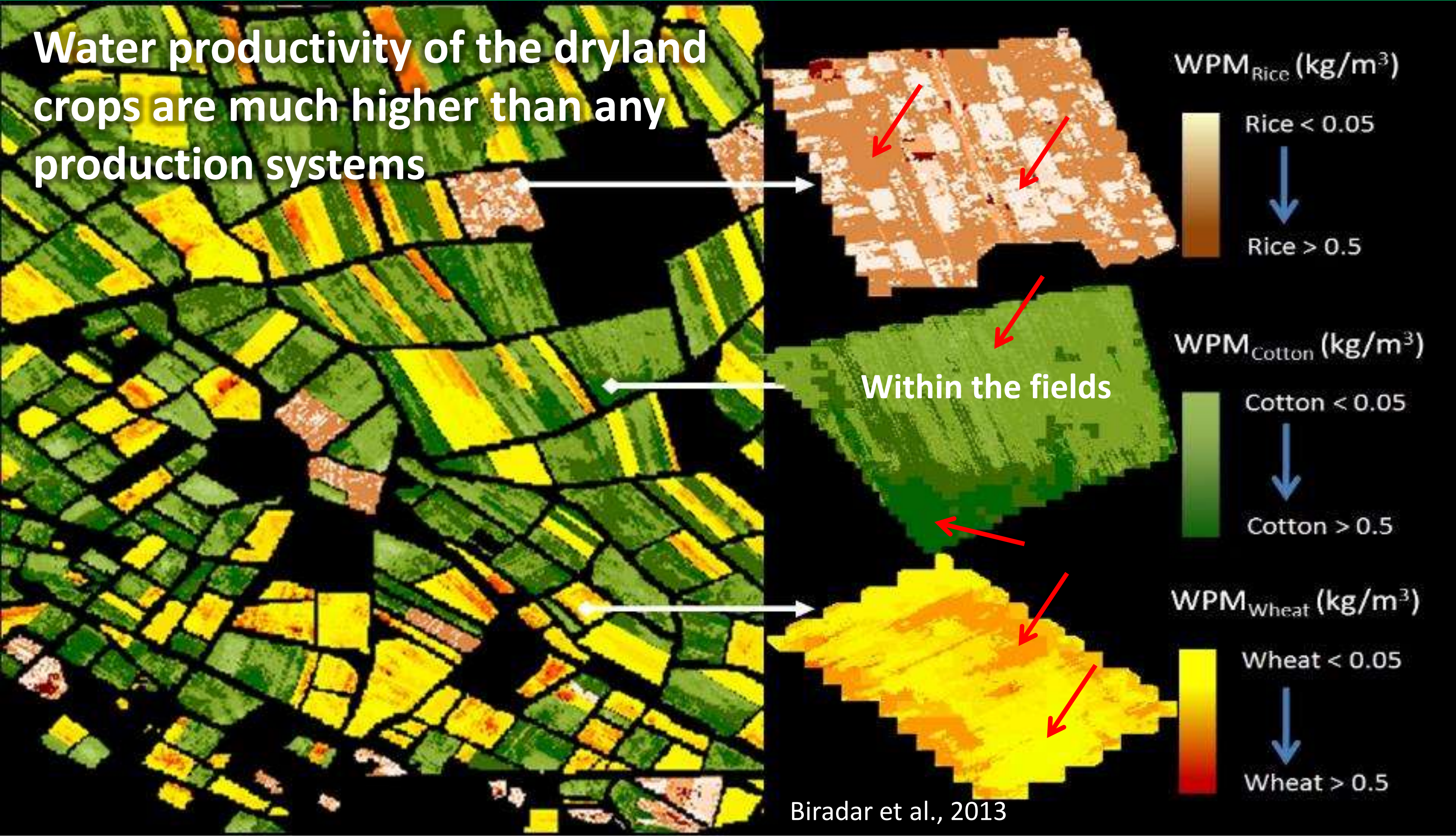
Fallow from July to January (7 months)




geoagro.icarda.org/en/research/details/SARD-SC
Research
Programs
Projects
Digital Agricu
IFAD-CC
EU-IFAD-CS
HSAD
SARD-SC
CANA
Watershed
Pest & Diseas
Outreach
FAQ
My Account
Option1: by crops and varieties
Select by crop
Low
Medium
High
Select by crop and variety
Select the biophysical parameters of your area of interest
Add biophysic
Click on Find suitable crops/var. suitable to your location
It will display recommended varieties as shown
Ethiopia
ICARDA Computer ....docx
To be announced.docx
Show all downloads...

Where are those Yield Gaps?

Inter and Intra Field Variability



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.

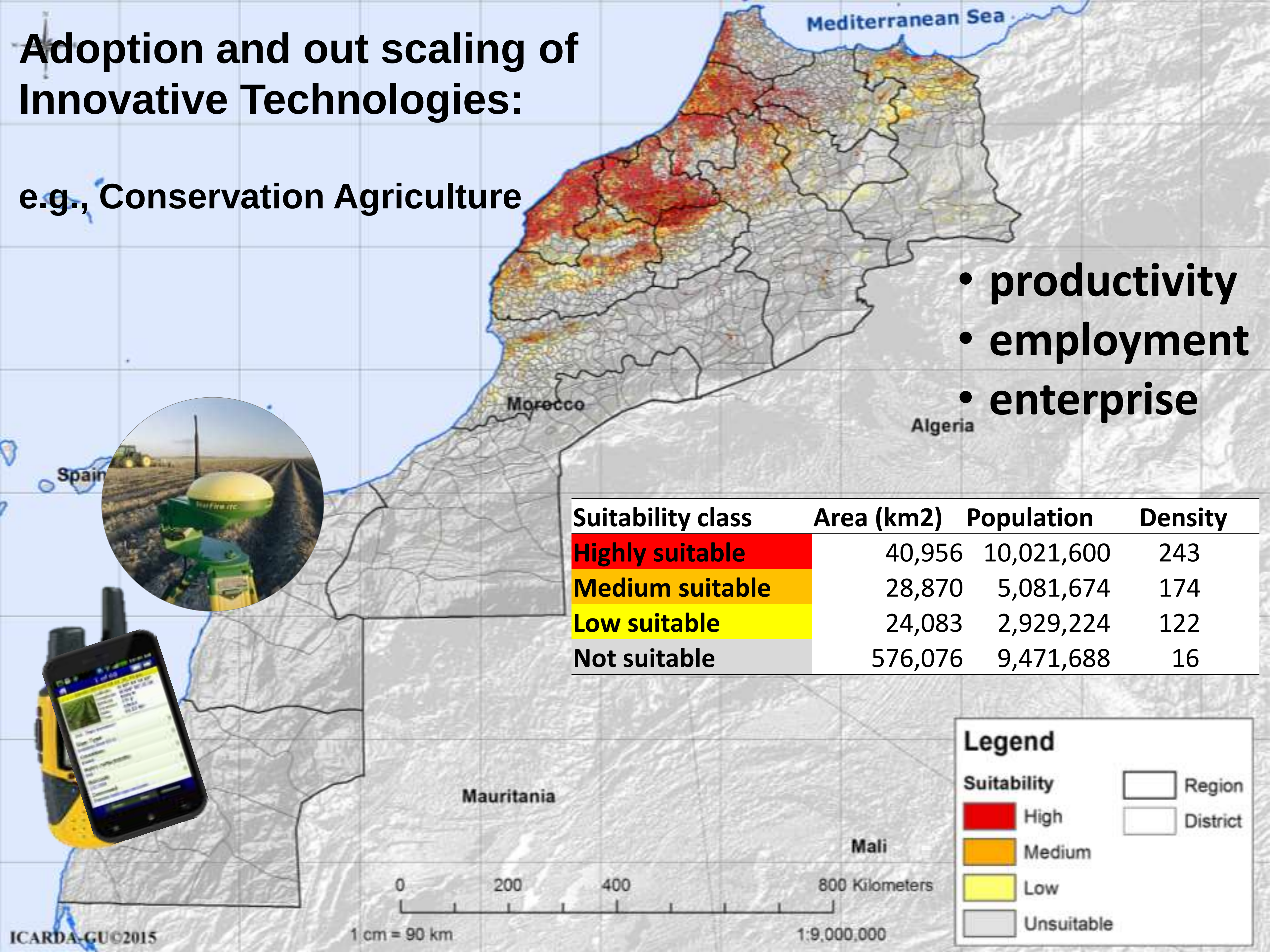
WP of Cotton	0.42 kg/m^3	0.50 USD/m^3
WP of Wheat	0.60 kg/m^3	0.33 USD/m^3
WP of Rice paddy	0.50 kg/m^3	0.10 USD/m^3

Adoption and out scaling of Innovative Technologies:

e.g., Conservation Agriculture

- **productivity**
- **employment**
- **enterprise**

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



Measuring Impact of Successful interventions

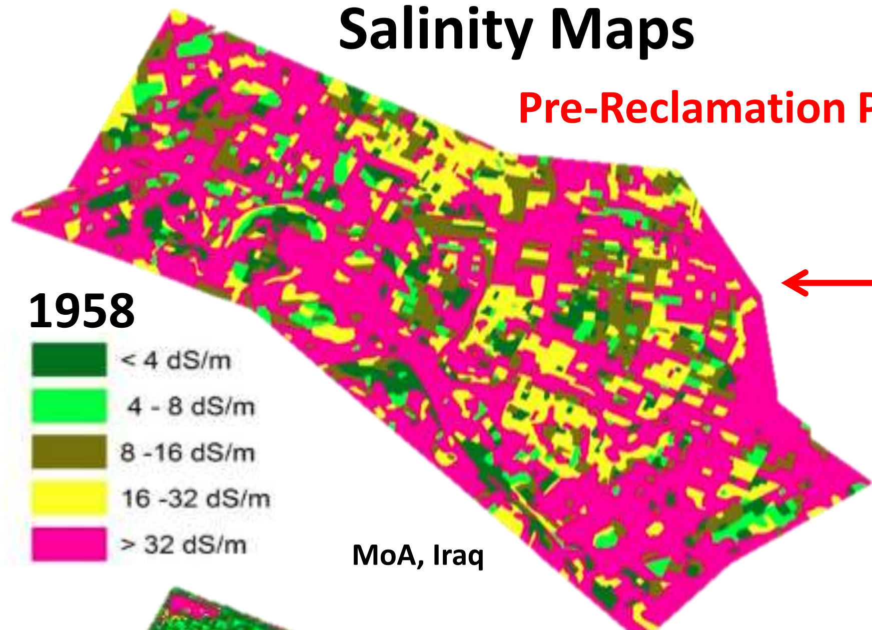
Soil Salinity, Dujaila, Iraq

Salinity Maps

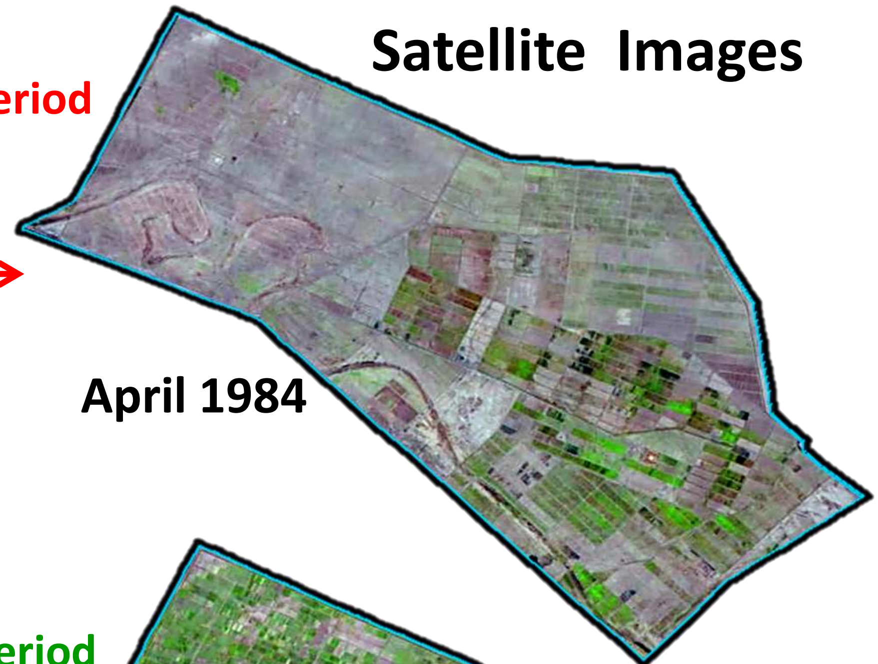
Satellite Images

Pre-Reclamation Period

1958

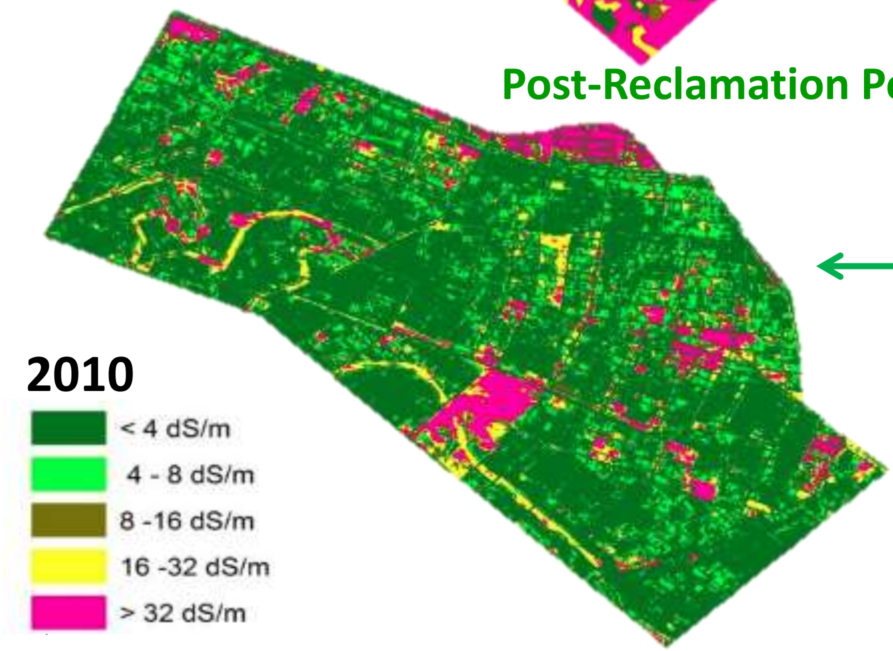


April 1984

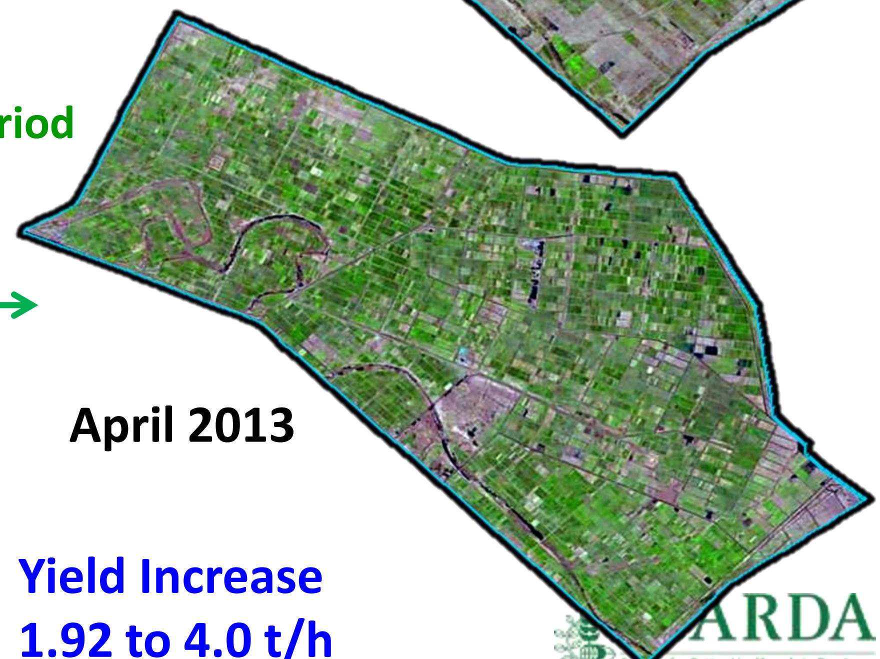


Post-Reclamation Period

2010



April 2013

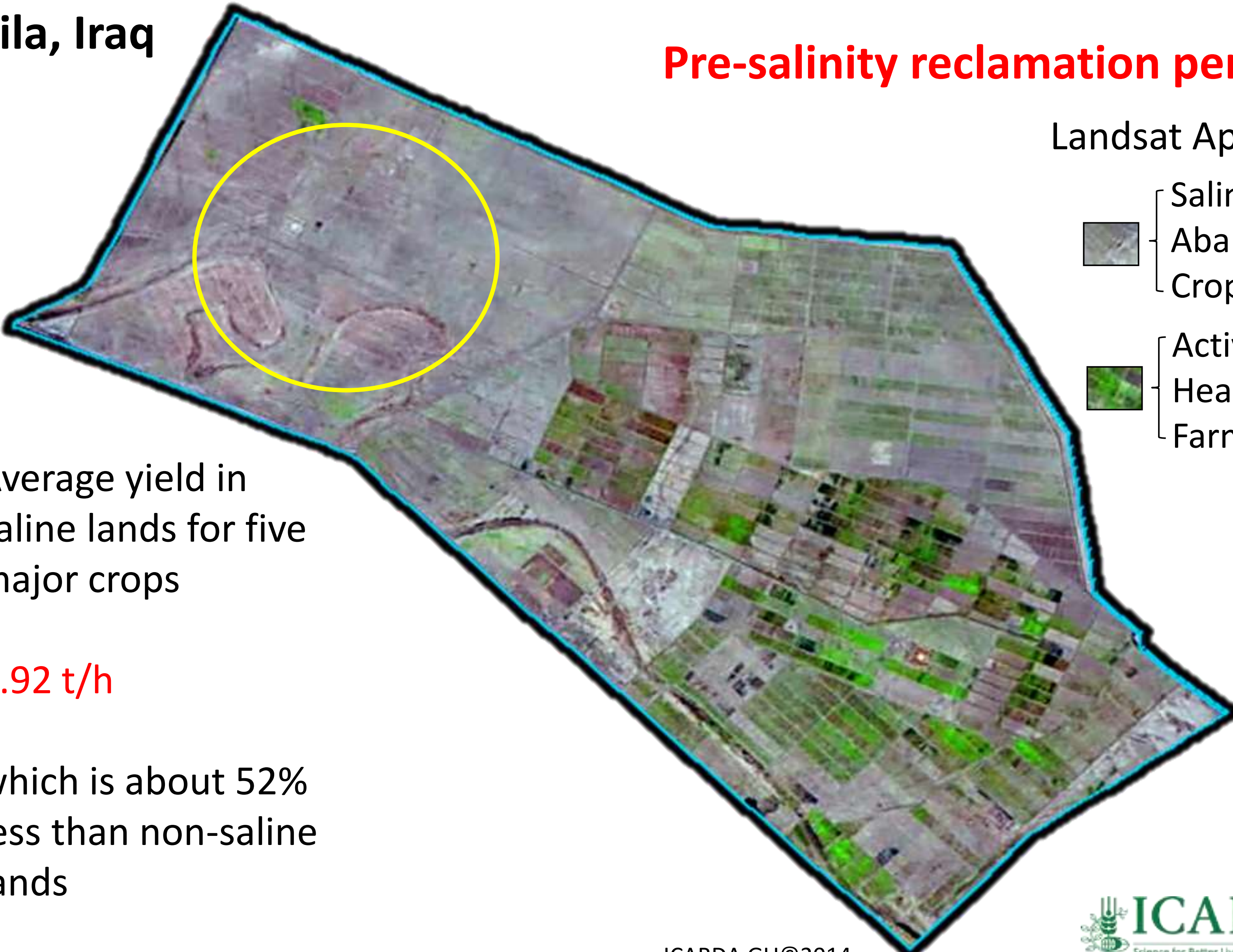


Yield Increase
1.92 to 4.0 t/h

Measuring Impact of Successful interventions

Soil Salinity, Dujaila, Iraq

Dujaila, Iraq



Pre-salinity reclamation period

Landsat April 1984

- Saline or Abandoned Croplands
- Active or Healthy Farmlands

Average yield in saline lands for five major crops

1.92 t/h

which is about 52% less than non-saline lands

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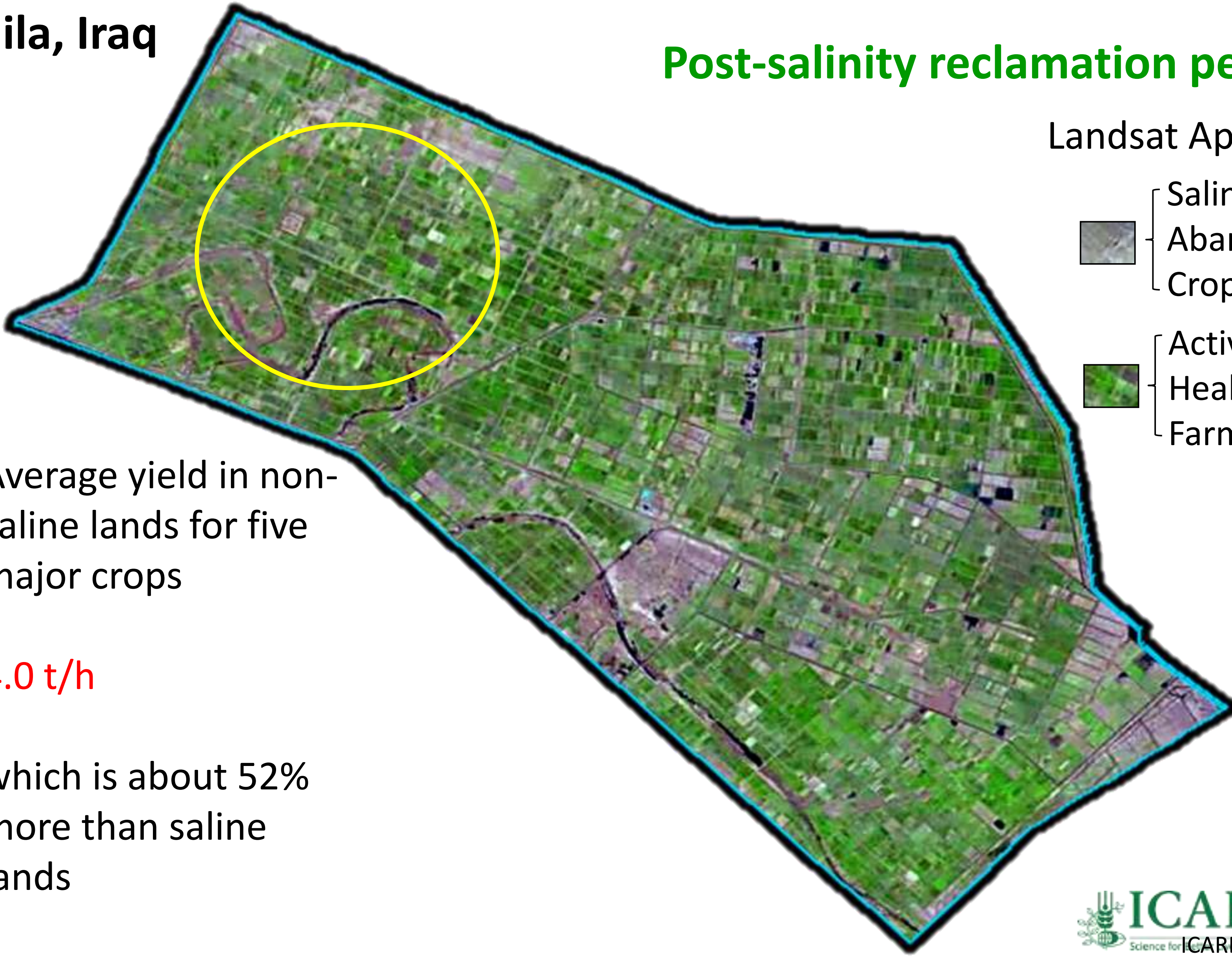
Measuring Impact of Successful interventions

Soil Salinity, Dujaila, Iraq

Dujaila, Iraq

Post-salinity reclamation period



Landsat April 2013

- Saline or Abandoned Croplands
- Active or Healthy Farmlands

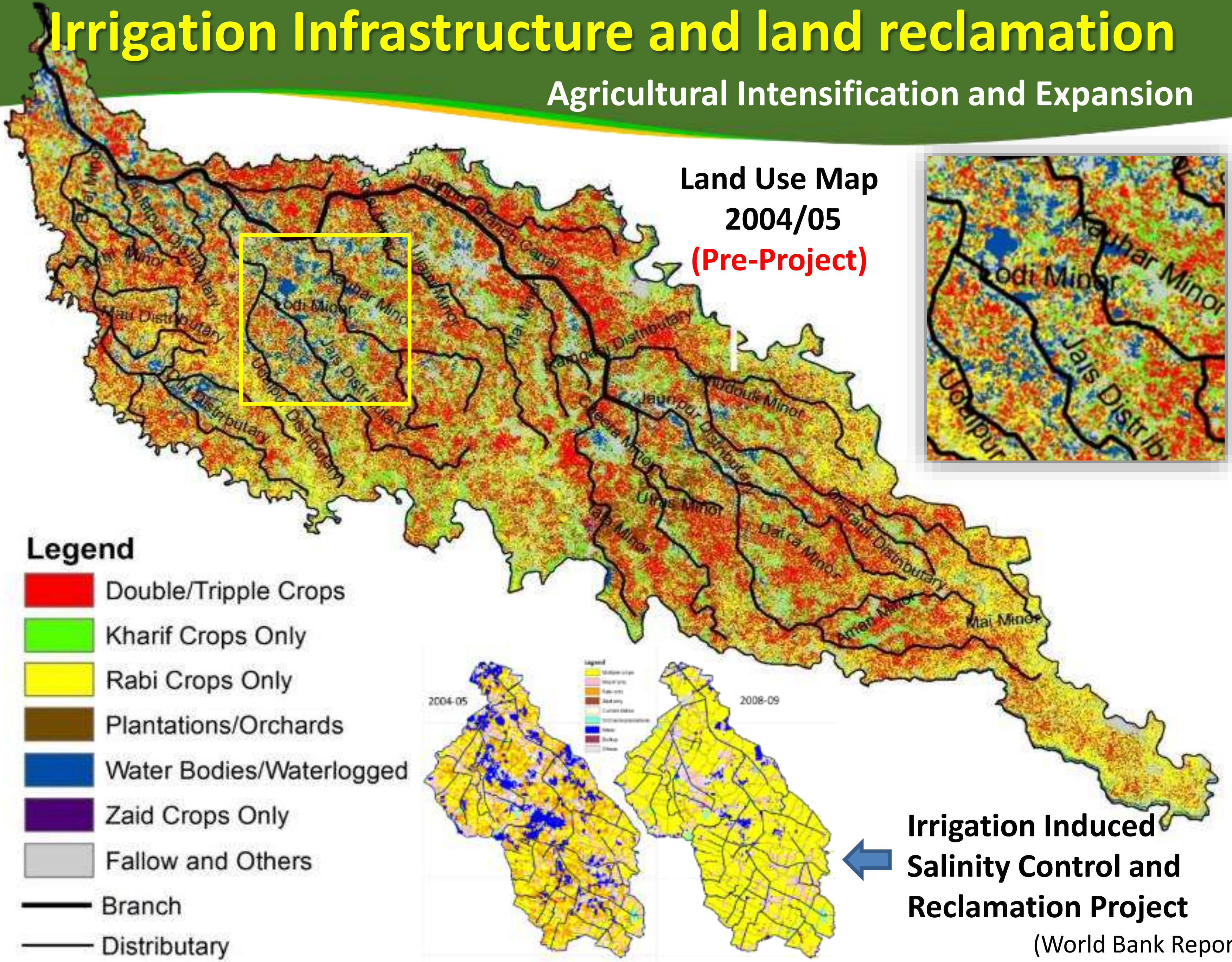
Average yield in non-saline lands for five major crops

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)

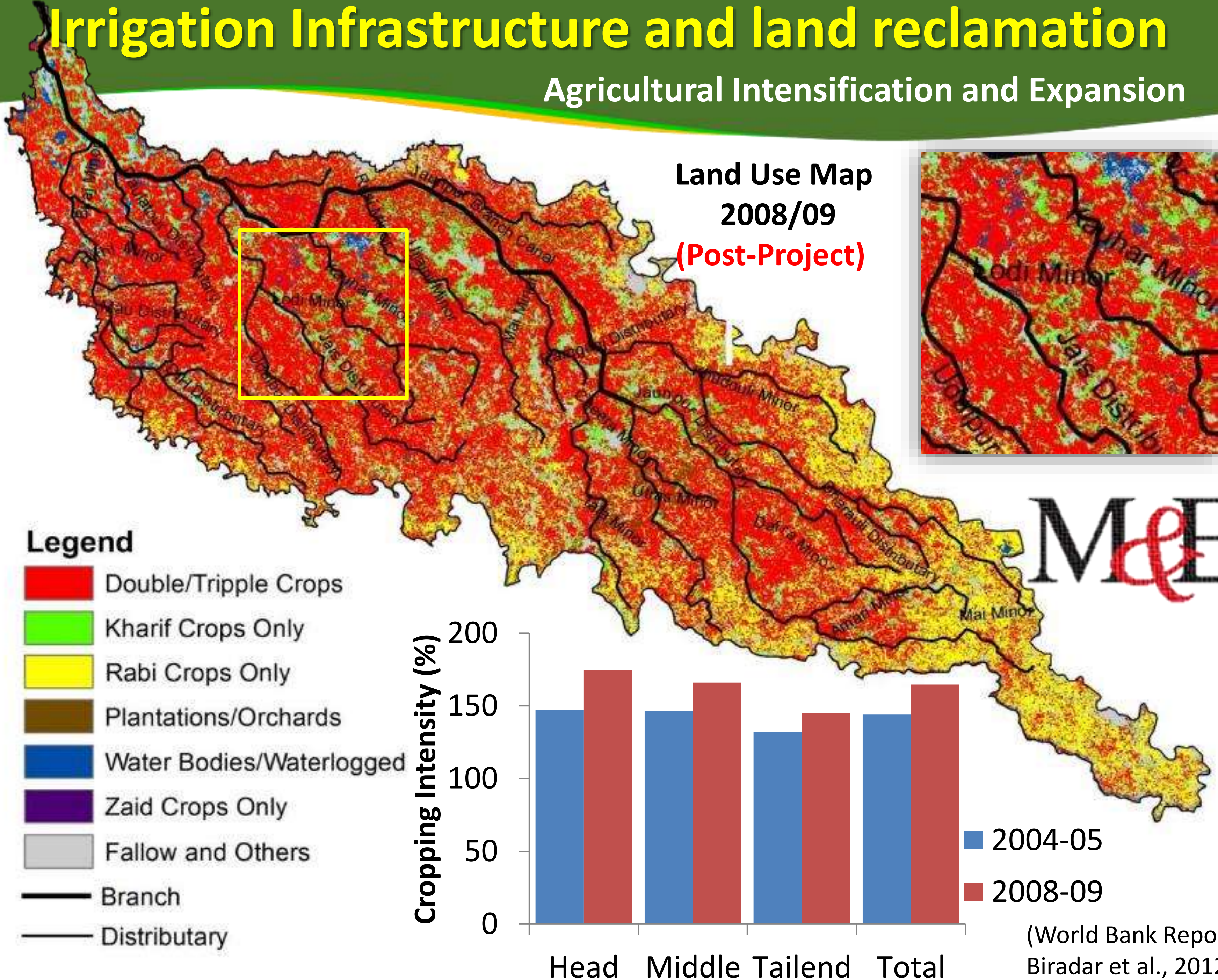
Irrigation Induced Salinity Control and Reclamation Project

(World Bank Report, Biradar et al., 2012)

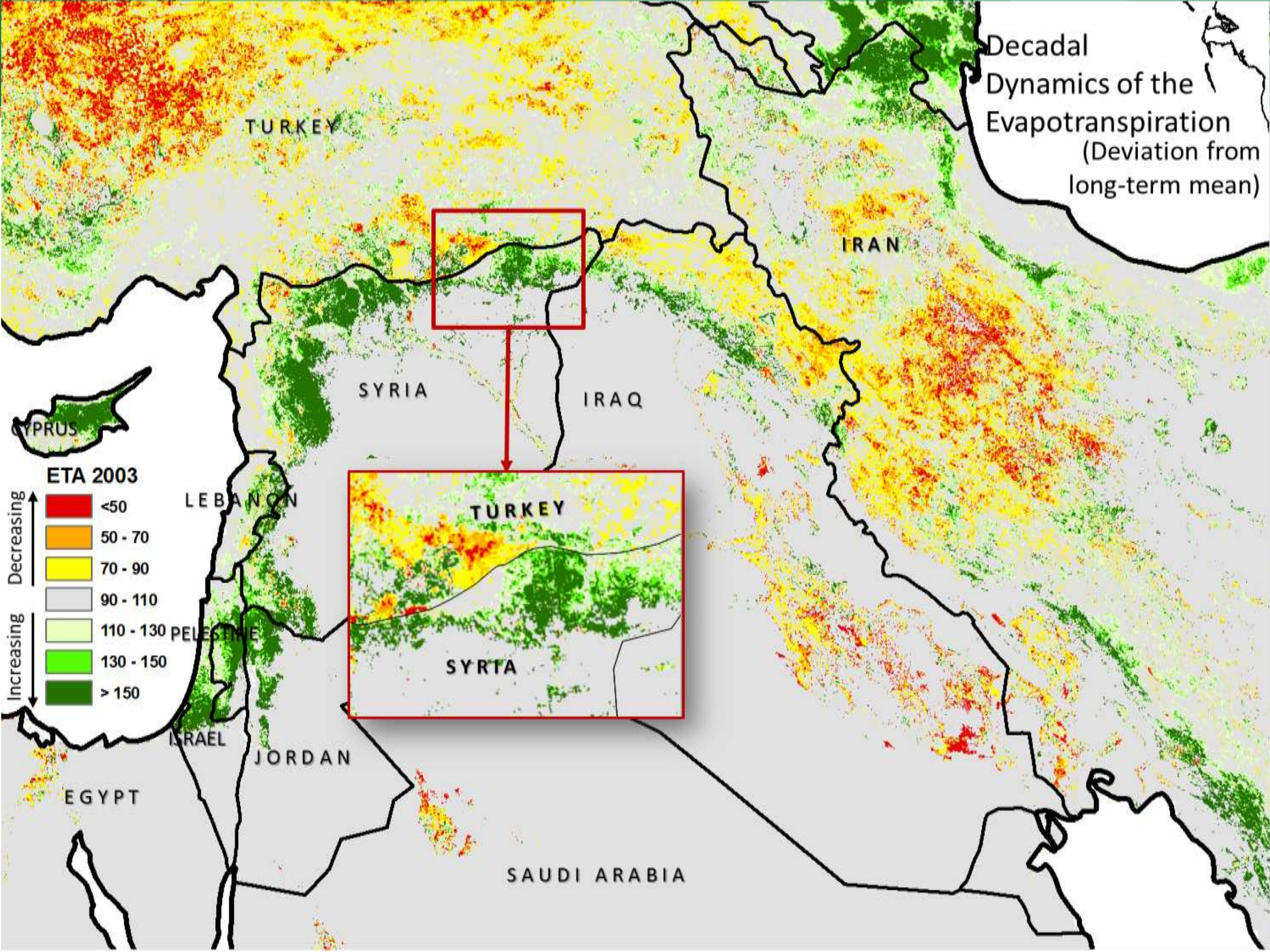
Irrigation Infrastructure and land reclamation

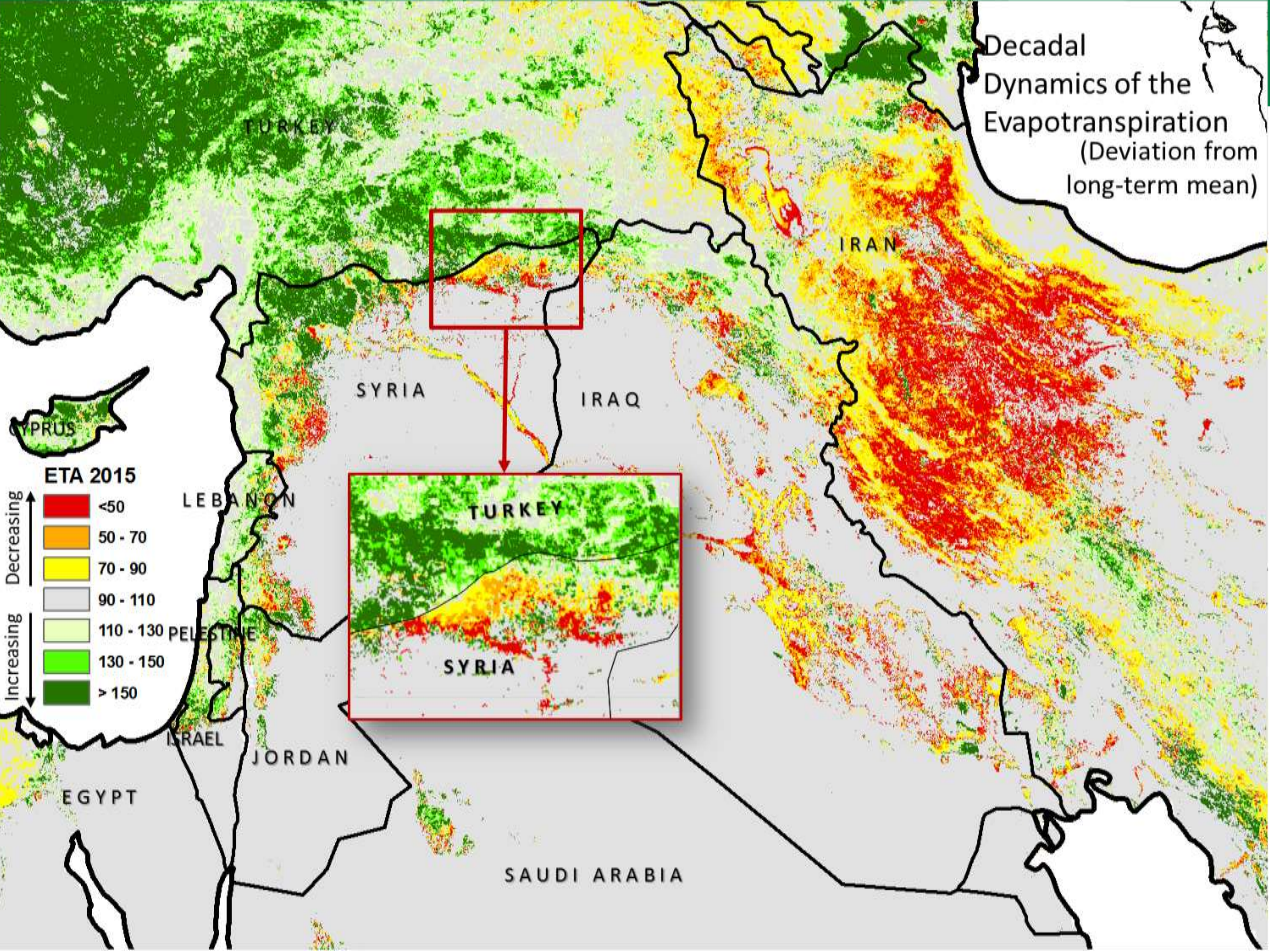
Agricultural Intensification and Expansion

Land Use Map 2008/09
(Post-Project)



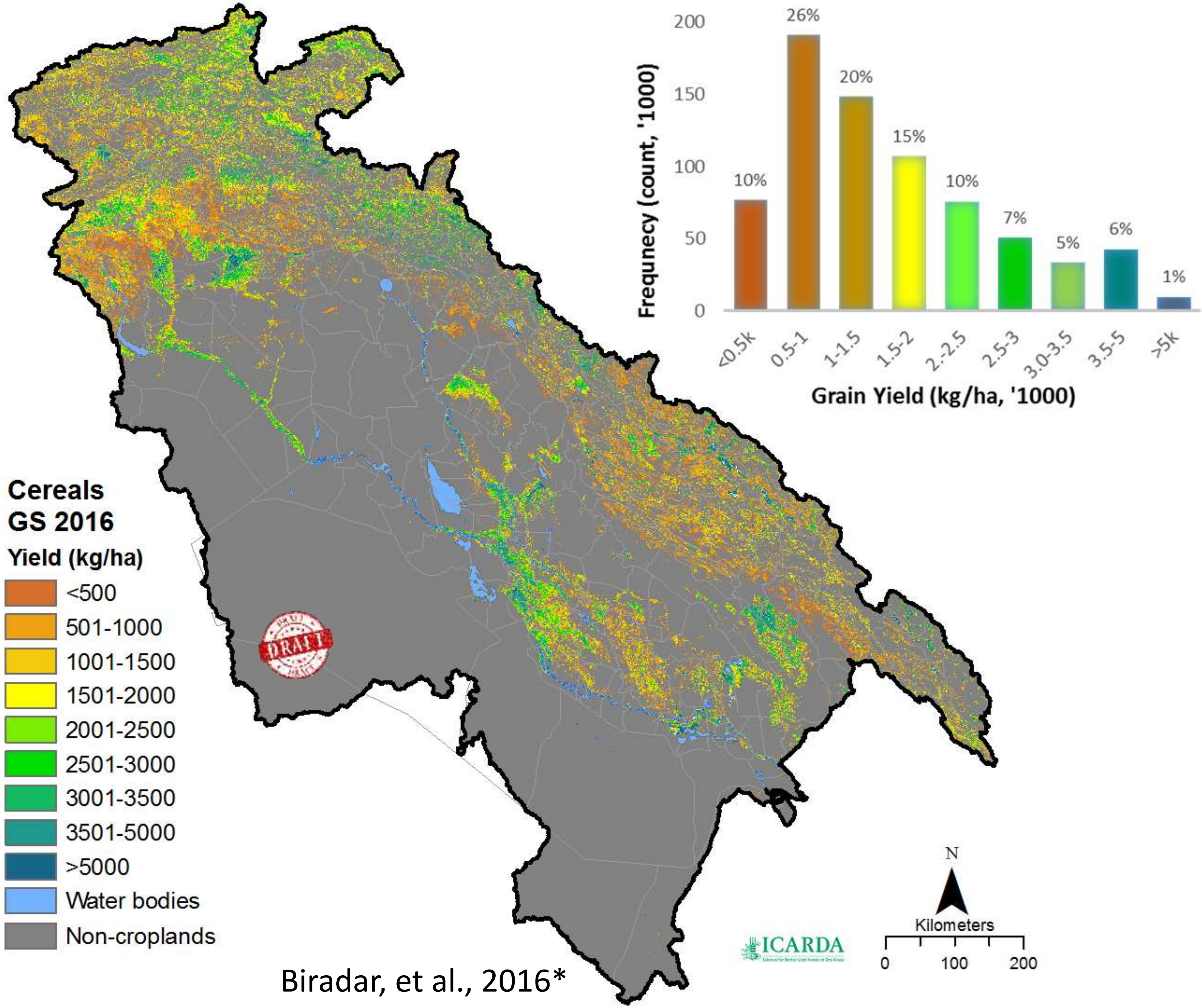
(World Bank Reports, Biradar et al., 2012)


Decadal Dynamics of the Evapotranspiration
(Deviation from long-term mean)
TURKEY
IRAN
SYRIA
IRAQ
CYPRUS
LEBANON
PELESTINE
ISRAEL
JORDAN
EGYPT
SAUDI ARABIA
TURKEY
SYRIA
ETA 2003
Decreasing
Increasing
<50
50 - 70
70 - 90
90 - 110
110 - 130
130 - 150
> 150



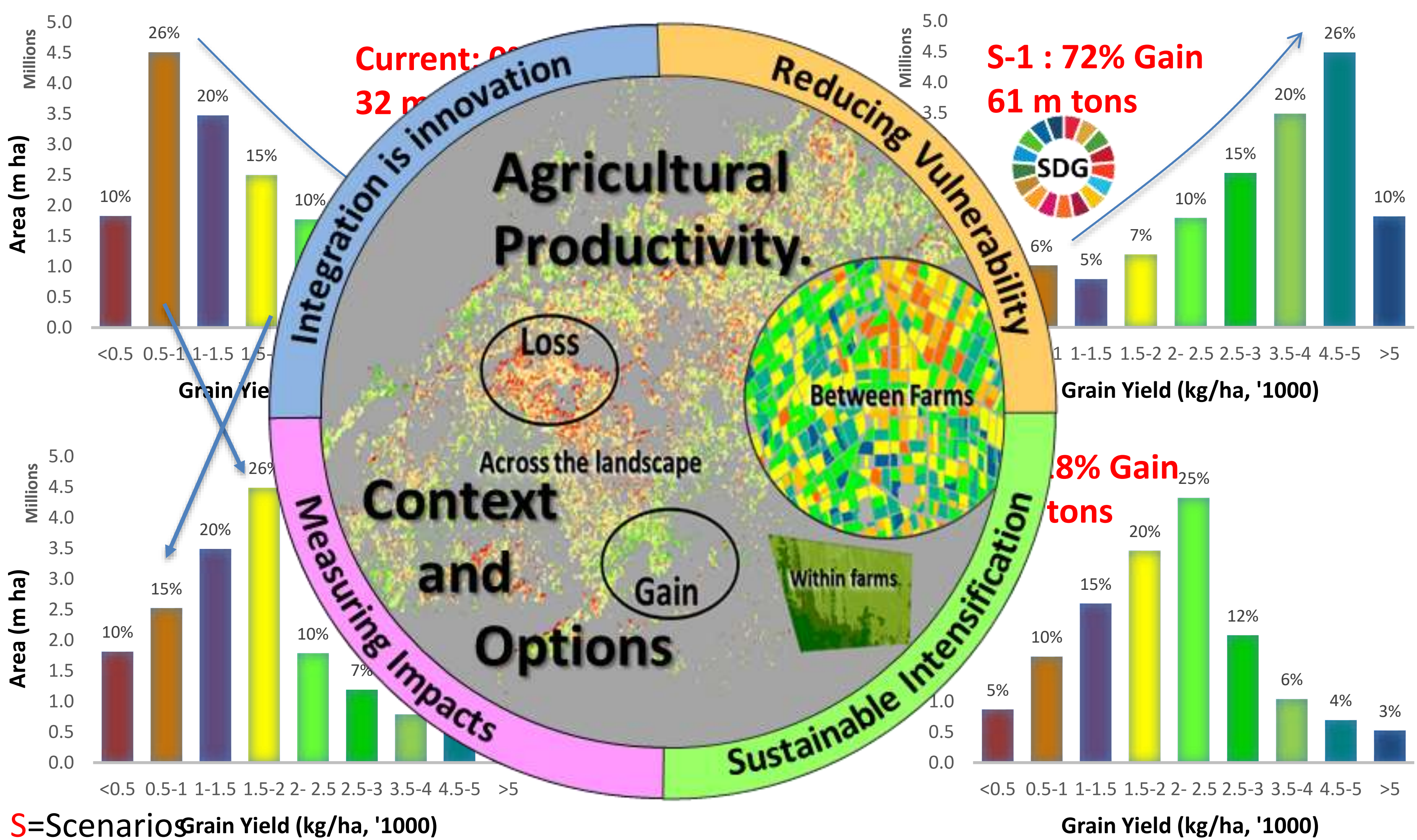
Decadal
Dynamics of the
Evapotranspiration
(Deviation from
long-term mean)
TURKEY
IRAN
SYRIA
IRAQ
CYPRUS
LEBANON
PELESTINE
ISRAEL
JORDAN
EGYPT
SAUDI ARABIA
TURKEY
SYRIA
ETA 2015
Decreasing
Increasing
<50
50 - 70
70 - 90
90 - 110
110 - 130
130 - 150
> 150

Agricultural Productivity and Production



Biradar, et al., 2016*

Location specific Investment, Interventions and Impacts



S=Scenarios

Biradar, et al., 2016*

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Connecting the dots of resilience

Agricultural production systems heavily compromised sustainable food production and health of the lives and planet earth by neglecting climate smart crops (dryland cereals and legumes)

Integrated farming systems with better soil, water, trees, and livestock management for nutritious food and agro-ecosystems for a sustainable future

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in an inch of land and bunch of crop

Harvesting multiple gains

-genetic and breeding? 15-20

-management and agronomy? 50-60

-socio-economy and ecology? 20-35

Thank You

c.biradar@cgiar.org

avoid the unmanageable and manage the unavoidable

-IPCC Confronting Climate Change:

ICARDA Science for Better Livelihoods in Dry Areas