Sustainable water management for irrigation: from efficiency to eco-efficiency concept

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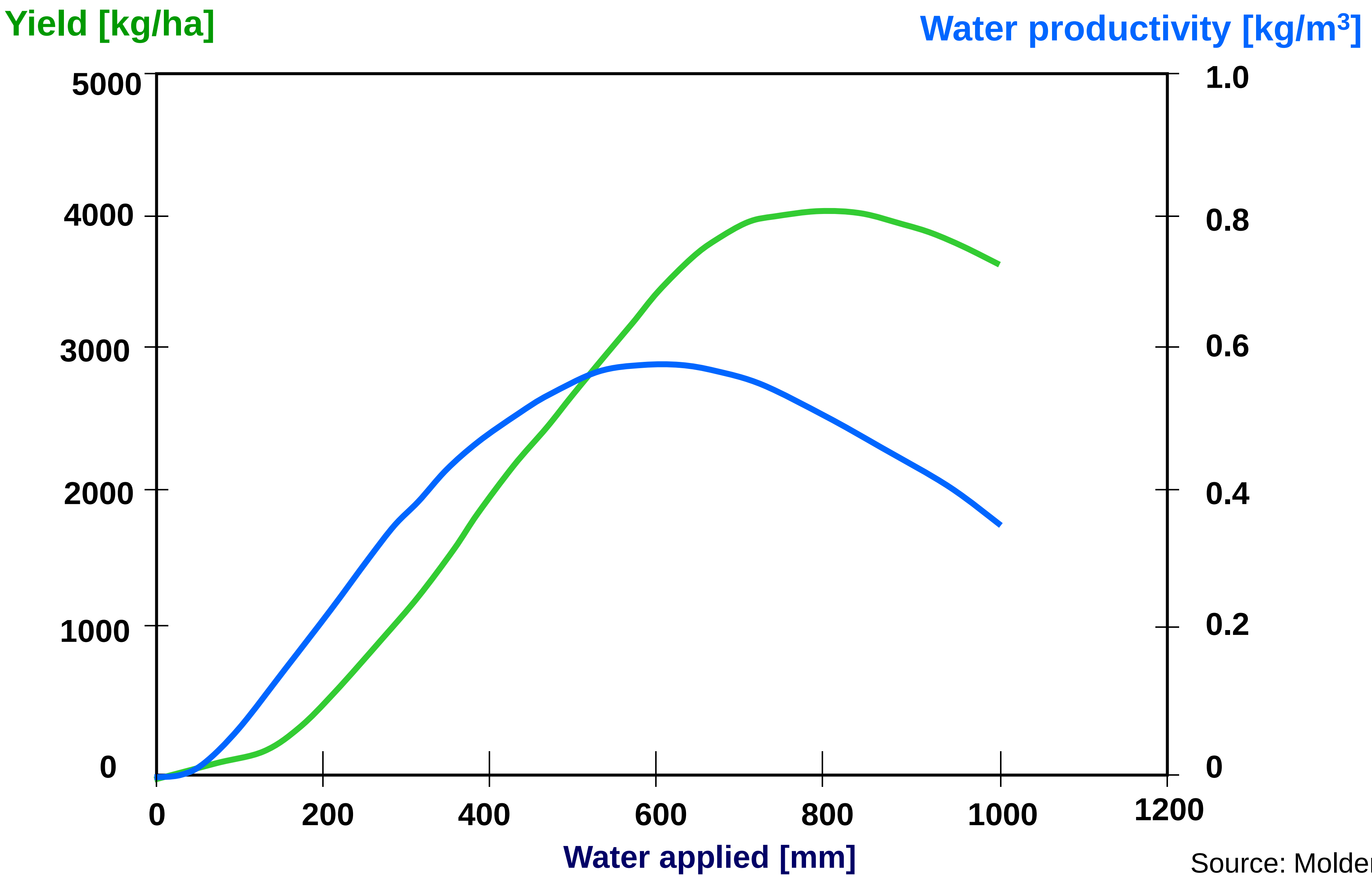
Debate from the beginning of the Century:

Maximizing YIELD vs. WATER PRODUCTIVITY



Source: Molden at al., 2003

Definitions of terms related to water use efficiency (WUE), crop water productivity (WP) and economic water productivity (EWP) often used in the literature. The * symbol means that the indicator is not recommended for evaluating the agricultural use of water (see Sections 2.1 for details and 3.3.1 for discussion).

Indicator	Units	Eq. No.	Definition and details
$WUE_c = \frac{ET_c}{I+P}$	$\frac{m^3 ha^{-1}}{m^3 ha^{-1}}$	1	*Crop WUE*: Ratio between the actual crop evapotranspiration (ET_c) and the total water applied by irrigation (I) and precipitation (P). After Perry et al. (2009).
$WUE_i = \frac{A_N}{g_s}$	$\frac{\mu mol\ CO_2\ m^{-2} s^{-1}}{mol\ H_2O\ m^{-2}\ s^{-1}}$	2	*Intrinsic WUE*: Ratio between the net CO_2 assimilation rate (A_N), or net photosynthesis, and the stomatal conductance (g_s). Measurements are made at the leaf level (in a leaf or a group of leaves), for a short period of time (normally from seconds to minutes). After Osmond et al. (1980).
$^{*}WUE_p = \frac{biomass}{E_p}$	$\frac{kg\ plant^{-1}}{m^3 plant^{-1}}$	3	*Plant WUE*: Ratio between total biomass produced by a plant along the growing season and the total amount of water transpired by the plant in the same period (E_p). After Viets (1962) and Flexas et al. (2010).
$^{*}WUE_c = \frac{biomass}{ET_c}$	$\frac{kg\ ha^{-1}}{m^3 ha^{-1}}$	4	*Crop WUE*: Ratio between total biomass produced by a crop along the growing season and the total amount of water consumed by the crop, or crop evapotranspiration (ET_c), in the same period. After Viets (1962) and Flexas et al. (2010).
$WP_c = \frac{yield}{ET_c}$	$\frac{kg\ ha^{-1}}{m^3 ha^{-1}}$	5	*Crop Water Productivity:* Ratio between the marketable yield produced by a crop and the water consumed by the crop or crop evapotranspiration (ET_c). Some authors call it "Bio-physical Crop Water Productivity" or "Physical Crop Water Productivity", to differentiate from the Economic Water productivity. After Kijne et al. (2003)
$WP_c = \frac{yield}{TWU}$	$\frac{kg\ ha^{-1}}{m^3 ha^{-1}}$	6	*Crop Water Productivity:* Some authors propose the total amount of water involved in crop production (TWU) as denominator of WP_c (See Section 2.1 for details). After Rodrigues and Pereira (2009).
$WP_I = \frac{yield}{IWU}$	$\frac{kg\ ha^{-1}}{m^3 ha^{-1}}$	7	*Irrigation Water Productivity*: Ratio between the marketable yield produced by a crop along the growing season and the irrigation water applied (IWU) in the same period. After Rodrigues and Pereira (2009).
$GEWP_I = \frac{Gross\ Margin}{IWU}$	$\frac{€\ ha^{-1}}{m^3 ha^{-1}}$	8	*Gross Economic Irrigation Water Productivity*: Ratio between the Gross Margin (revenue-variable costs) (in whatever currency; euros are used in this case) related to a crop along the growing season and the irrigation water applied (IWU) in the same period. See text for details on the Gross Margin.
$NEWP_I = \frac{Net\ Margin}{IWU}$	$\frac{€\ ha^{-1}}{m^3 ha^{-1}}$	9	*Net Economic Irrigation Water Productivity*: Ratio between the Net Margin (revenue – variable and fix costs) (in whatever currency; euros are used in this case related to a crop along the growing season and the irrigation water applied (IWU) in the same period
$EWP_c = \frac{Profit}{TWU}$	$\frac{€\ ha^{-1}}{m^3 ha^{-1}}$	10	*Economic Crop Water Productivity*: Ratio between the Profit (revenue-variable, fix and opportunity costs) (in whatever currency; euros are used in this case) produced by a crop along the growing season and the total amount of water involved in crop production (TWU). See Section 2.1 for details on TWU.
$EWP_I = \frac{Profit}{IWU}$	$\frac{€\ ha^{-1}}{m^3 ha^{-1}}$	11	*Economic Irrigation Water Productivity*: Ratio between the Profit (revenue-variable, fix and opportunity costs) (in whatever currency; euros are used in this case) produced by a crop along the growing season and the irrigation water applied (IWU) in the same period.

Source: Fernàndez et al., 2020

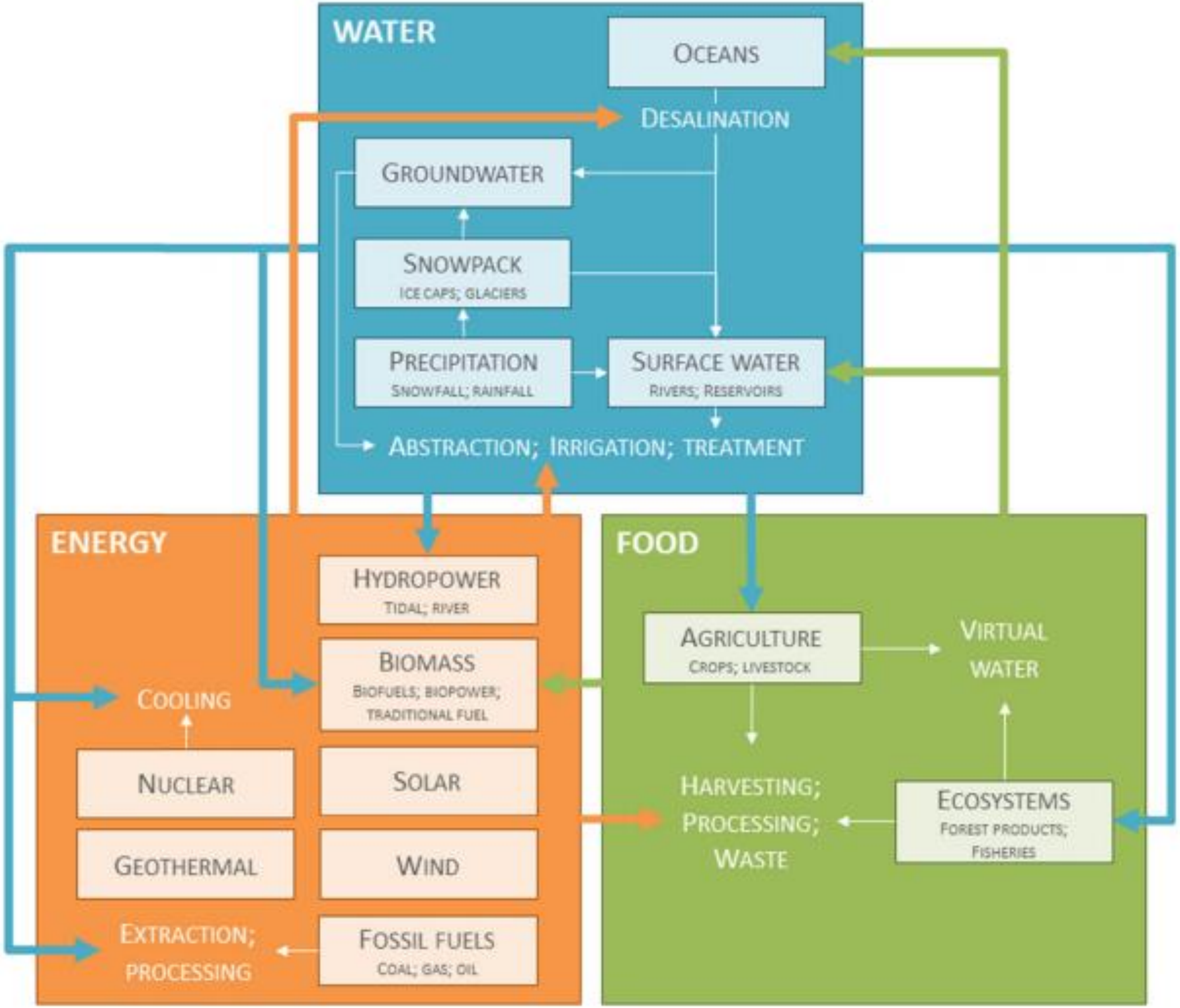
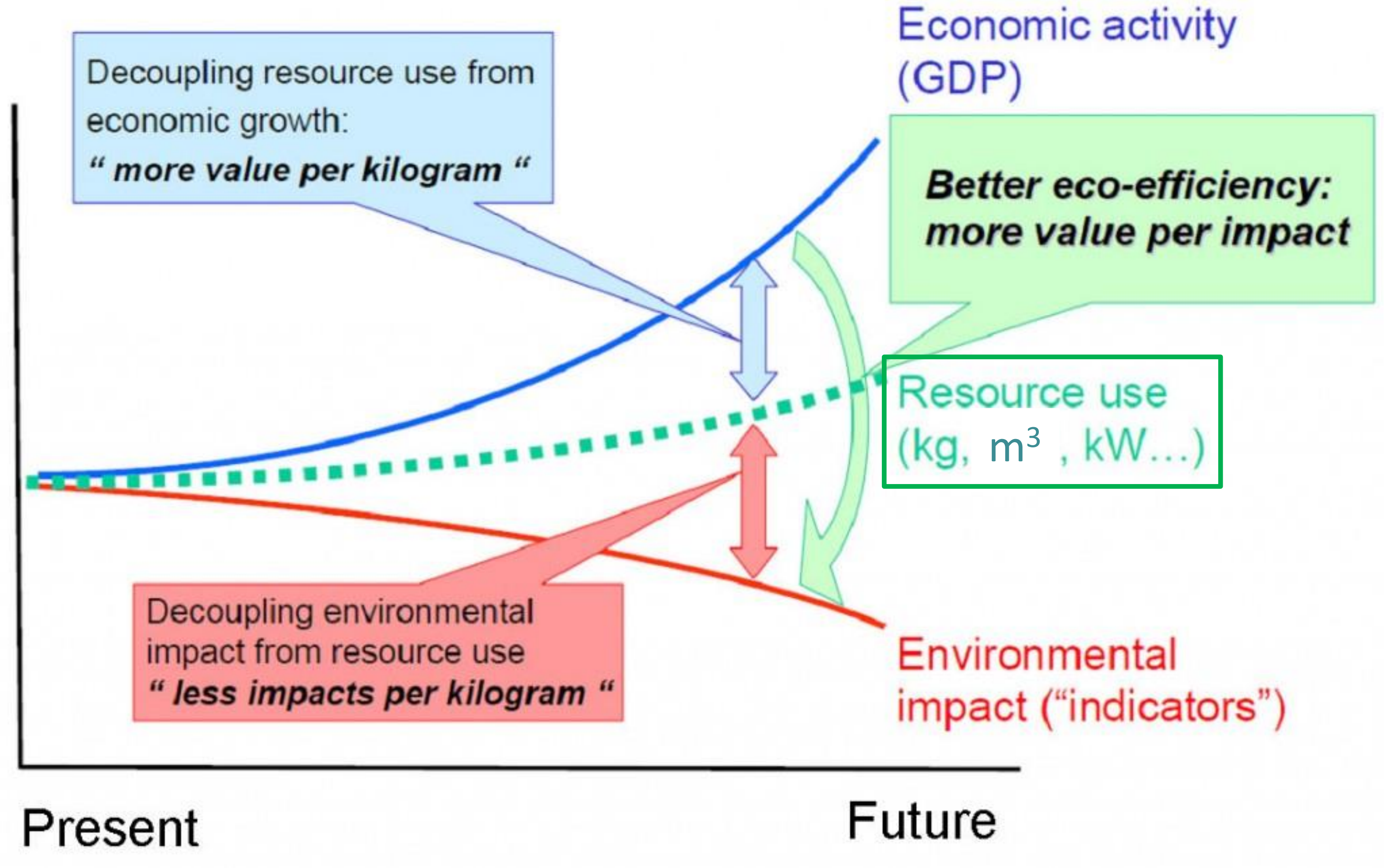


Fig. 3. The environmental nexus system defines the major flows within and between water, energy and food systems.

Source: Biggs et al., 2015

From efficiency to ECO-EFFICIENCY …

Economic activity, RESOURCE USE, environmental impact



Source : http://www.eea.europa.eu/

Assessing Agricultural Eco-Efficiency

Product market value – Cost of production (€)

↑

AGRICULTURAL PRODUCT ADDED VALUE

ENVIRONMENTAL IMPACT

↓

- Water withdrawal (m^3)
- Energy consumption (kWh)
- Fertilizers (N, P) application (kg)
- Emissions (kg CO_2 eq)

Composite System Indicator

Resource Exploitation Indicator (withdrawal/availability), REI

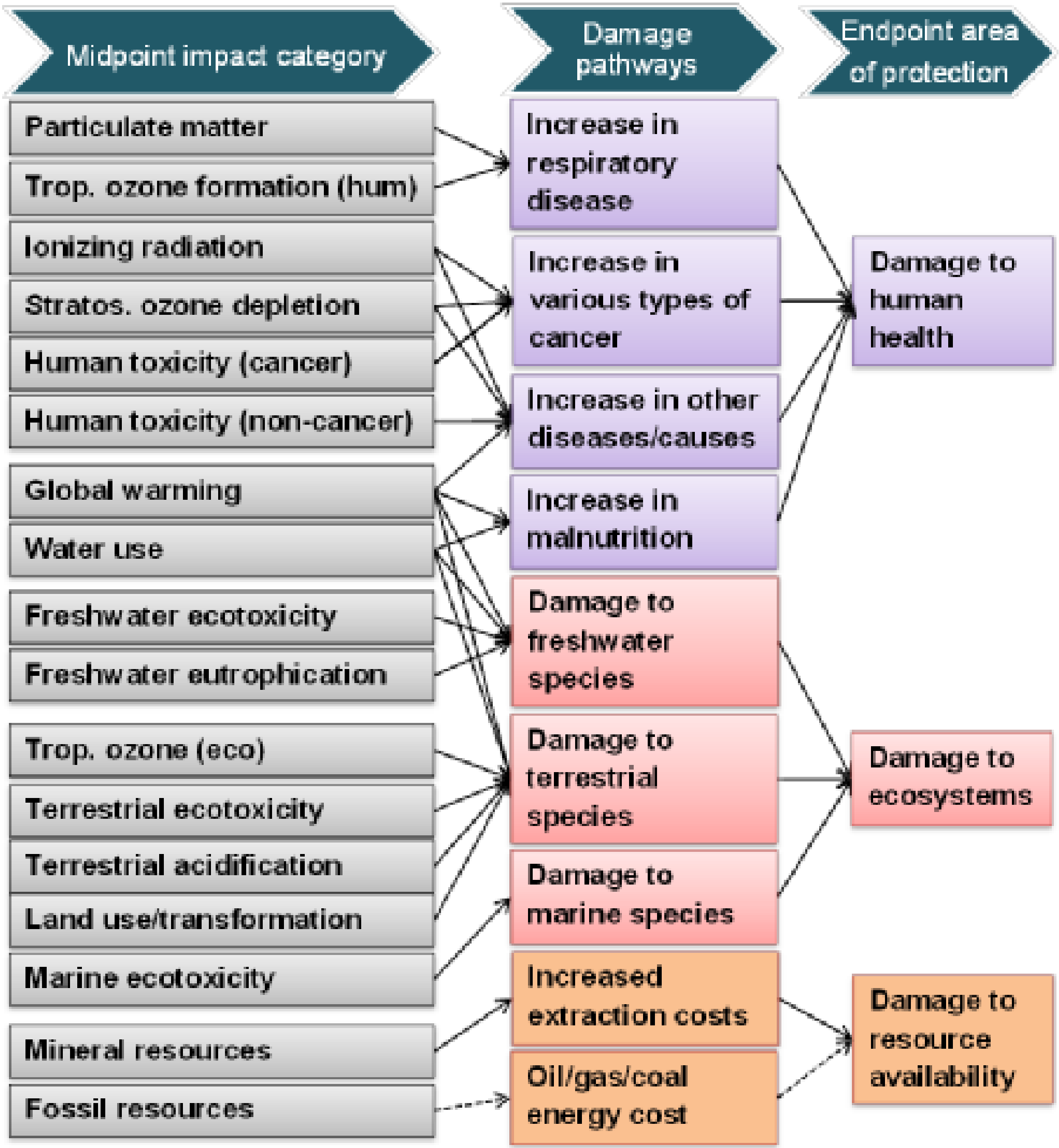
Life Cycle Impact Assessment - LCIA

LCIA translates emissions and resource extractions into a limited number of environmental impact scores by means of so-called characterisation factors.

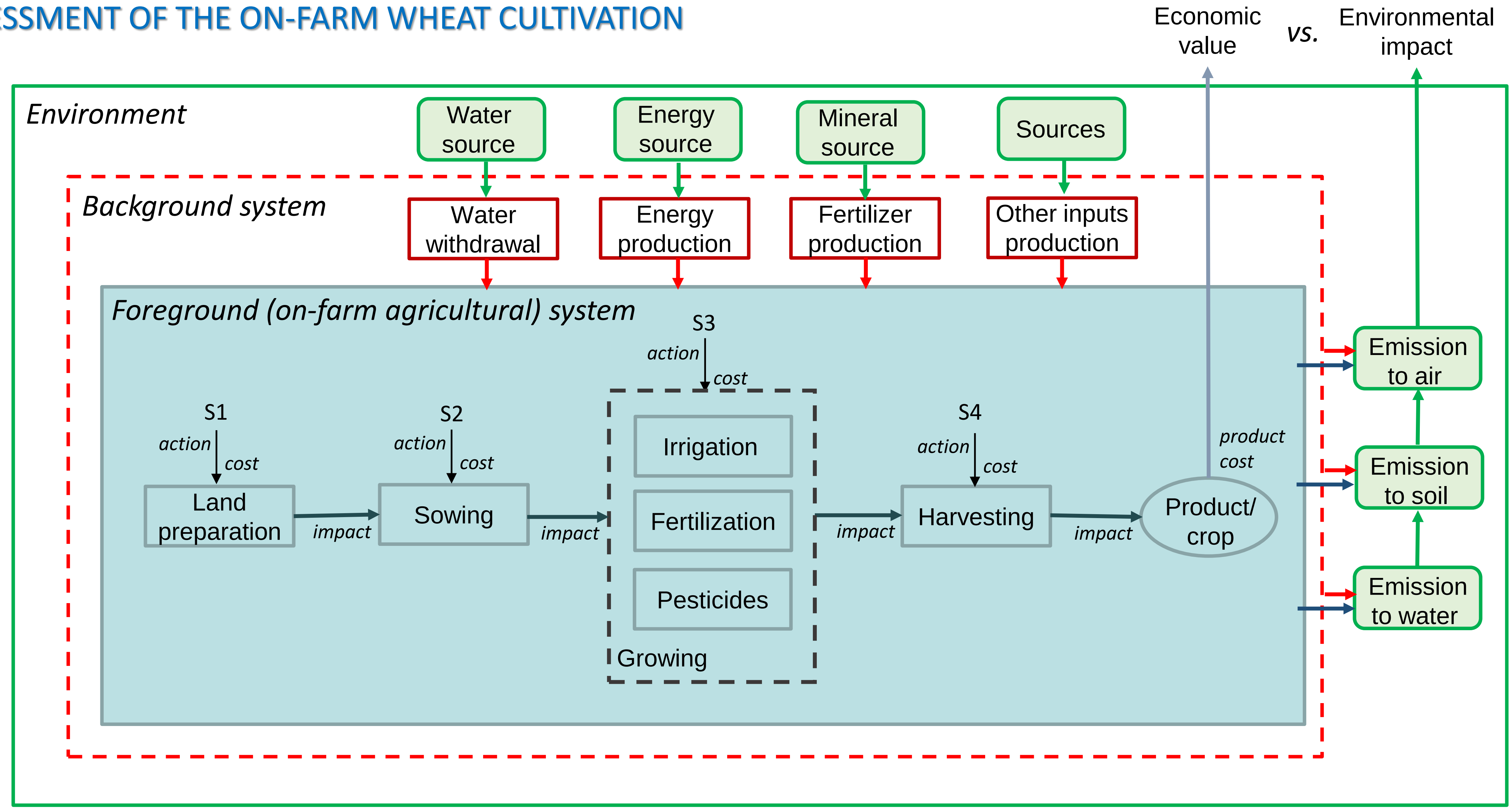
There are two mainstream ways to derive characterisation factors, i.e. at midpoint level and at endpoint level. ReCiPe model calculates:
- 18 midpoint indicators
- 3 endpoint indicators

<u>Midpoint indicators</u> focus on single environmental problems, for example climate change, or acidification or freshwater ecotoxicity.

<u>Endpoint indicators</u> show the environmental impact on three higher aggregation levels:
1) effect on human health,
2) biodiversity and
3) resource scarcity.

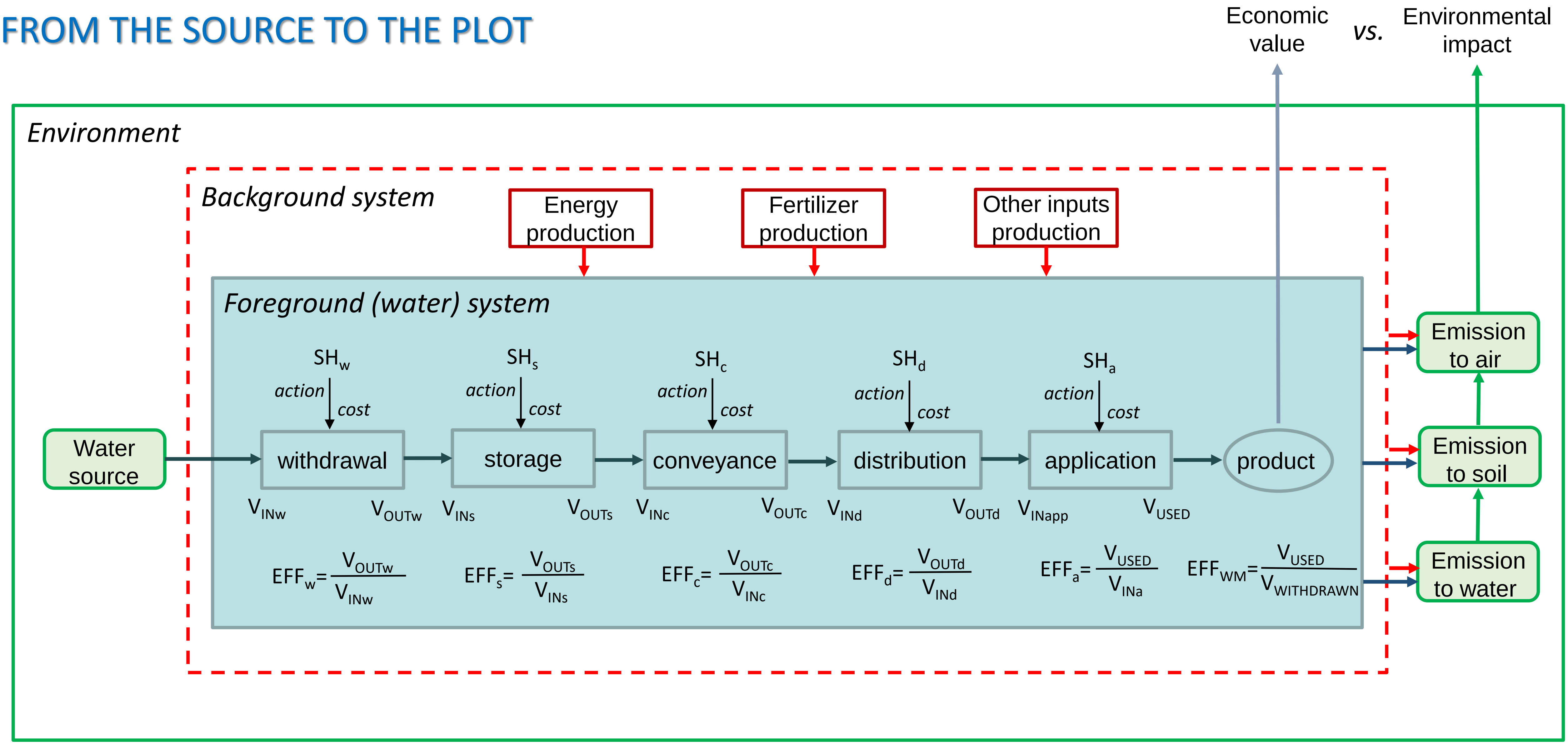


SYSTEM BOUNDARIES AND STAGES (S) FOR THE ECO-EFFICIENCY ASSESSMENT OF THE ON-FARM WHEAT CULTIVATION



Source: Todorovic et al., 2018

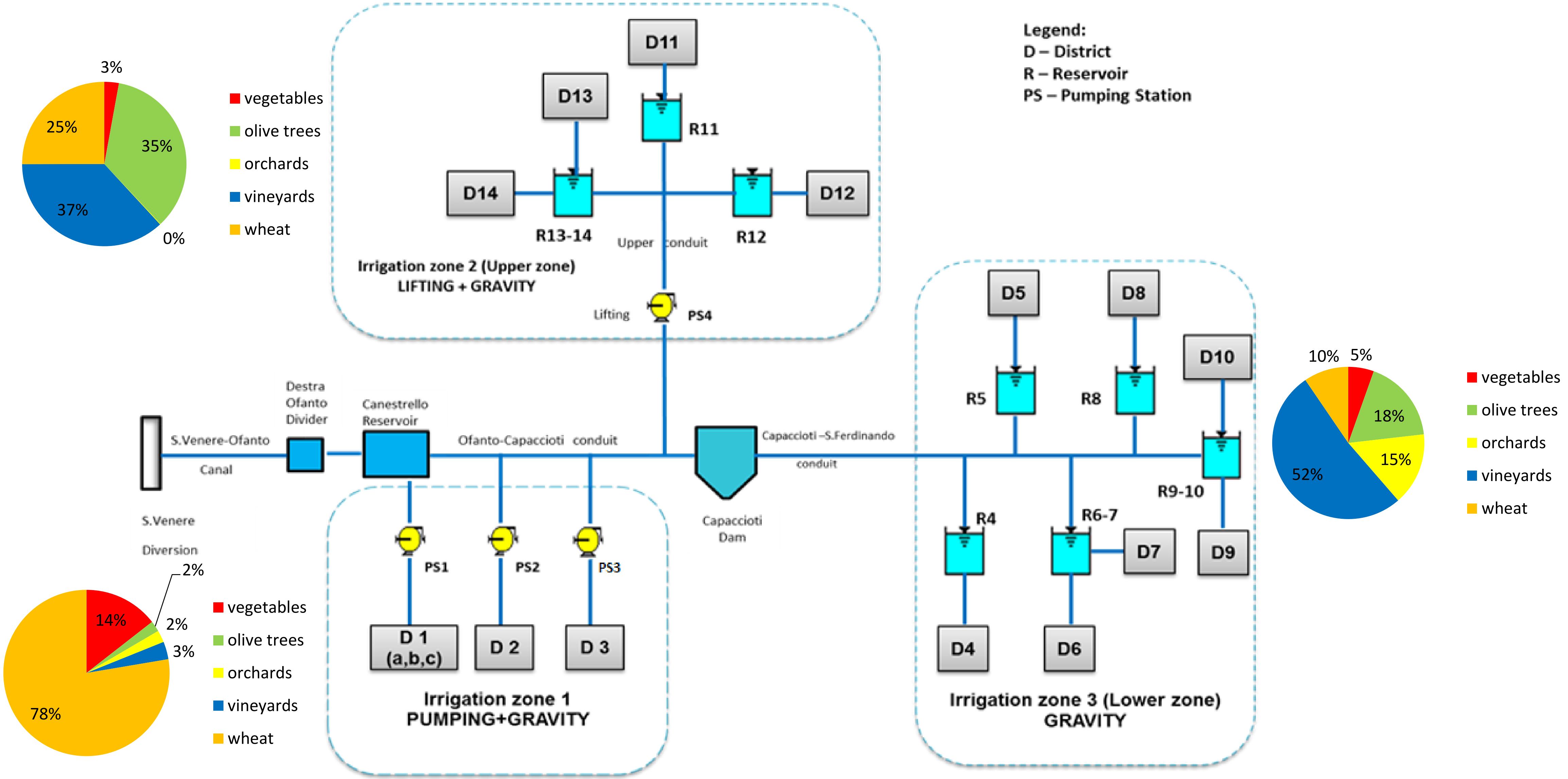
VALUE CHAIN OF WATER
FROM THE SOURCE TO THE PLOT



V indicates water volumes – inflows and outflows for different stages indicated as w (withdrawal), s (storage), c (conveyance), d (distribution), a (application). SH and EFF indicate the corresponding stakeholders and water management efficiencies, respectively.

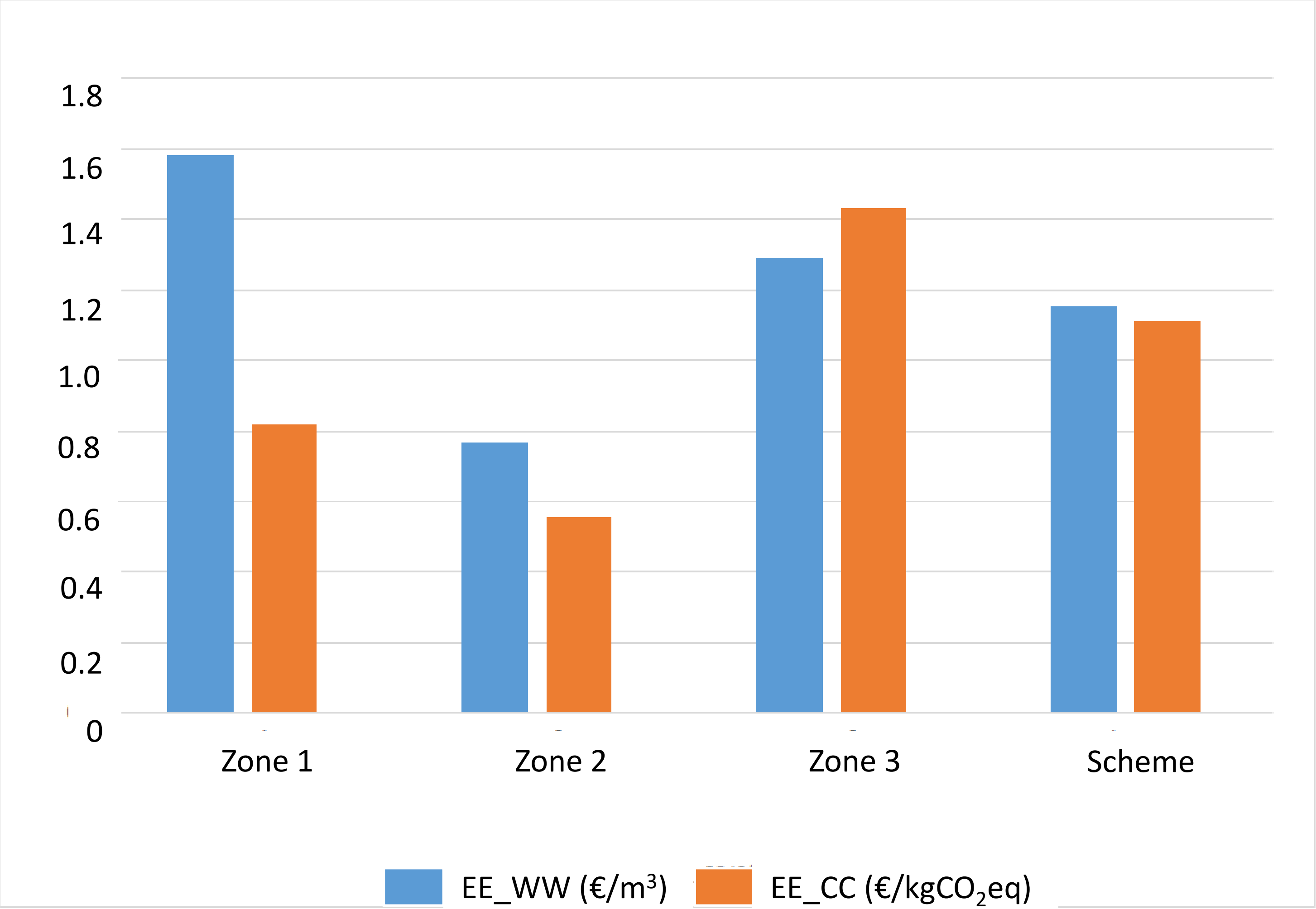
Source: Todorovic, 2017

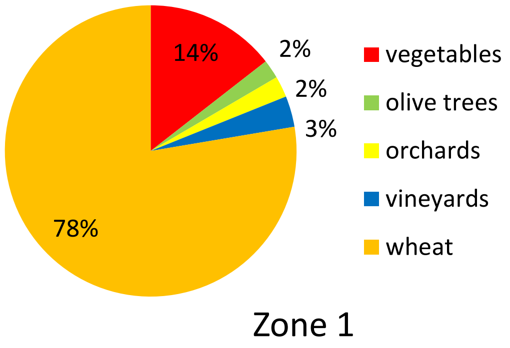
Water supply chain mapping of *Sinistra Ofanto* irrigation scheme

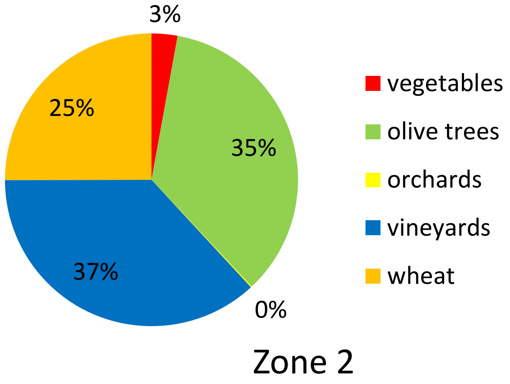


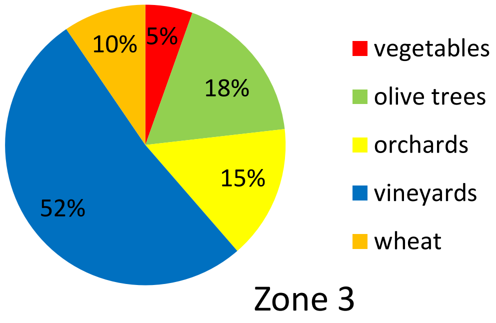
Source: Todorovic, 2018

Eco-efficiency of *Sinistra Ofanto* irrigation scheme

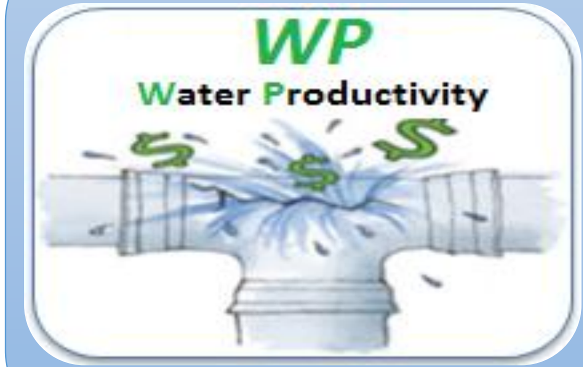








ECO-INNOVATIVE technologies for agricultural water use



Monitoring SPAC, smart irrigation scheduling

More efficient irrigation techniques (drip, subsurface)

Remote automated control of irrigation water supply

Devices for control of water withdrawal from aquifers

Cropping pattern change

Use of treated waste water

Energy Efficiency

Electricity/Solar powered irrigation pumps

Eco-friendly variable speed pumps

Network sectoring and dynamic pressure regulation

ECOFARM

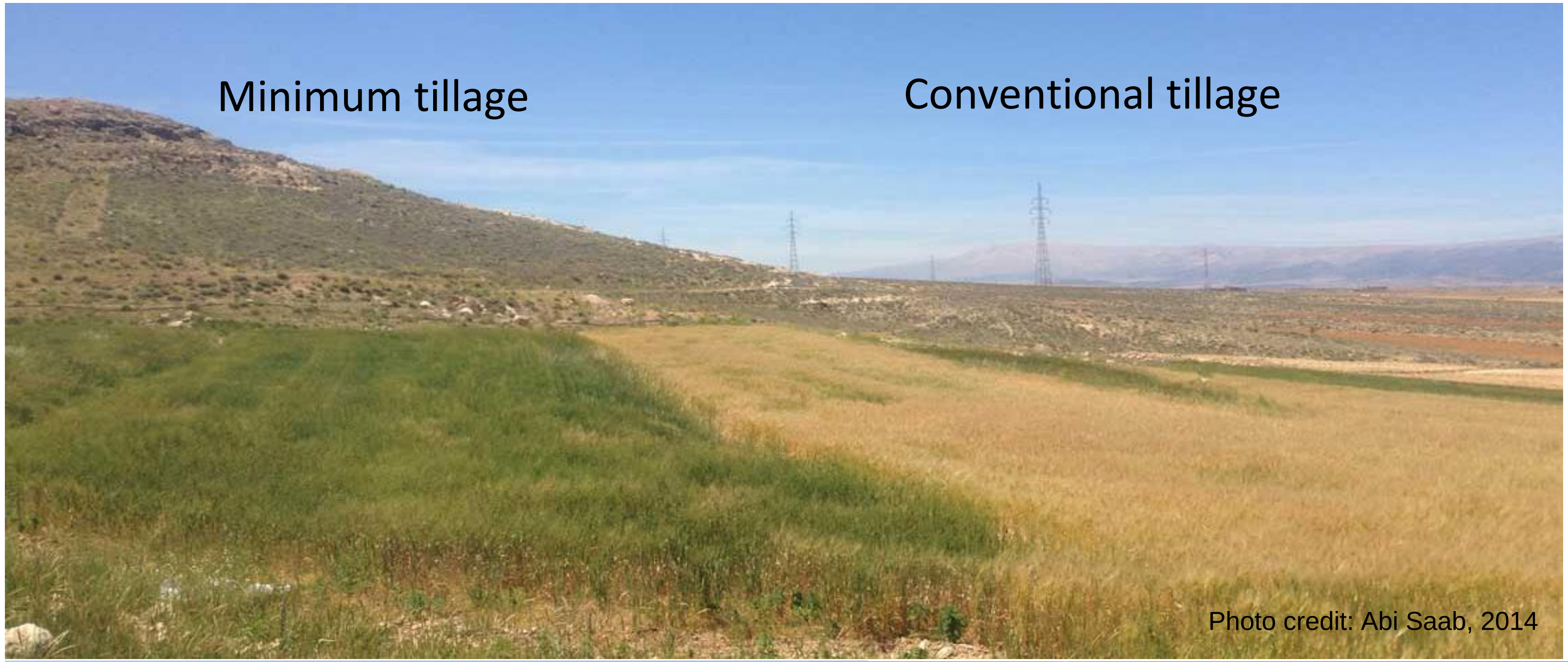
Cropping pattern

Application of minimum tillage

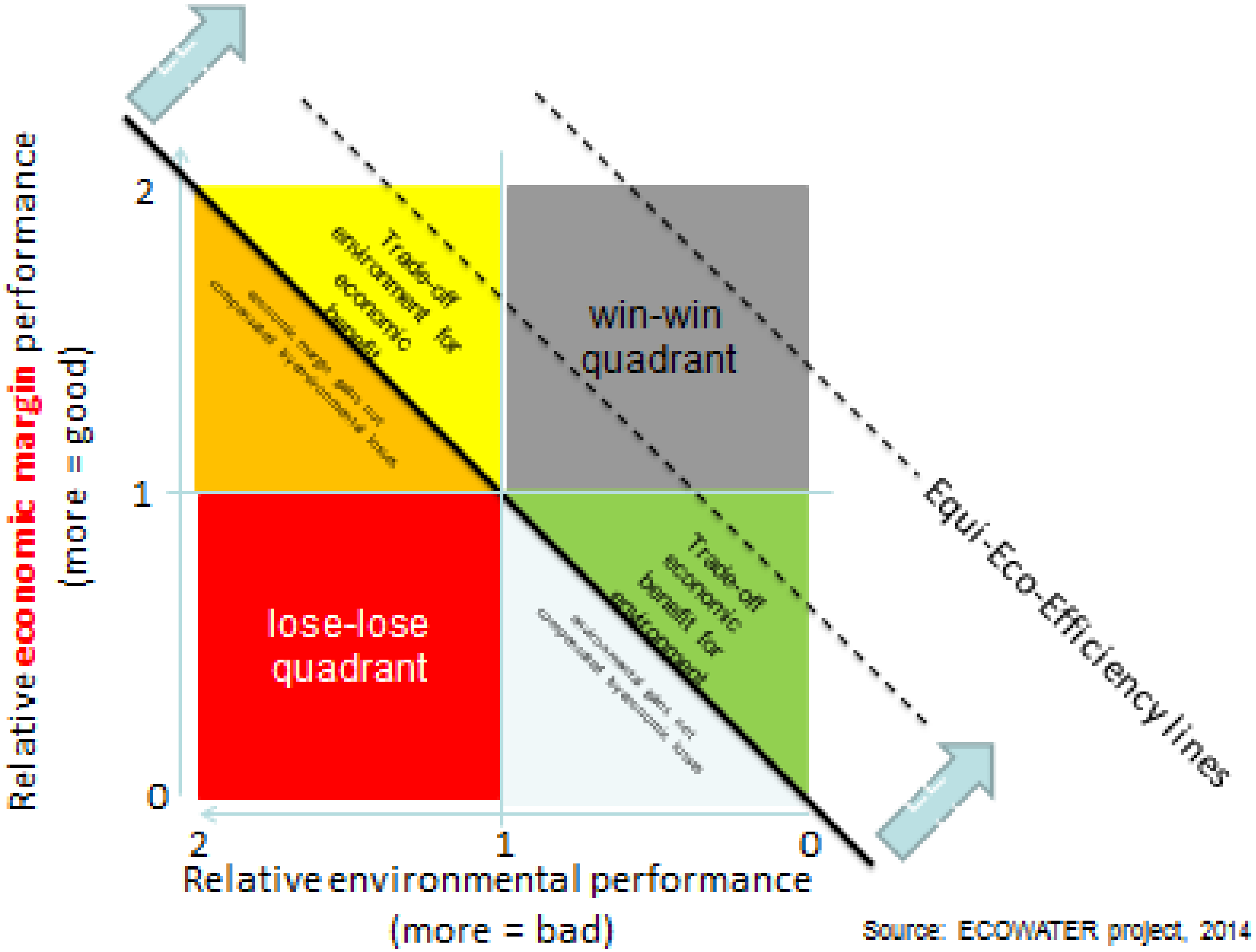
Use of biodegradable mulches

Organic Farming (fertilizers, etc.)

SMART (ECO-EFFICIENT) AGRICULTURE … without irrigation



Way forward ...



Source: ECOWATER project, 2014

CIHEAM STRATEGIC AGENDA 2025

PROTECT THE PLANET

Combating
Triple Waste

1 Knowledge and Know-How
2 Natural Resources and Energy
3 Food Chain

FOOD SECURITY AND NUTRITION

Boosting
Sustainable Agriculture and Food

4 Mediterranean Diet
5 Agro-Ecology
6 Food Safety & Quality
7 Access to Food

INCLUSIVE DEVELOPMENT

Investing
in New Generations and Fragile Territories

8 Youth employability and employment
9 Rural and Coastal Development
10 Gender Equality and Vulnerable Groups Inclusion
11 Agro-Smart Business

CRISES AND RESILIENCE

Preventing
Risks and Managing Tensions

12 Mobilities & Migrations
13 Climate Change
14 Animal and Plant Health
15 Agricultural Markets

OUR TOOLS

- Education and Training
- Research and Innovation
- Networks and Open Knowledge Platform
- Project and Technical Assistance
- Policy Dialogue and Partnership

OUR APPROACHES

- Holistic Vision of Development
- Multilateral Approach
- Bottom-Up Collaboration
- Problem Solving Oriented Projects

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