Adoption of Improved Water Technology in Agriculture: Drivers and Barriers

11th Rosenberg International Forum on Water Policy University of Cape Town, 24-27 October 2023

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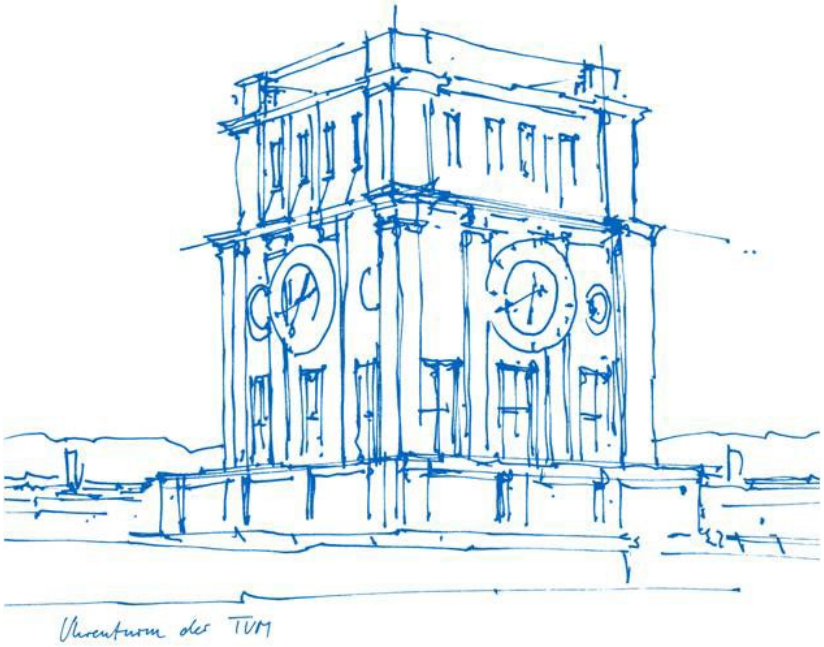

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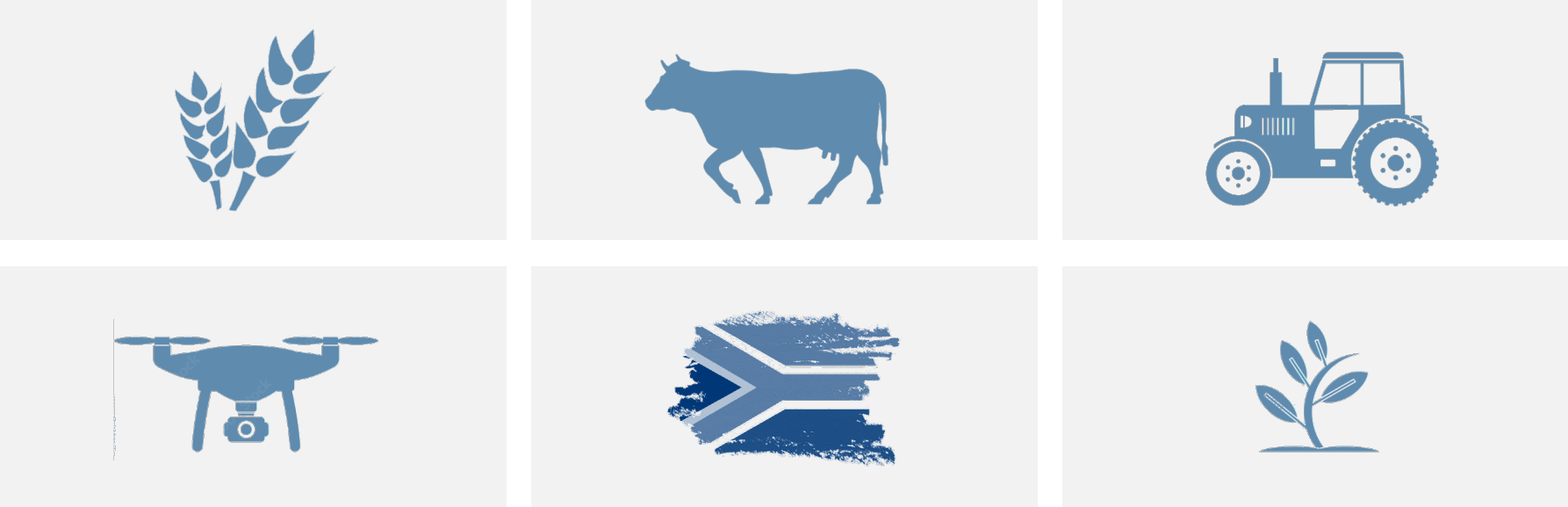


Outline

I. Water Scarcity and Agriculture

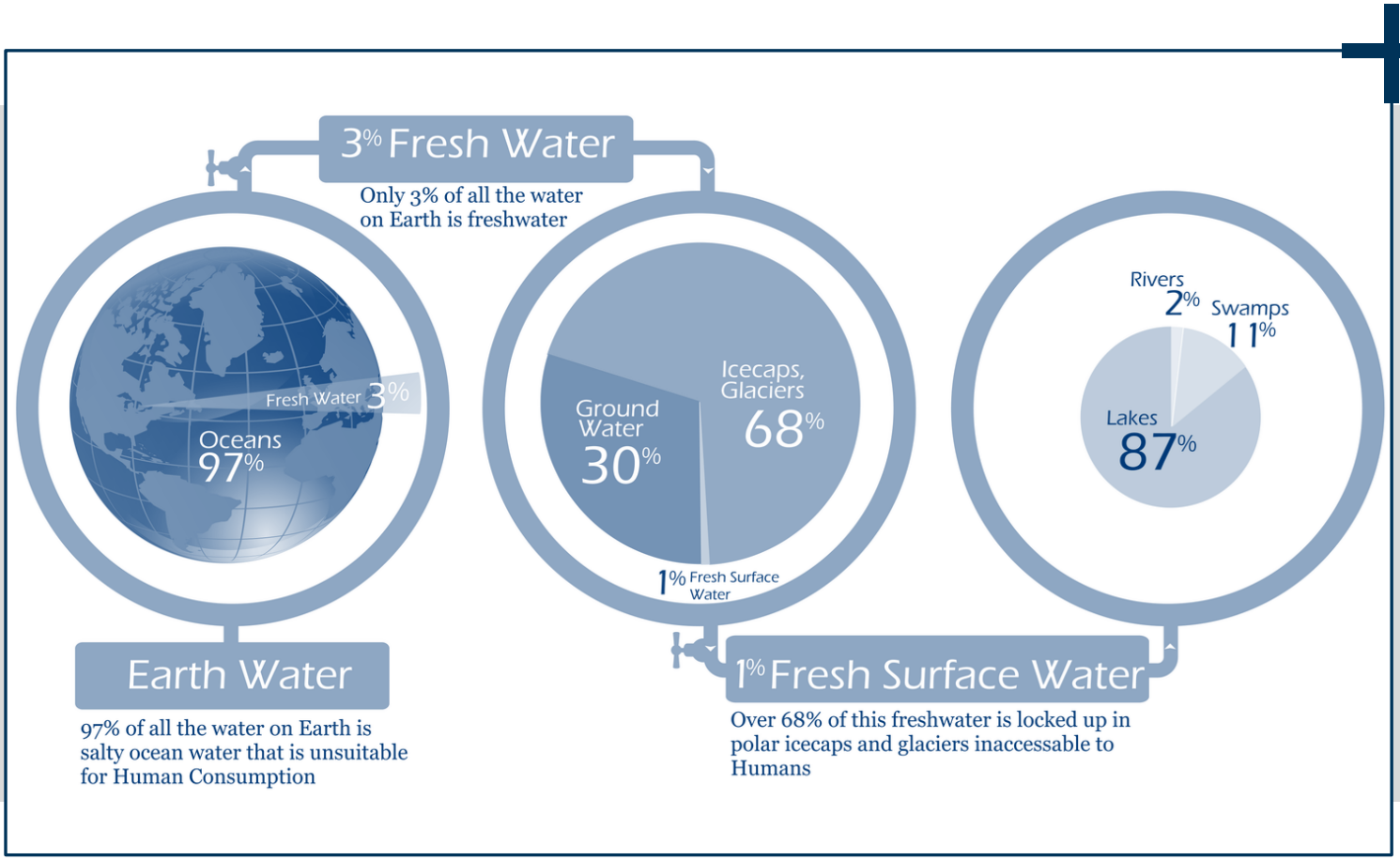
II. Technology and Adoption

III. Drivers and Barriers

IV. Measurement

V. Conclusion

Water on Earth



Water Stress and Water Scarcity

(1) Increase in population (world population projected to reach 8.6 billion by 2030).

(2) Steadily increasing agricultural and industrial production (competition among different users is rising).

(3) Significant water pollution and wastage.

(4) Climate change intensifies the situation (supply of water is becoming more unpredictable due to climate change).

Water: Scarce natural resource with high demand from multiple users.

Why agricultural water?

Agriculture: Largest user of freshwater withdrawals worldwide (70-90%).

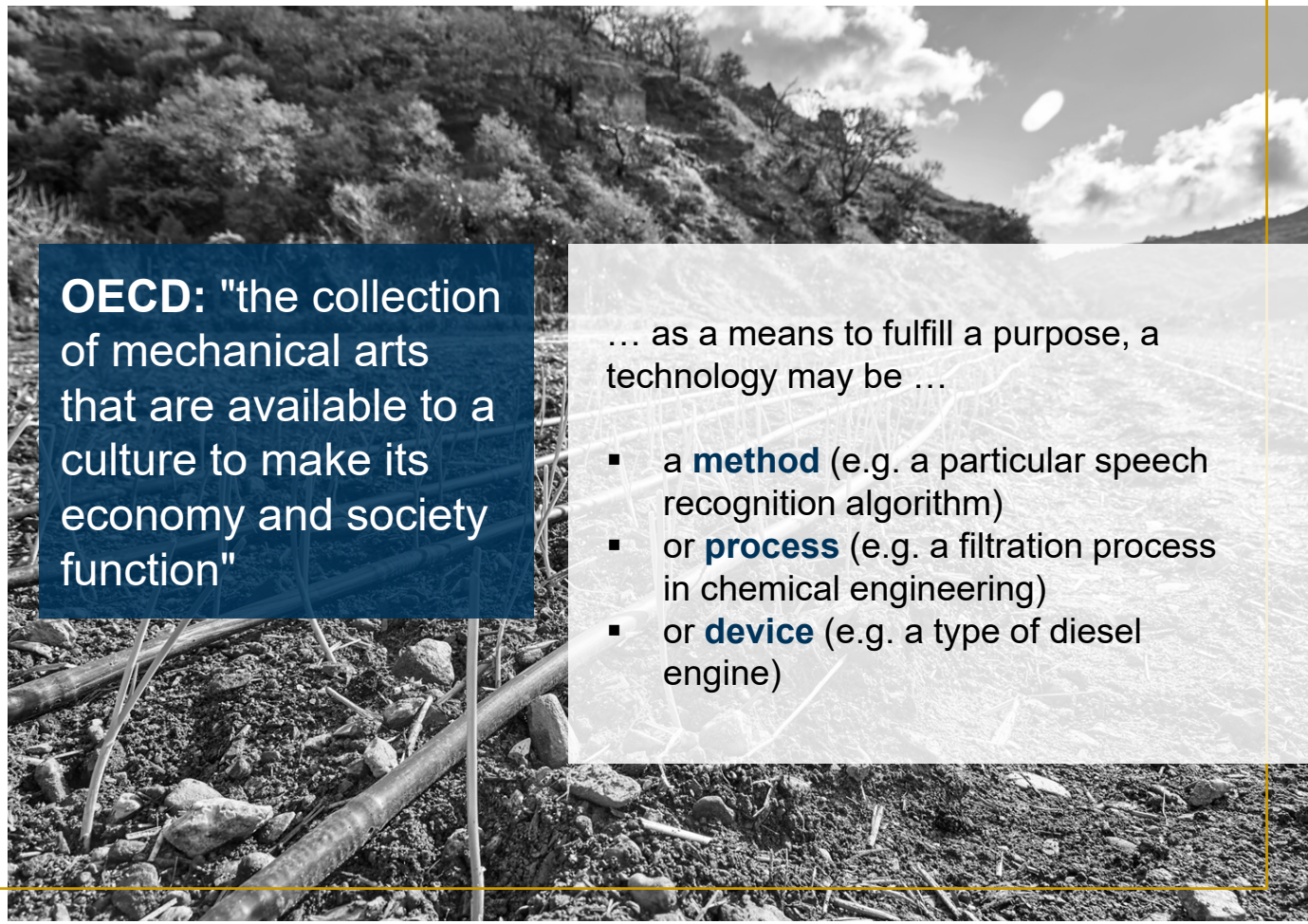
Current Direction: Sustainable agricultural water management initiatives.

Shift to more efficient, water-saving irrigation technologies (FAO 2012, IFPRI 2017, United Nations 2015, World Bank 2017)

Enhance the economic performance of irrigated agriculture and promote the sustainability of agricultural production.

What is technology?

- a technology is a **means to fulfill a human purpose**
- a technology is an **assemblage of practices and components**
- a technology is the **entire collection of devices and engineering practices available to a culture**



OECD: "the collection of mechanical arts that are available to a culture to make its economy and society function"

… as a means to fulfill a purpose, a technology may be …

- a **method** (e.g. a particular speech recognition algorithm)
- or **process** (e.g. a filtration process in chemical engineering)
- or **device** (e.g. a type of diesel engine)

What is technology?

$Y = f(X)$

Y = agricultural output

f = general agri production technology

X = (x_1 labor, x_2 land, x_3 water … x_n)

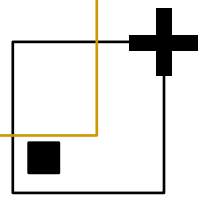
$x_3 = g(x_{w4}$ wat purch, x_{w1} labor, x_{w5} material, x_{w6} capital …)

g_o = irrigation technology

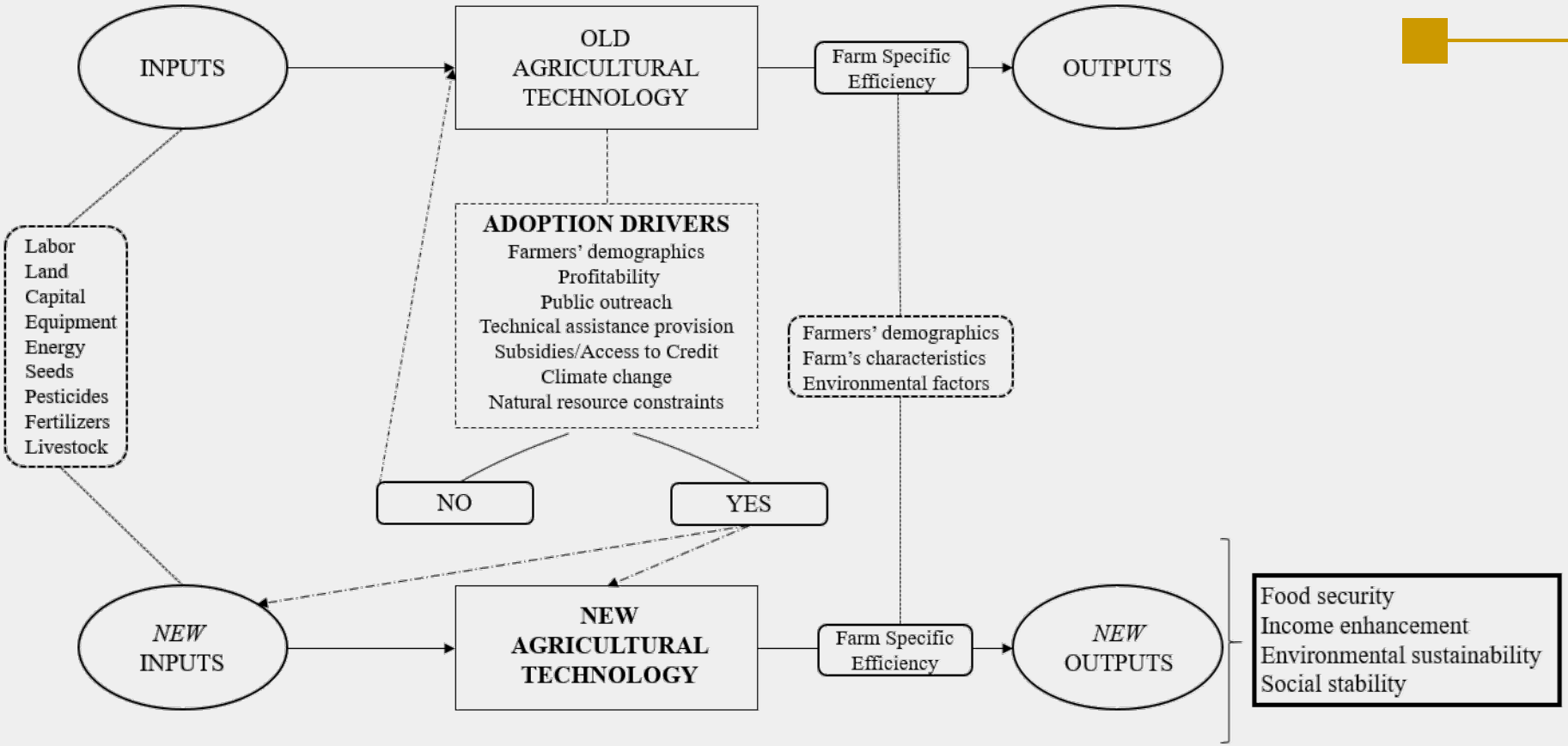
XW = water specific (share of) inputs

g_n = AI controlled irrigation technology

$Y = f(X, \mathbf{g_n(XW)}, Z)$



Adoption of Agricultural Technologies



Technology Adoption and Diffusion

Hypotheses to explain direction of technological change

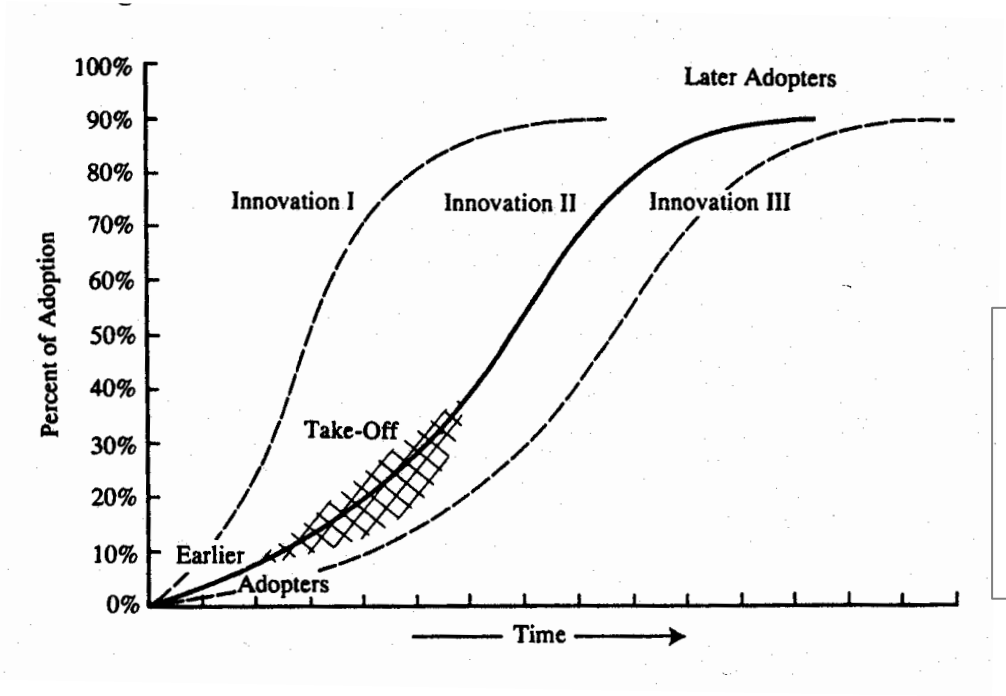
Hypothesis of entrepreneurship
(J. Schumpeter, T.W. Schultz)

Hypothesis of induced innovation
(Y. Hayami, V. W. Ruttan und H.P. Binswanger)

Hypothesis of path dependency of technological change
(N. Rosenberg, W.B. Arthur)

Technology Adoption and Diffusion

S-shaped diffusion curve

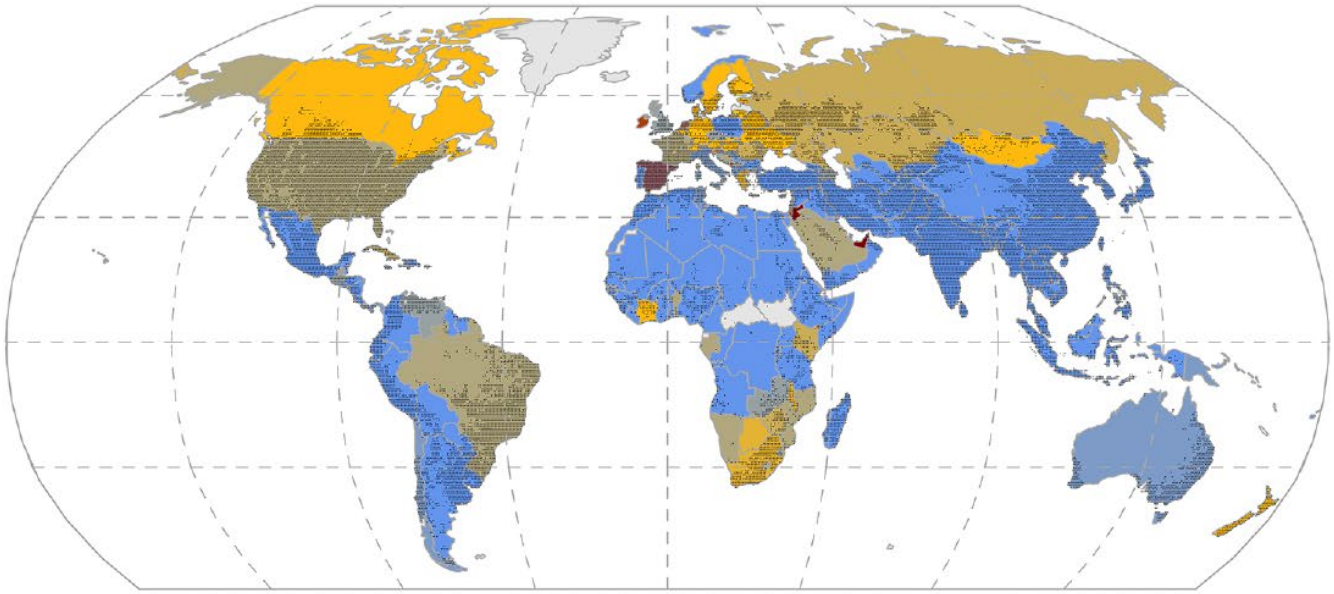


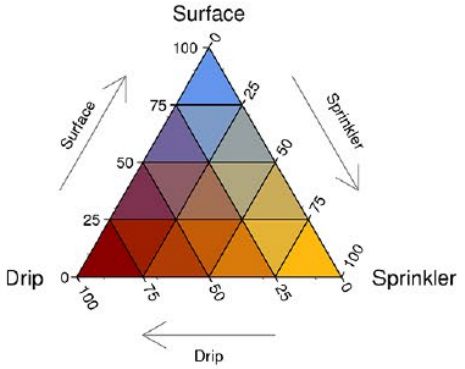
Rogers (1962, 1995)

… diffusion as the process by which an innovation is **communicated** through certain channels over time among the members of a social system

… found that diffusion is an **S-shaped function of time**

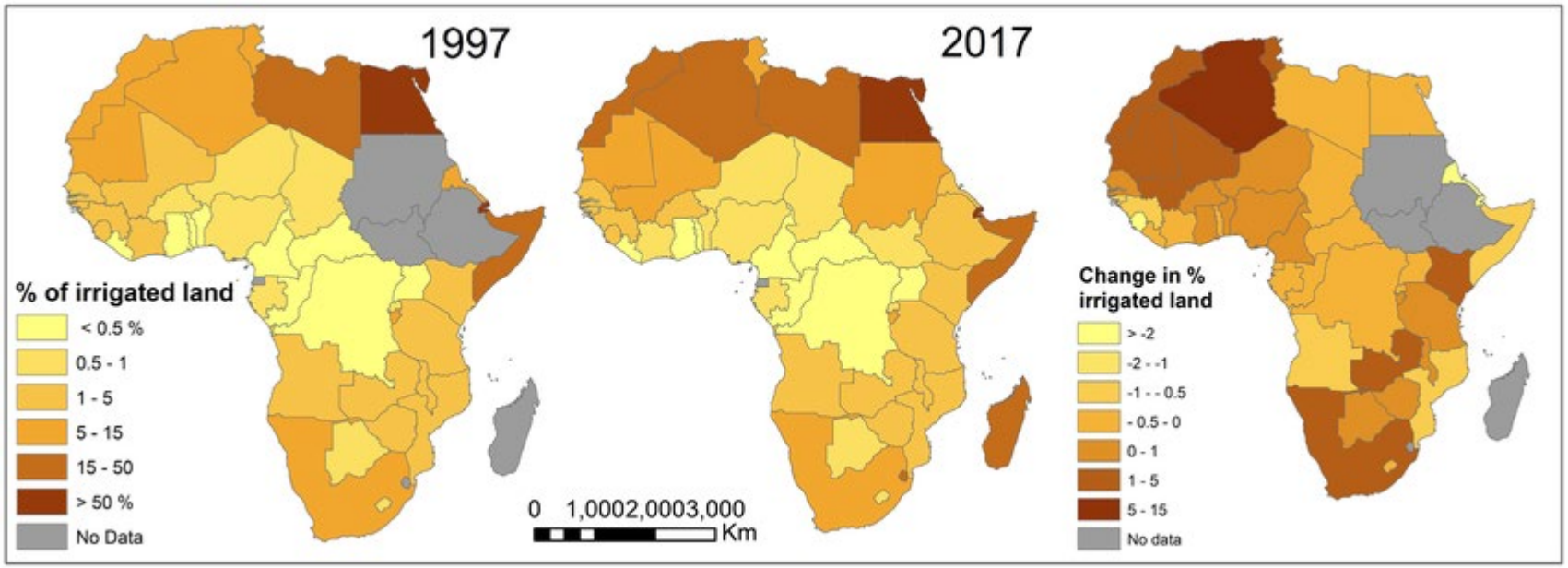
Global Irrigation Technology Pattern





(Jägermeyr et al., 2015)

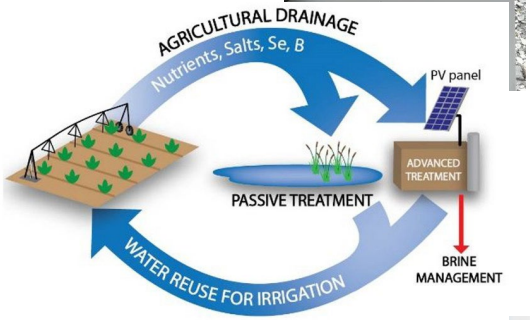
Change in % Irrigated Land in Africa



Emerging Approaches

In the last years, alternative approaches to water-conservation technologies have emerged that started to gain more attention

- Groundwater management and metering
- Reuse of treated wastewater
- Implementation of AI in irrigation control
- Connection with other existing technologies (complementarity and substitutability)



Benefits of Improved Water Technology

The adoption of water conserving irrigation technologies can:

Decrease crop failure risk associated with extreme climate events	**Conserve natural resources**	**Boost crop yields and farm employment**	
Increase agricultural production	**Improve land productivity**	**Enhance Incomes and Food Security**	

Example: Drip irrigation

+

Increased Crop Yields
Water Conservation
Improved Crop Quality
Reduced Labor Costs
Minimized Soil Erosion
Adaptation to Climate Change
Diversification of Crops

−

High initial costs
Clogging

Adoption Decision

With new technology available it still is on the farmers to adopt it.

“[Adoption is] a decision to make full use of an innovation as the best course of action available” (Rogers, 1995)

Different factors were found to influence the adoption of advanced water technology for farmers all over the world.

- Socioeconomic drivers
- Environmental drivers
- Institutional drivers

Socioeconomic Drivers

Age: the younger, the more open to new technologies

Availability of financial and technical support, i.e. extension services

Feder G, Just RE, Zilberman D (1985) Adoption of agricultural innovations in developing countries: A survey. *Econ Dev Cult Change* 33:255–298

Green, Gareth, David Sunding, David Zilberman, and Doug Parker. Explaining irrigation technology choices: a microparameter approach. *American Journal of Agricultural Economics* 78, no. 4 (1996): 1064-1072.

Feder G, Umali DL (1993) The adoption of agricultural innovations. A review. *Technol Forecast Soc Change* 43:215–239.

Income level and affordability

Agroclimatic | Environmental Drivers

Farm size and tenure

Caswell, M.F., and Zilberman, D. (1986). The Effects of Well Depth and Land Quality on the Choice of Irrigation Technology. *American Journal of Agricultural Economics* 68,4(1986):798–811.

Caswell, M.F. (1991). Irrigation Technology Adoption Decisions: Empirical Evidence. In: Dinar, A., Zilberman, D. (eds) *The Economics and Management of Water and Drainage in Agriculture*. Springer, Boston, MA.

Dinar, A., Campbell, M.B. & Zilberman, D. Adoption of improved irrigation and drainage reduction technologies under limiting environmental conditions. *Environmental and Resource Economics* **2**, 373–398 (1992).

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Institutional Drivers

Outreach support and education programs

Caswell, Margriet, Erik Lichtenberg, and David Zilberman. The Effects of Pricing Policies on Water Conservation and Drainage. *American Journal of Agricultural Economics* 72, no. 4 (1990): 883–90.

Scheierling, S.M.; Young, R.A.; Cardon, G.E. Public subsidies for water-conserving irrigation investments: Hydrologic, agronomic, and economic assessment. *Water Resources Res*earch 2006, 42, W03428.

Dinar A, Karagiannis G, Tzouvelekas V (2007) Evaluating the impact of public and private agricultural extension on farms performance: A non-neutral stochastic frontier approach. *Agricultural Economics* 36:135–146.

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Potential Barriers

Heterogeneity in the adoption of new water technologies can stem from:

Risk Preferences
Actual/observed Risks
Knowledge and Ability
Access to Credit, Market Distance, Infrastructure
Local/Regional Policy Discrepancies
Technological Externalities and Learning
Free-Riding Behavior

Empirical Measurement | Adoption | Ex Ante

Depending on specific research problem, dependent on setting and resources …

- experiments: field or lab
- RCTs
- Stated Preferences Approaches (wtp | wta)
  - Choice Modelling
  - Contingent Valuation

Scenario 1: Suppose options A, B and C are the ONLY ones available

Note: The first column describes different characteristics that will change under different wetland management options. The next columns describe different outcomes of the wetland management options.

The following factors will vary under different management options	OPTION A (status quo- no change)	OPTION B	OPTION C
Percentage of area having healthy vegetation 	50%	60%	80%
Number of Sarus cranes visiting the wetlands 	150 birds	300 birds	450 birds
Number of fish species 	40 species	50 species	70 species
Number of local households worse-off 	0	900	900
Once-off change in your current monthly electricity bill 	No change	Increase VND 10,000	Increase VND 50,000

If there were a vote (in which if the majority votes for the option you choose then the option will be selected), you would vote for:

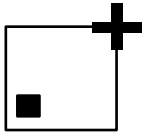
TICK ONE BOX ONLY

Option A ☐
Option B ☐
Option C ☐

Empirical Measurement | Adoption | Ex Post

Depending on specific research problem, dependent variable and nature of data …

- discrete, continuous or limited dependent variable (adoption), e.g. number of adopters, share of adopters, speed of adoption etc.
- cross-section, panel, time-series data
- bias remedies: endogeneity, selection (un-/observable)
- sequential technologies, complementary technologies, bundles
- micro vs. macro focus (e.g. institutional framework, innovation system)



Empirical Measurement | Impact

Depending on specific research problem, outcome indicator and nature of data …

- identification strategy is key

Balancing covariates between adopter farms and non-adopter farms before adoption through **Propensity Score Matching** to identify suitable treatment and control groups

Estimating the effect of adoption via **Difference-in-Difference** (control group: non-adopter farms)

Dynamic analysis at sector level: **Time-Series Autoregressive Distributed Lagged Model** (ARDL) after structural break test

Dynamic analysis at farm level: **Panel Regression (Fixed Effects Model)**

Statistical identification of dynamic drivers for impact at farm level: **Multinomial Regression**

Comparing changes of an aggregate outcome (e.g. yield/income per region) between an adopter region and non-adopter region **Synthetic Control Units/Groups (SCG)**

One can build synthetic control regions based on a donor pool of untreated units to establish causality; variables to form weights needed, typically on an aggregate level

Conclusion

1- While there are many promising approaches to conserve agricultural water and to make its use most effective, adoption rates are still too low …

… policy intervention is needed to overcome the barriers.

2- Contribute toward improved agricultural water policies by estimating the magnitude of gains from the more effective use of water in agriculture …

3- Effectiveness of these policies depends on the proper measurement of agricultural water efficiency and water's contribution to agricultural productivity

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THANK YOU VERY MUCH

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