Water4Crops

"Integrating bio-treated wastewater reuse and valorisations with enhanced water use efficiency to support the Green Economy in EU and India".

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Water Research Institute – National Research Council
IRSA-CNR
International Crops Research Institute for the Semi-Arid Tropics
ICRISAT

Water4Crops

A twinned EU-India R&D Project

Duration: 4 years

EU starting date: 1ts August 2012

India starting date: 1ts November 2012

Water4Crops-EU
EC-FP7
Coord. Dr. Antonio Lopez

IRSA CNR

EC contribution:

≈ 6 Mio €

DBT contribution:

≈ 3 Mio €

Water4Crops-India
INDIA-DBT
Coord. Dr. Suhas P. Wani

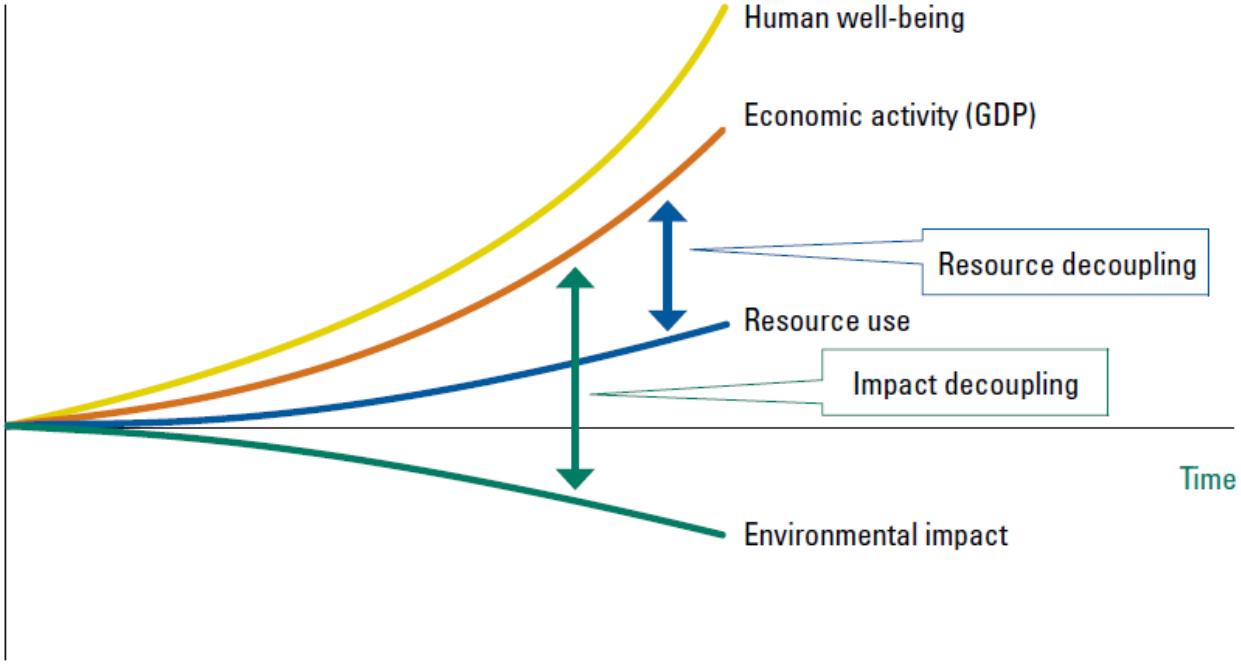
ICRISAT
Science with a human face

Aim

Better management of water, land and crops aimed at a viable, stronger and sustainable green economy

DECOUPLING: A key concept of GREEN ECONOMY

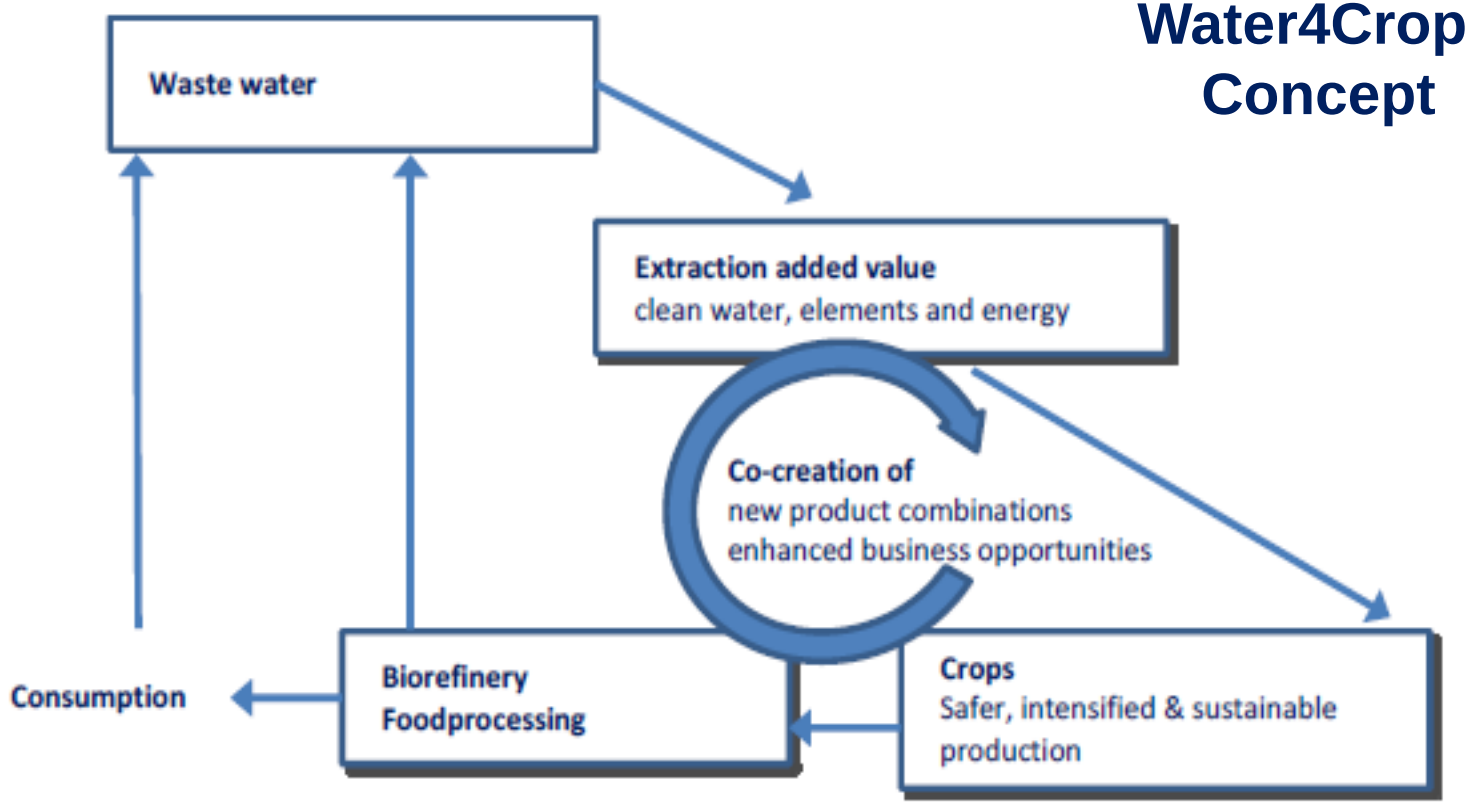
Decoupling Natural Resources Use and Environmental Impacts from Economic Growth (UNEP 2011)



W4Cs objectives

- Valorize agro-food-industry wastewater by recovering valuable chemicals
- Increase water availability by treating and reusing wastewater
- Enhance water use efficiency by improved agronomics, plant breeding and innovative irrigation techniques.
- Co-create innovative combinations of wastewater bio-treatment and high-value products bio-production for the development of agri-business in Europe and India towards a “Green Growth”.
- Enhance stakeholders participation within the co-creation process as well as Europe-India cooperation through Mirror Cases and INNOVA Platforms tools

Water4Crops Concept



W4Cs

Two W4Cs key tools

Mirror Cases and INNOVA Platforms

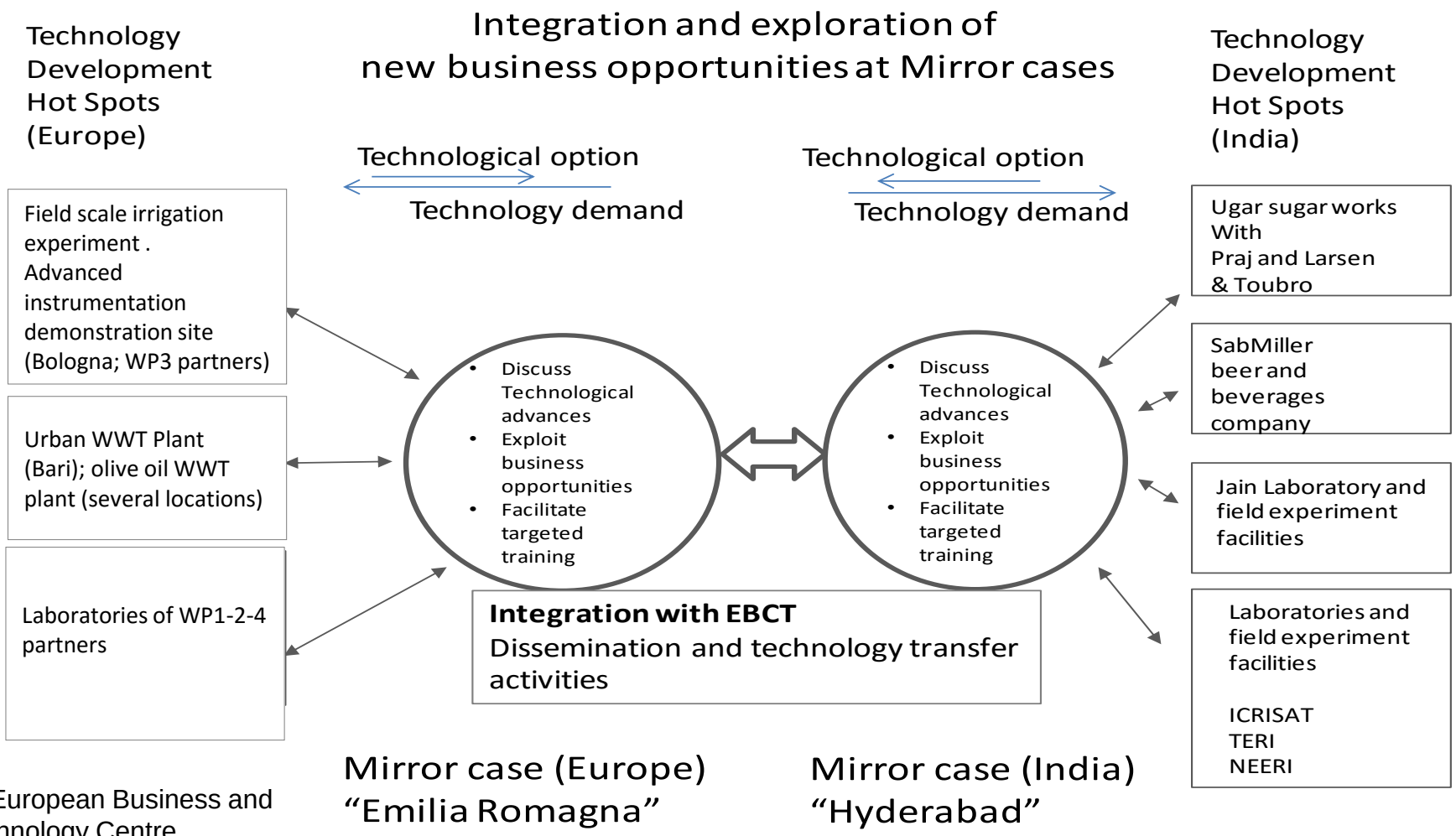
EU - Mirror Case at: Bologna - Emilia Romagna (Italy)

INDIA - Mirror Case at: Hyderabad - Andrah Pradesh

Innovations in Sustainable Water and Wastewater Treatment Systems (ISWATS)

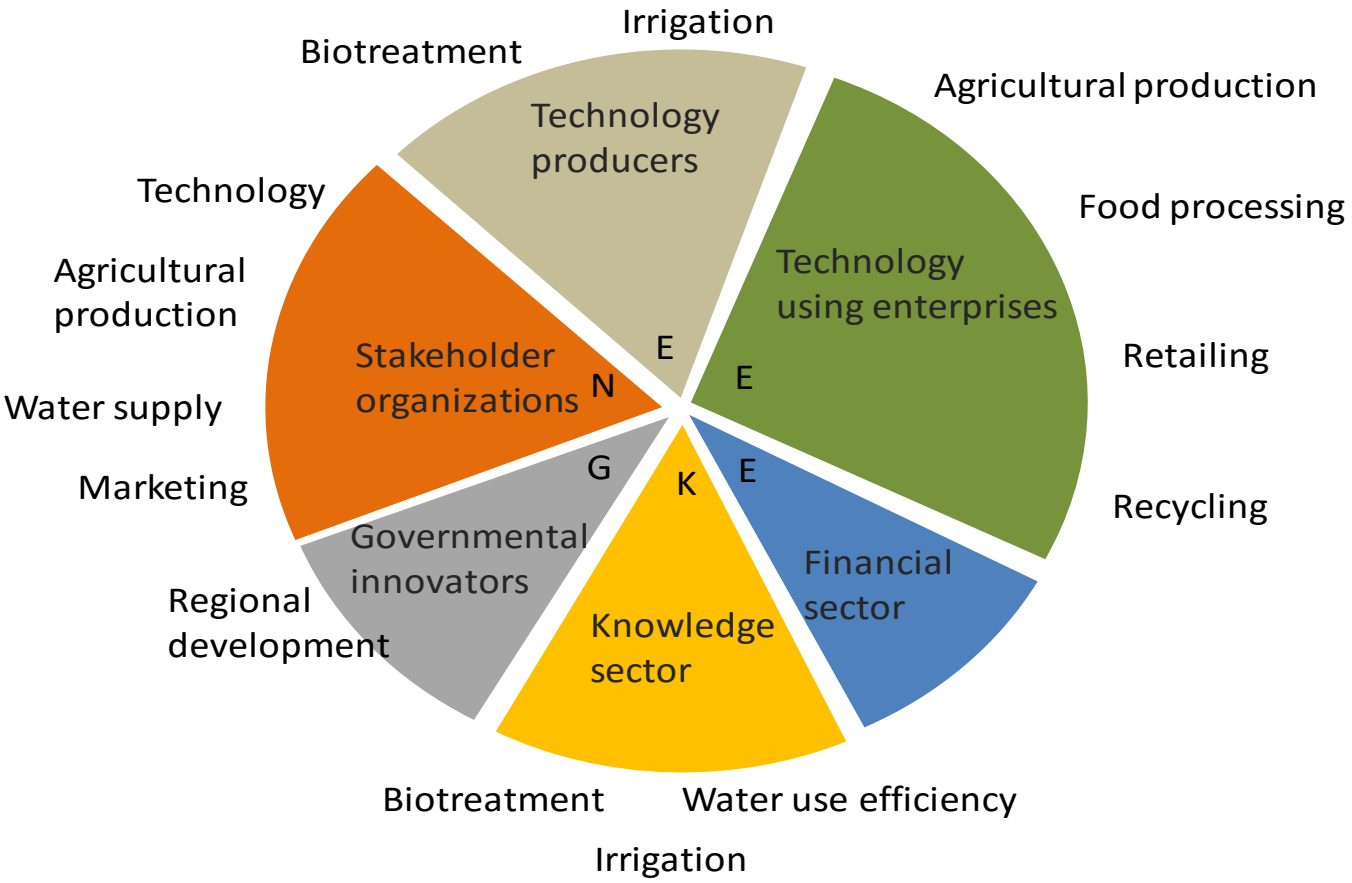
Pune 21-23 April 2016

Integration and exploration of new business opportunities at Mirror cases



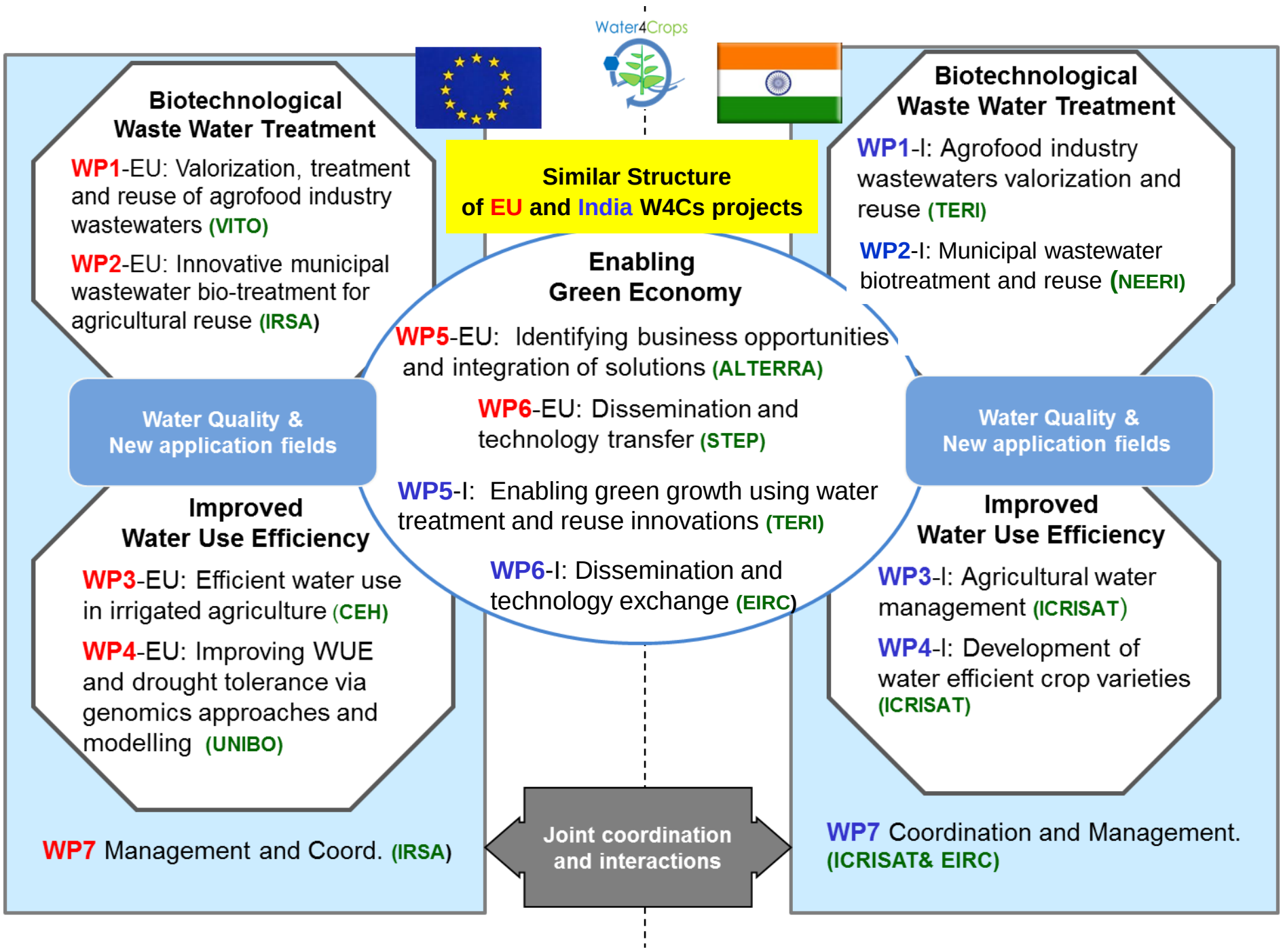
(*) European Business and Technology Centre

Targeted Composition of the INNOVA platform at Mirror cases



Through the **INNOVA platforms**, the **Mirror Cases** will:

- Transmit stakeholder demands to technology developers
- Reflect the achievements of technology developers to identify new solutions and business opportunities
- Mirror the experience of Europe and India for mutual advancements


Water4Crops
Biotechnological Waste Water Treatment
WP1-EU: Valorization, treatment and reuse of agrofood industry wastewaters (VITO)
WP2-EU: Innovative municipal wastewater bio-treatment for agricultural reuse (IRSA)
Similar Structure of EU and India W4Cs projects
Biotechnological Waste Water Treatment
WP1-I: Agrofood industry wastewaters valorization and reuse (TERI)
WP2-I: Municipal wastewater biotreatment and reuse (NEERI)
Enabling Green Economy
WP5-EU: Identifying business opportunities and integration of solutions (ALTERRA)
WP6-EU: Dissemination and technology transfer (STEP)
WP5-I: Enabling green growth using water treatment and reuse innovations (TERI)
WP6-I: Dissemination and technology exchange (EIRC)
Water Quality & New application fields
Water Quality & New application fields
Improved Water Use Efficiency
WP3-EU: Efficient water use in irrigated agriculture (CEH)
WP4-EU: Improving WUE and drought tolerance via genomics approaches and modelling (UNIBO)
Improved Water Use Efficiency
WP3-I: Agricultural water management (ICRISAT)
WP4-I: Development of water efficient crop varieties (ICRISAT)
WP7 Management and Coord. (IRSA)
Joint coordination and interactions
WP7 Coordination and Management. (ICRISAT& EIRC)

European Consortium: 21 Partners (including 7 SMEs) from 8 Countries

Participant name	Short name	Country
Istituto di Ricerca Sulle Acque del Consiglio Nazionale delle Ricerche **(COORDINATOR)**	**IRSA**	**Italy**
Natural Environment Research Council - Centre for Ecology and Hydrology	NERC	United Kingdom
University of Applied Sciences Northwestern Switzerland	FHNW	Switzerland
Università di Bologna - DiSTA Università di Bologna – DICAM	UNIBO	Italy
Flemish Institute for Technological Research	VITO	Belgium
Technical University of Crete	TUC	Greece
Helmholtz Centre for Environmental Research	UFZ	Germany
Università di Catania	UNICT	Italy
Centre National du Machinisme Agricole, du Genie Rural, des Eaux et des Forets	IRSTEA (ex CEMAGREF)	France
Institut National de la Recherche Agronomique	INRA	France
Stichting Dienst Landbouwkundig Onderzoek	ALTERRA	The Netherlands
Consorzio di Bonifica di Secondo Grado per il Canale Emiliano Romagnolo	CER	Italy
Deutsche Gesellschaft für Internationale Zusammenarbeit	GIZ	Germany
Università di Roma “La Sapienza”	UNIRM	Italy
SIMA-tec GmbH	SIMA-TEC	Germany
BionActis International Group SA	BIONACTIS	Switzerland
INOFEA GmbH	INOFEA	Switzerland
VITA 34 AG	VITA	Germany
TM-solutions	TM	Greece
Horta srl	HORTA	Italy
S.T.E.P. Consulting GmbH	STEP	Germany

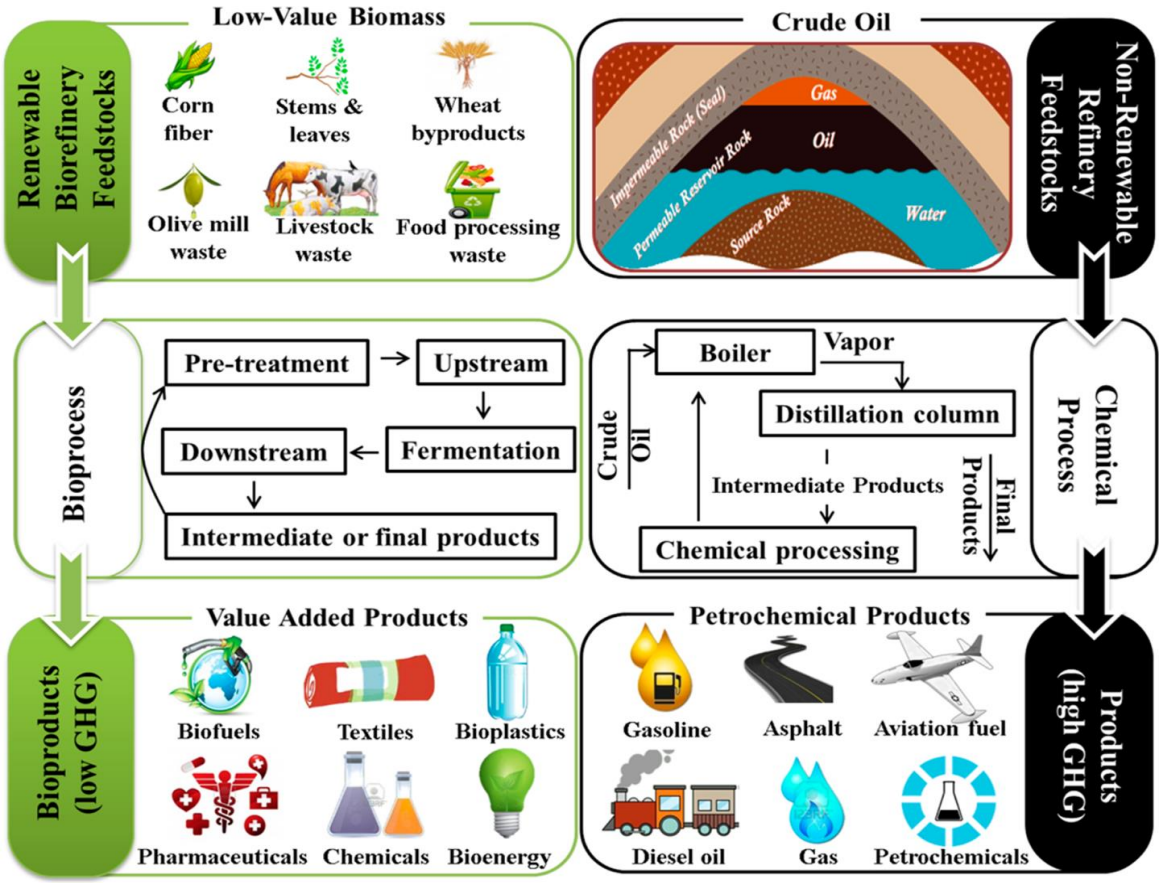
Innovations in Sustainable Water and Wastewater Treatment Systems (ISWATS)

Pune 21-23 April 2016

1	International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
2	The Energy and Resources Institute (TERI)
3	University of Agricultural Sciences Dharwad (UASD)
4	MS Swaminathan Research Foundation (MSSRF)
5	National Environmental Engineering Research Institute (NEERI)
6	Jain Irrigation Systems Limited (JISL)
7	Euro India Research Centre (EIRC)
8	SABMiller (SABM)
9	University of Agricultural Sciences Bangalore (UASB)
10	Ugar Sugar (UGSG)
11	KCP Sugar Industry

Indian Consortium

WP1 _ Wastes valorization: using biomass or agro-food wastewater instead of oil for producing energy and chemicals (biorefinery concept)



EU_WP1 (Valorization, treatment and reuse of agrofood industry wastewaters)

Volatile Fatty Acid (VFA) recovery from (Biorefinery) Brewery wastewater:

- recovery techniques compared and optimized off-line
- membrane-based reactive extraction set-up assembled and integrated with fermentor producing VFA
- integrated set-up tested and optimized with satisfactory results
- adiabatic extraction procedure developed and optimized off-line at lab-scale

Selective polyphenol recovery from Olive Mill Wastewater (OMW):

- selection of cyclodextrin-based polyurethanes (CDPs) produced and tested at multi-gram scale
- upscaling of CDP production technology to production plant achieved and Standard Operating Procedure available
- design, construction and installation of a lab-scale reactor for selective extraction of targeted phenolic compounds

Overall extraction of polyphenols from OMW:

- sorption and desorption stage optimized
- continuous sorption plant designed, assembled and tested with satisfactory results

- **PHA production on dephenolized organic leftover of OMW:**
- pure and mixed culture approaches assessed

WP2_MWW Treatment Technologies for Agricultural Reuse

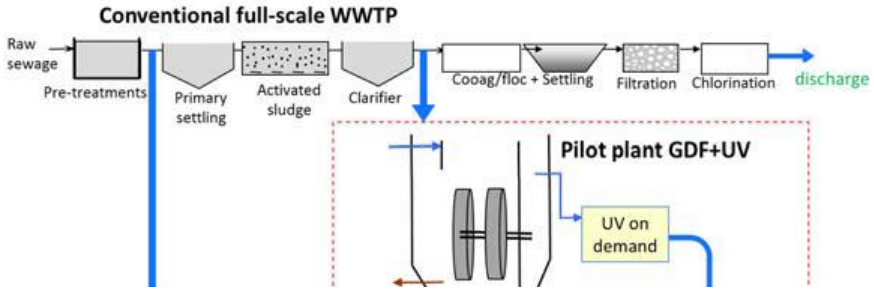
Constructed wetland at ICRISAT , Patancheru

Field of fennels irrigated with membrane filtered MWW in S. Italy

TiO2-coated Clay Aggregate In Novel Inactivation Unit

SBBGR – Innovative Compact WW treatment unit

Horizontal Subsurface CW (H-SSF)+ lagooning + storage reservoir



GDF- Gravity Filter Disk + UV treatment unit

EU_WP2 (Innovative municipal wastewater bio-treatment for agricultural reuse)

• Set up and running of innovative **wastewater treatment plants based on surface filtration** (membrane and cloth) for effluent reuse in irrigation.

• Assessment of lab-scale and pilot scale **Sequencing Batch Biofilter Granular Reactor** (SBBGR) effectiveness for producing treated wastewater suitable for agriculture reuse.

• Selection of redox mediators completed, various **nanobiocatalysts** produced and **improved process for tertiary treatment of wastewater.**

• Definition and use of new bio-molecular **protocols** as well as common conventional methods, **for evaluation of pathogens and antibiotic resistance gene (ARGs)** level and removal in innovative treatments for effluent reuse in irrigation.

• **WW hygienization by Constructed Wetlands**. Improved time-space yield of faecal indicator elimination in combination with slow sand filters or UV disinfection units .

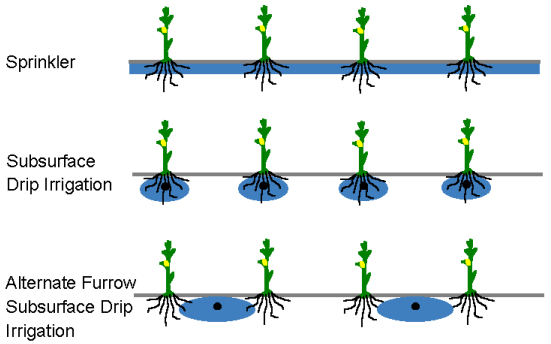
• **Investigation of CW hydraulics and hydrology**. Set up and running Constructed wetlands for WW reuse with particular attention to wetland hydrology **(ET)** and hydraulics **(clogging)**.

• Performance assessment of the **rhizofiltration technology for the removal of heavy metals from wastewater through CWs** pilots with selected halophytic wetland plants and the effect of plant species on the mechanisms regulating N cycling in CWs.

• Design and operation of innovative constructed wetlands (HSSF, FWS, VFW) planted with halophytes, innovative slow sand filter **and solar inactivate unit**. Batch experiment of suitable plant species for pathogen reduction, selection of material for construction of floating plant mats, set up and **running pilot scale experiment with floating plant mats at a sewage treatment** plant in Leipzig, Germany, microbial analyses for proving pathogen reduction

WP3_Optimizing Agriculture Water Management

- Integrating treated wastewater reuse with :
  - **Improved agronomic practices**
  - **Efficient irrigation system and strategy**
- Assessing impact of treated wastewater reuse on soil and crop quality
  - Laboratory scale leaching experiment
  - Field scale leaching experiments



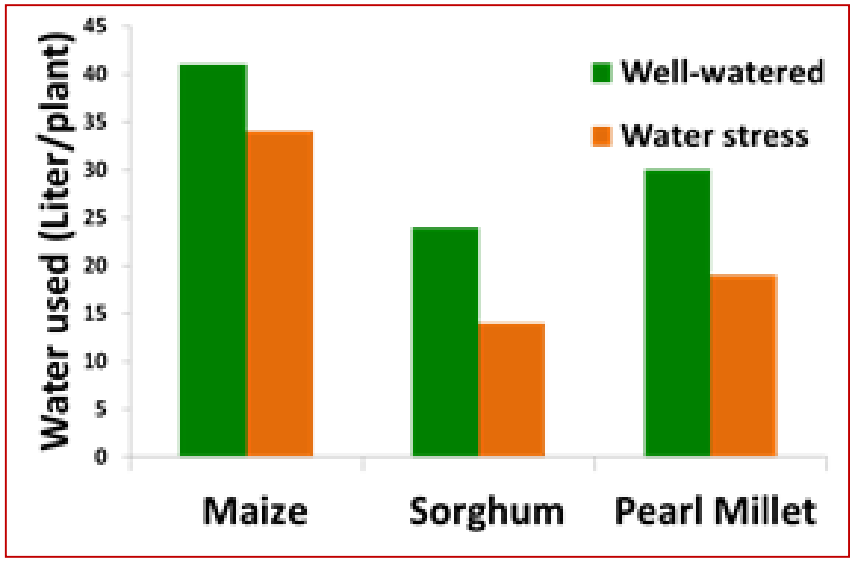
SAB Miller fields

COSMOS soil moisture sensors “Area based”

EU_WP3 (Efficient water use in Irrigated Agriculture)

- **Proper selection of irrigation systems**. The most suitable irrigation system for the entire crop rotation (potato, maize, processing tomato) grown in the experimental site in Bologna was found to be the drip irrigation system.
- **Proper selection of irrigation strategies:** namely, the Regulated Deficit Irrigation (RDI) and the Partial Root Drying method (PRD). Yield obtained by PRD irrigation strategy was higher than RDI strategy and the yield obtained using TWW was higher than SW water quality. The second year crop (maize) did not confirm these preliminary results
- **A new prototype dripper has been manufactured using a 3D printing technique**. Some endurance tests were conducted showing that the propotype was able to withstand up to 4bar pressure in the lab.
- **The water drift by wind when using sprinkler irrigation,** was studied and a suitable model to minimize the loss by drift was successfully tested.
- **New technologies for measuring key parameters were used**, i.e: **Eddy covariance (ET and gas-exchange between soil- plant-atmosphere), Scintillometer (ET) and COSMOS (water soil content), Electrical Resistivity Tomography (ERT) (soil moisture distribution and irrigation application efficiency)**
- **Modeling with SALTMED the impact of TWW reuse combined with the impact of irrigation system and strategies** for potato 2013 and maize 2014 seasons was carried out. The water productivity, on average, was 11% higher for PRD compared with RDI.
- **Data required to run the APEX model have been collected**, georeferenced, quality controlled and put into a Geodatabase used to run the model. The modelled stream network (including the artificial one), the sub-basins distribution and the outlet location have been completed.

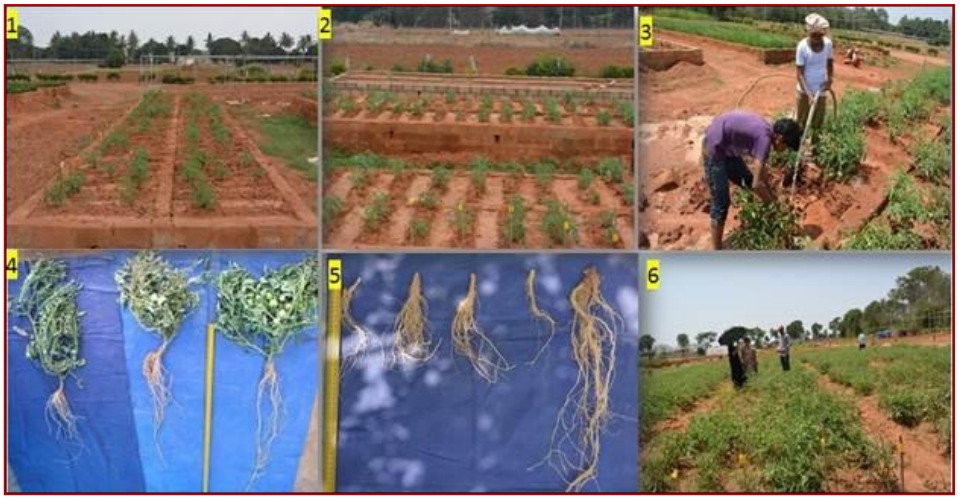
WP4_Enhancing Water Use Efficiency by plant breeding



Comparative abilities of maize, sorghum, and pearl millet for effective water use

Mapping of genomic regions controlling traits related to draught tolerance/WUE in tomato

- Root studies
- Diversity studies
- Drought tolerance studies



EU_WP4 (Improving WUE and drought tolerance of maize, sorghum, millet and tomato via genomics approaches and modelling)

- **Genotypic information of isogenic Introgression Lines (IL)** collection based on the 50K SNP array
- **Information on the level of isogenicity of QTL-NILs** (Quantitative Trail Locus – Near Isogenic Lines) for seminal roots in maize
- **Production of a large population of segmental isolines for a major QTL for seminal roots in maize**
- **Genomic characterization of an IL maize collection**, parental lines and newly developed nearisogenic segmental lines.
- **Analysis of the genetic control of root traits and their relationship with yield and water use efficiency (WUE) in maize and tomato.**
- **Characterization of the maize IL collection for agronomic traits** related with WUE and roots characteristics.
- **Phenotyping of all 75 ILs for brace root features and WUE using the lysimeter platform (ICRISAT - India).**
- **Characterization of major QTLs identified** in Task 4.2.a for brace roots, agronomic traits and WUE using plants in F1 hybrid generation. The field experiments have been carried out for the two seasons (2014 and 2015 in progress) in two location of the Po Valley at Horta (Ravenna) and UNIBO (Bologna).
- **Phenotypically test in rhizotrons two NIL pairs for the two major QTLs** identified in Task 4.2.a for brace roots, agronomic traits and WUE.

EU_WP5 (Identifying business opportunities and integration of solutions)

- **Assessment of exiting gaps in knowledge, attitude and skills** as well as training needs of the potential users of wastewater reuse and valorisation technologies.
- **INNOVA platform established**
- first INNOVA meeting held
- The INNOVA process is well under way after 36 months. The knowledge level and barriers and opportunities for bringing the W4C technologies towards the market are becoming increasingly clear through the use of a questionnaire and two INNOVA platform meetings
- Especially, insight into (societal) costs and benefits of W4C technologies has contributed to the development of a shortlist of W4C technologies with business potential
- **The transdisciplinary co-creation process facilitated in the INNOVA platform meetings facilitated the emergence of new innovative concepts (CASCADE bio refinery concept) for valorization of wastewater and increasing water use efficiency**
- **Trends and boundary conditions have been discussed and defined.** A report has been delivered. Factsheets and a publication are expected to follow.

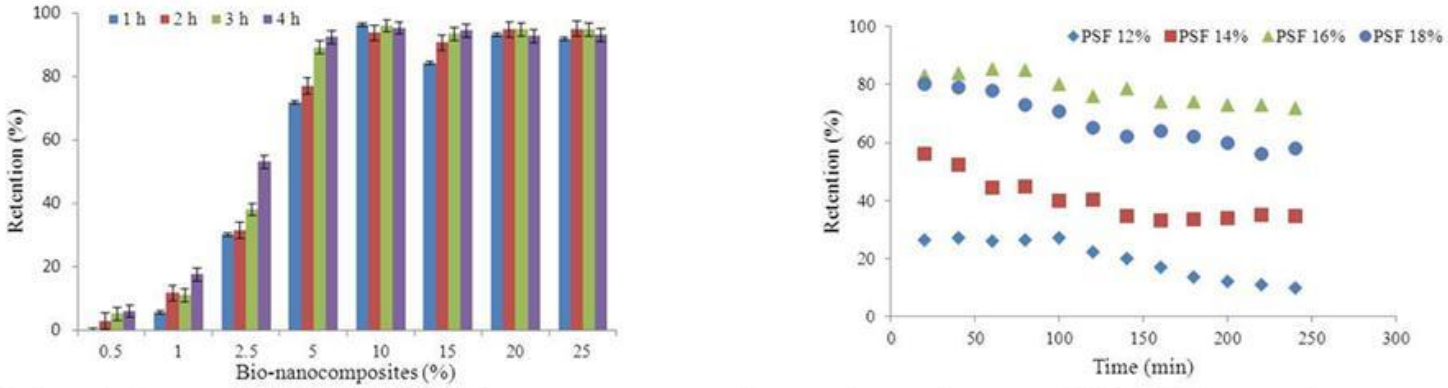
EU_WP6 (Dissemination and technology transfer)

- **Identification of customers / local business demands** and W4Cs technological offer
- **Project webpage and public dissemination material**
- **Establishment of dissemination plan with EBCT** (European Business and Technology Centre)
- **Contacts with European Parliament Members and high level delegations**
- Knowledge **Brokerage event** on W4Cs Trainable Outputs on both waste water treatment and reuse at the first INNOVA meeting in December 2013 in **Bari-Italy**
- Special **Brokerage session** on 9-10 October, 2014 in the framework of **Mumbai IFAT Trade Fair India 2014**
- Knowledge **Brokerage event** on W4Cs technologies at the second INNOVA meeting in **Bologna, Italy**, on 18th of November, 2014
- **Training Workshops:** in **New Delhi on** 3-5 March, 2014 and **Bangalore** on 19 May 2014.
- Water4Crops was presented to a wide audience of water related stakeholders at the **IFAT Trade Fair in Munich**, May 2014
- Water4Crops activities and goals presented into several other public events in EU and India

63 Peer-reviewed publications (44 published , 4 accepted, 15 submitted)
35 EU-Deliverables produced. Most of them are public and downloadable from the project web site (http://www.water4crops.org)

INDIA_WP 1
Carbons and membranes for the recovery of phenolics / pigments

- Polysulphone (PSF) membranes with incorporation of bio-nanocomposites were tested for melanoidins recovery. The focus was on development of bio-nanocomposites/PSF MMMs that operate at lower pressure (1-2 bar) with high melanodins retention.
- Further work on process development for recovery of melanoidins/phenolics from distillery wastewater is on-going.

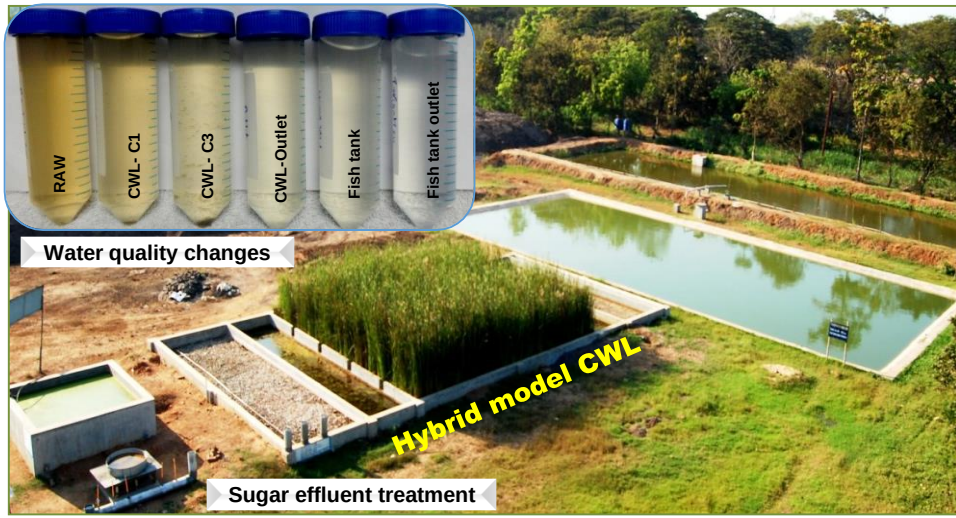


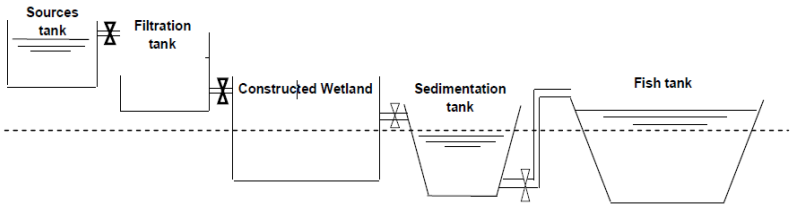
Melanoidins recovery by (a) bio-nanocomposites adsorption, and (b) PSF membrane filtration at room temperature.

INDIA_WP 1

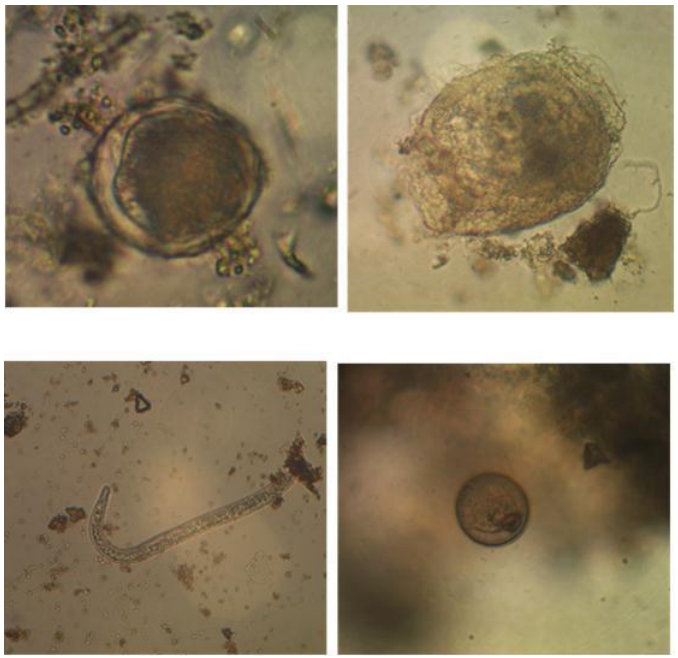
Enhancing quality of distillery spent wash (DSW) through sequential adaptation of indigenous microbial consortium

- To enhance the quality of DSW suitable to reuse in agriculture, indigenous bacterial consortium was adapted and used in the treatment process.
- Consortia from three different indigenous soils from Vuyyurru field and rhizospheres of Canna indica and Typha sp. was developed for plenol reduction.
- The indigenous algal isolates were tested for COD removal. These algal isolates also enhanced the sedimentation rate of contaminants present in the bacterial treated DSW.
- Further, the halophytes were used for phyto-remediation in constructed wetland to reduce salinity levels of treated water.





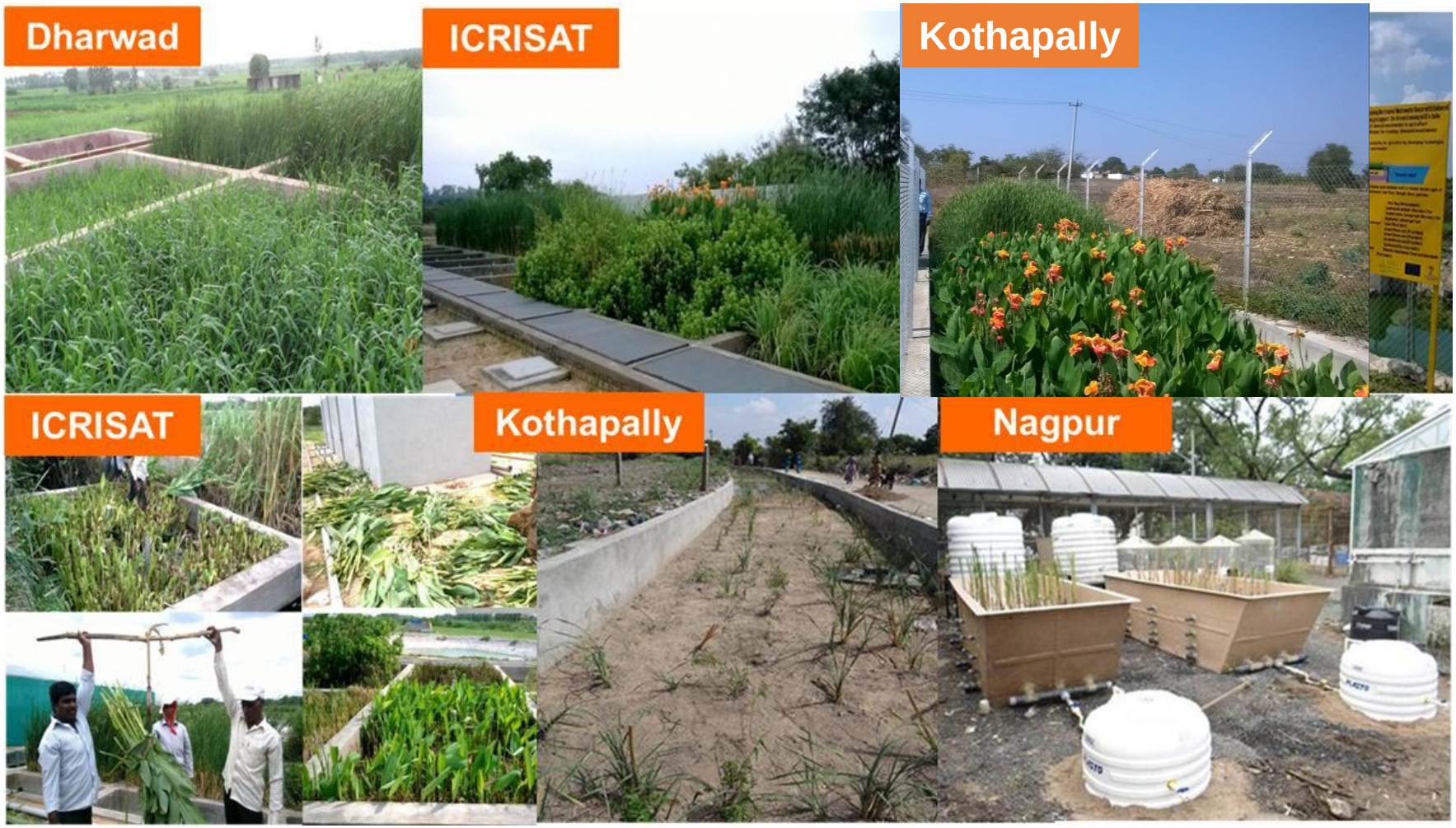
INDIA_WP 2
Municipal wastewater bio-treatment and reuse



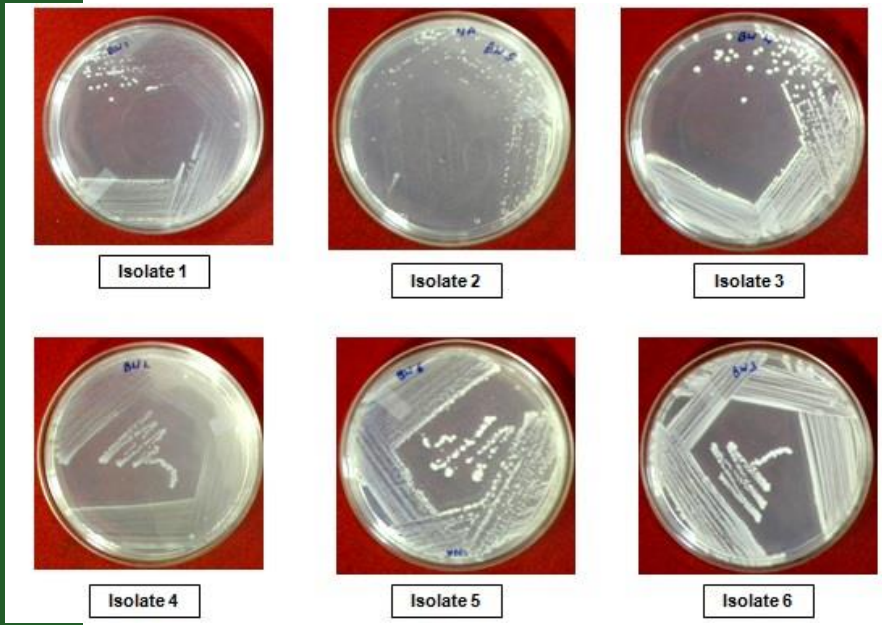
Nematode ova and protozoan cyst found in wastewater collected from Nag River.

Parameter	Values
EC (mS)	1.8-3.2
TS (mg/L)	1600-2600
TDS (mg/L)	400-1600
TSS (mg/L)	200-1800
NH_4-N (mg/L)	11.2-19.9
NO_3-N (mg/L)	0.32-4.74
Bacteria CFU/ml	158000-266000
BOD_5 (mg/L)	54.4-112.0
COD (mg/L)	128-352

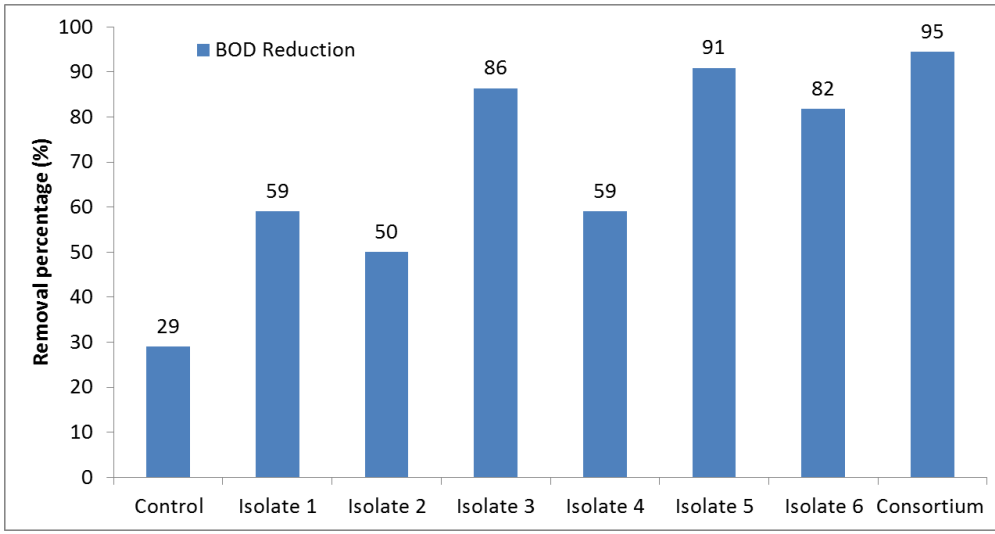
INDIA_WP 2
Demonstration of Constructed Wetland



INDIA_WP 2
Microbial consortium for wastewater treatment



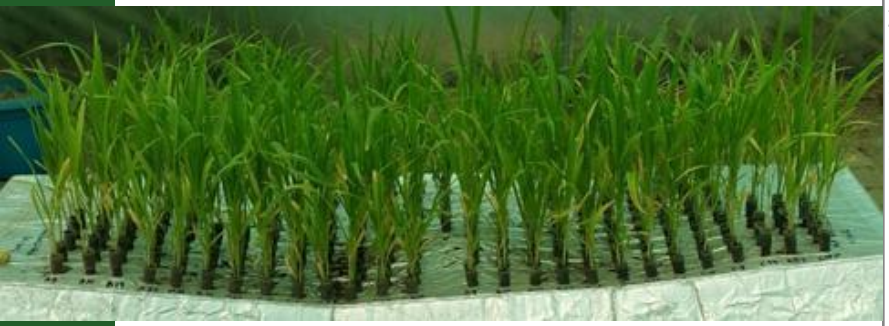
Bacterial cultures isolated from domestic wastewater collected from CSIR-NEERI



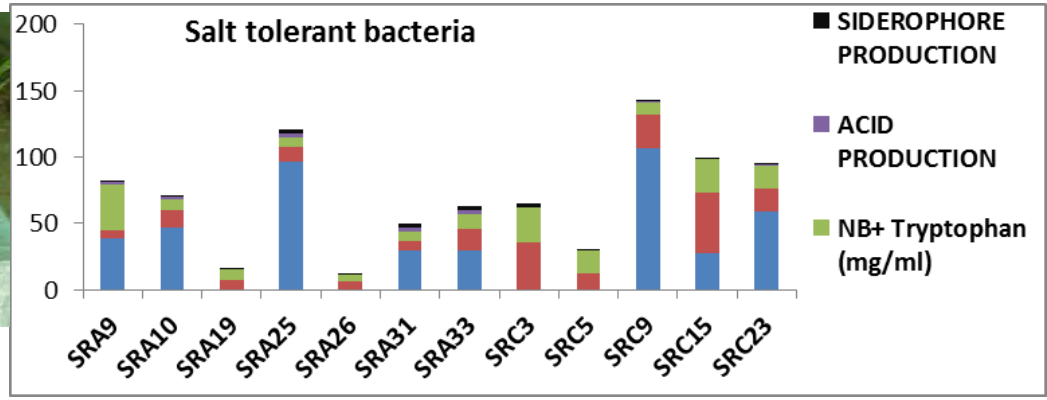
Percent BOD removal by isolates and consortium of isolate (3, 5, and 6)

INDIA_WP 2
Remediation of land previously loaded with biorefinery wastewater through biological means

- Twelve salt tolerant bacteria isolates were identified from sugarcane rhizosphere (@Ugar Sugar)
- Remediation of soil by drainage, green manure, and microbial culture (@Ugar Sugar)

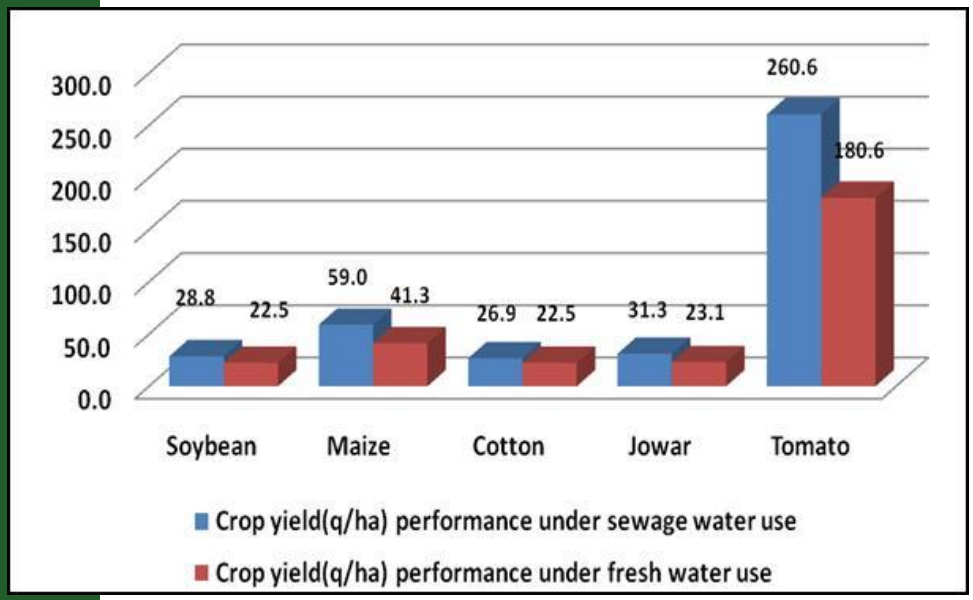


Microcosm (experimental ecosystem) setup for determination of best consortia of salt tolerant isolates

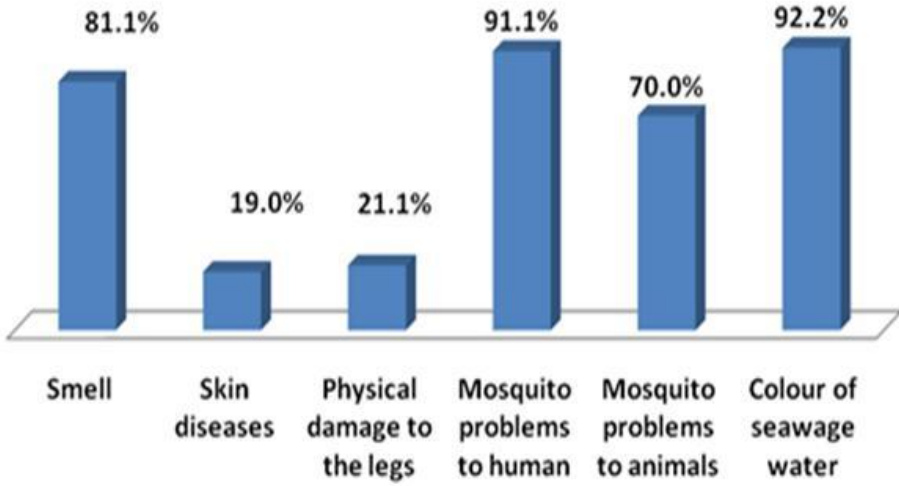


Overall functional screening of 12 salt tolerant bacteria to determine best consortia for greenhouse experiment on sweet sorghum Not referred in text

INDIA_WP 3
Agricultural water management



Increase in Yield



But may be at the cost of health

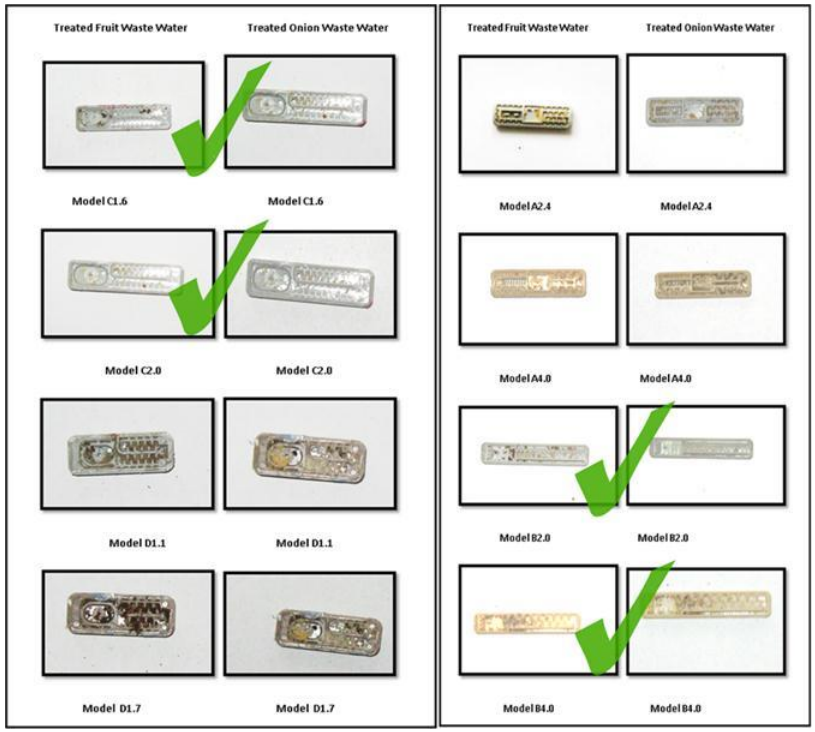
INDIA_WP 3
Impact assessment of wastewater on crops and soil

Locations	Crops	Wastewater type
JISL, Jalgaon	Maize	Bio-refinery wastewater
ICRISAT	Maize- Chickpea –Tomato; Soybean- Sorghum- Okra	Domestic and bio-refinery wastewater
KCP Sugar, Vuyyur/ Laxmipuram	Maize	Bio-refinery wastewater
UAS, Dharwad	Tomato-palak; okra-leafy vegetable; maize- wheat; sunflower; cotton; Soybean;	Domestic wastewater



INDIA_WP 3
Efficient irrigation system

- Eight different types of pressure compensating and non pressure compensating emitter were tested to find out the suitable emitter geometry under Treated wastewater from fruit processing plant (TFWW) and onion processing plant (TOWW)



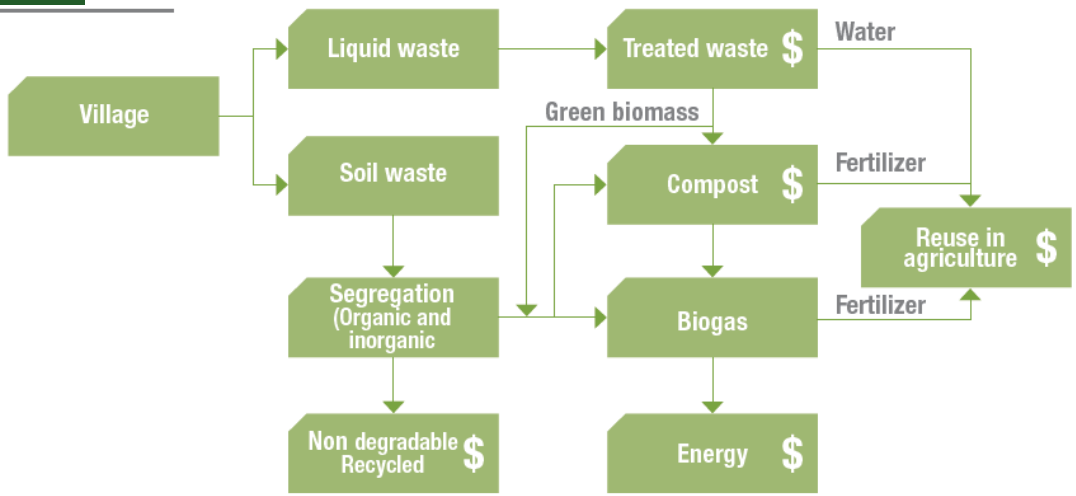
INDIA_WP 4
Development of Water Efficient Crop Cultivars

- Transpiration response to high VPD of contrasting germplasm of pearl millet, sorghum and maize and Gaspe Flint and B73 was studied.
- Assessment of staygreen QTL introgression lines of sorghum and pearl millet "QTL ideotypes" was completed.
- Three cycles of marker-assisted backcrossing was completed in chickpea for introgression of desired genomic region for drought tolerance from the germplasm accession ICC 4958 into the cultivars JAKI 9218 and JG 16. Promising drought tolerant lines were identified from evaluation of over 1100 MAGIC (multi-parent advanced generation intercross) lines in chickpea.
- In tomato, high yielding and drought tolerant genotypes were identified and hybridization was under taken to introgress drought tolerance traits from two wild species (S. pennellii and S. galapagenes) into the cultivated species. In another experiment, root studies in tomato lead to identifying some promising lines (LA 0292, LA 1632, EC 771609, EC 771598 and LA 1632) for root length, root volume and root to shoot ratio.

INDIA_WP 5
Enabling Green Growth using Water Treatment and Reuse Innovations

- Innovation Platform established
- Creation of Digiinnova Platform - LinkedIn Group
- Booklet of W4Cs technologies
- Fact sheets on
  - Legislation and standards and WWT&R
  - Health, public perceptions and WWT&R(including stakeholder dimensions)
  - Future agricultural production and WWT&R
  - Resource boundaries of WWT&R (labor, land, energy, water availability)
  - Investment climate and financing of WWT&R

INDIA_side
How can it be implemented through a green business model?



Green Business Model for Decentralized Waste Management System (DWMS) in Villages

- Increased use of waste through reuse of treated wastewater in agriculture and recycling solid waste as compost or bioenergy
- Involving community-based organizations, like women's Self-Help Groups (SHG), for planning, implementing and managing the DWMS as a green business model.

Decentralized Wastewater Treatment system for small community and reuse of treated water in agriculture

State	DWT - Planned
Telengana	6 (2 complete)
Karnataka	15 (1 complete)
Maharashtra	1
Uttar Pradesh	1 (complete)

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