IRRIGATION WATER BENEFITS WITHIN THE FRAMEWORK OF OPTIMAL WATER ALLOCATION IN THE ALFEIOS RIVER BASIN (GREECE)

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UNIVERSITY OF PATRAS

European Union
European Social Fund

OPERATIONAL PROGRAMME
EDUCATION AND LIFELONG LEARNING
investing in knowledge society
MINISTRY OF EDUCATION, LIFELONG LEARNING AND RELIGIOUS AFFAIRS
MANAGING AUTHORITY
Co- financed by Greece and the European Union

NSRF 2007-2013
programme for development
EUROPEAN SOCIAL FUND

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- Alfeios River Basin
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- CROPWAT and water-yield relationship
- Optimal water allocation technique under uncertain system conditions (Li et *al*., 2010)
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INTRODUCTION

- **Enactment of Water Framework Directive:** optimisation of water allocation

- **Benefit analysis**: determination of water value allocated to each water use

- Main water user in Mediterranean regions: **Agriculture:** fundamental social, economic and environmental role → **agricultural income**

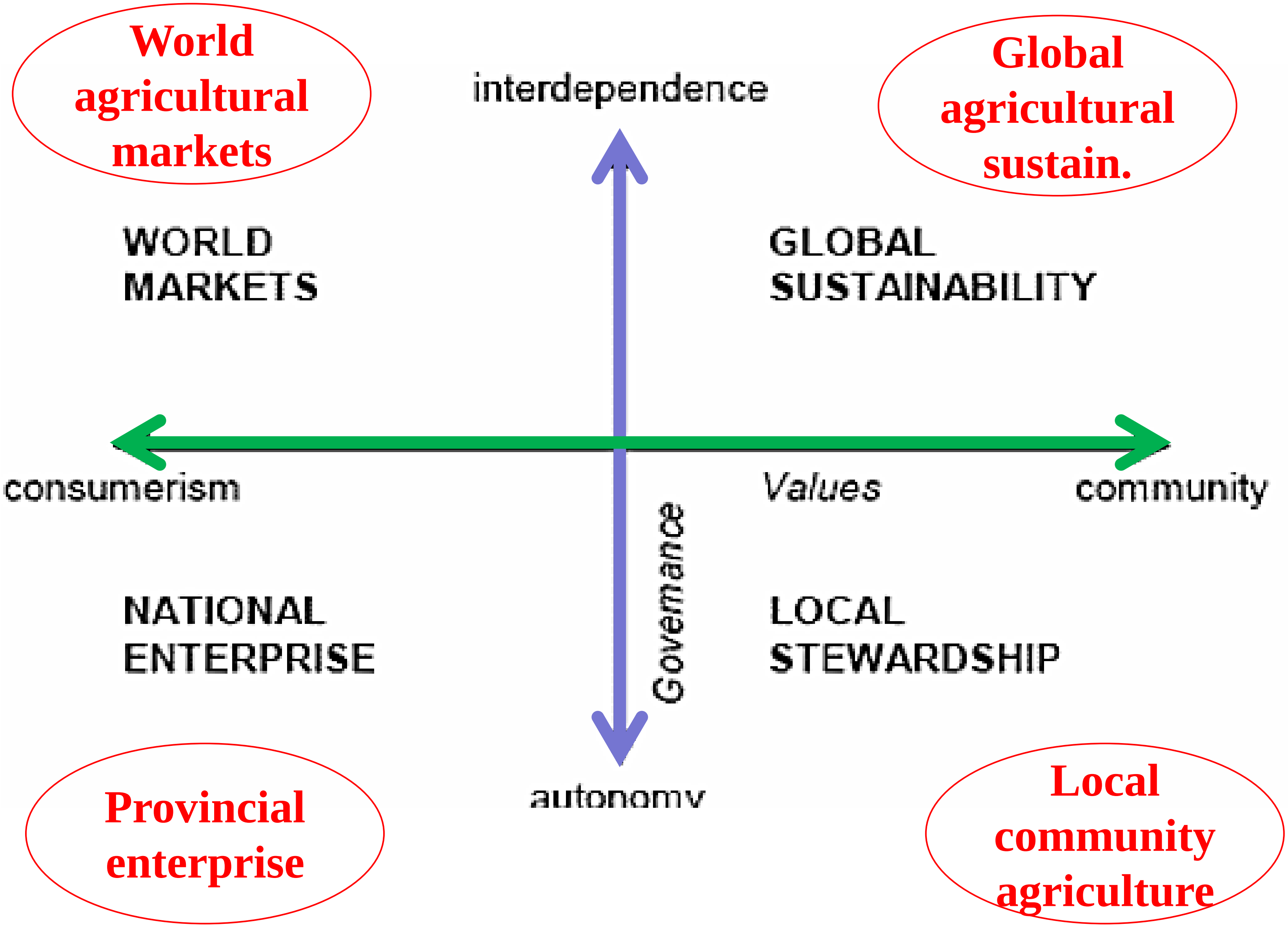
- **Aim:**

  Estimation of irrigation water benefits for various EU agricultural scenarios (WADI) based on an optimal water allocation technique under uncertain system conditions (Li et *al*., 2010)

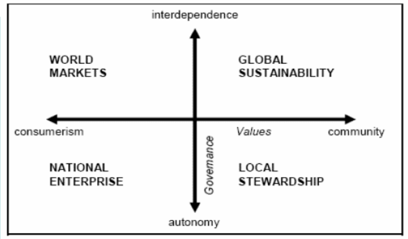
AGRICULTURAL FUTURE SCENARIOS

- **WADI Project:**
  - Alternative agricultural and water policy future scenarios expressing changes in the EU agricultural policy
  - Exploring economic, social and environmental performance of irrigation
  - Based on future scenarios of UK “Foresight“ programme
  - Combination of governmental and social preference in water policy
  - Based on past trends as starting point (Baseline Scenario): Narrative and qualitative indicator values

AGRICULTURAL FUTURE SCENARIOS



AGRICULTURAL FUTURE SCENARIOS



	Baseline	World agricultural markets		Global agricultural sustainability		Provincial agriculture		Local community agriculture	
Crops selling prices perceived by farmers		**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Maize	100	85	95	95	105	100	110	100	110
Maize area subsidy	100	0	0	75	85	90	100	85	95

Input Variables in agricultural production:

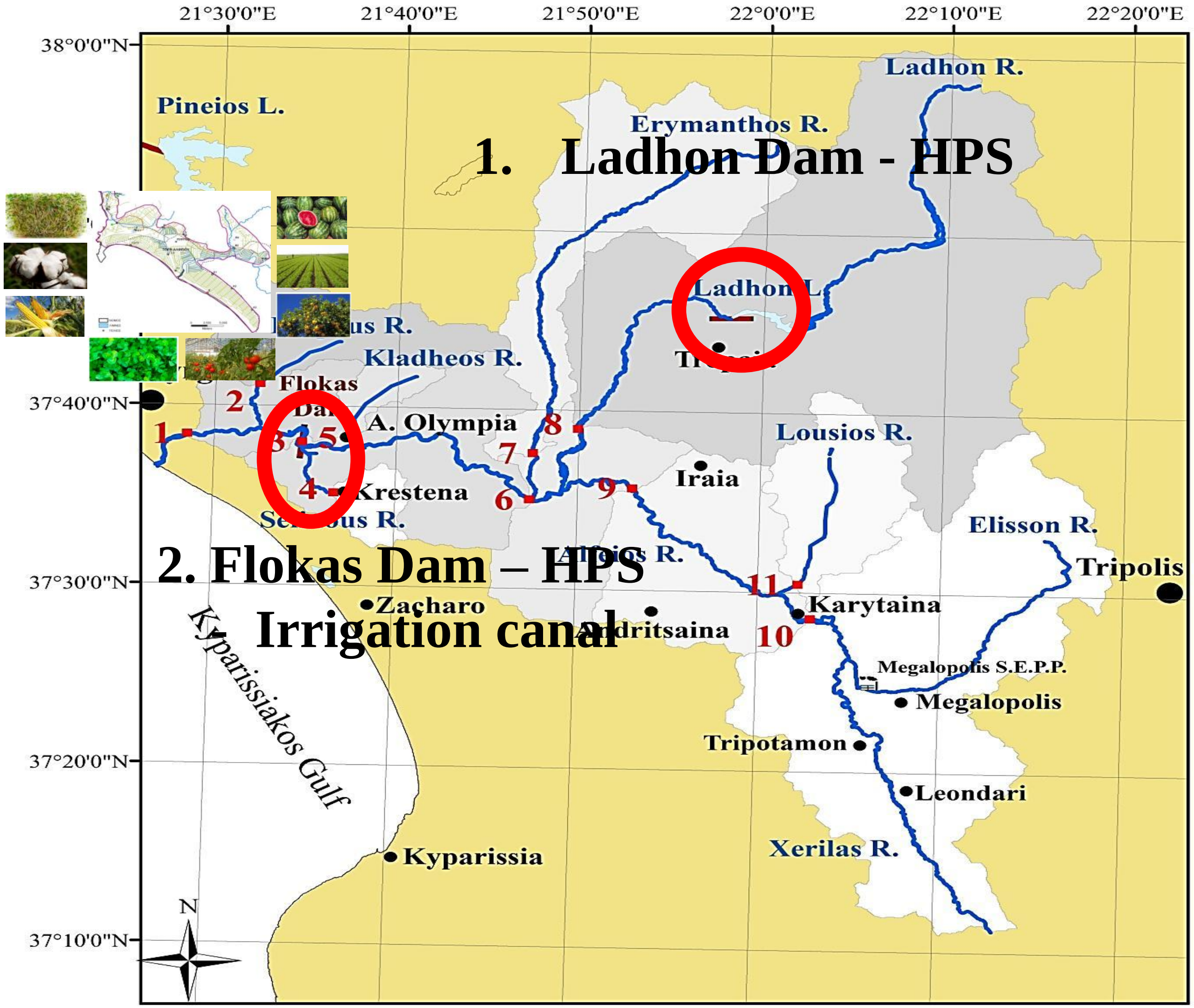
Seeds, Machinery, Water Prices, Contractor services, Labour, Land, restriction on chemical use, etc.

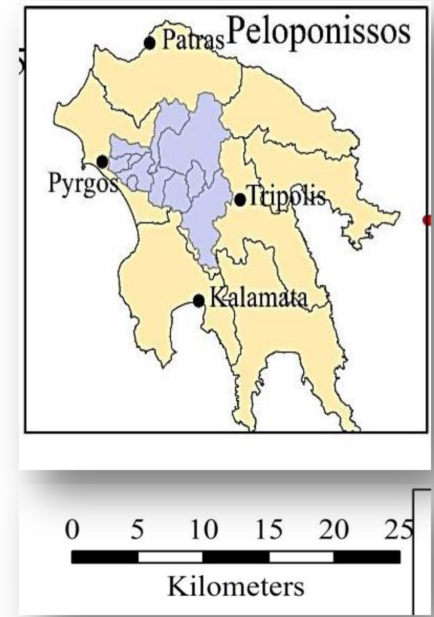
Fertilisers	100		85	100	140	150	100	110	150
Pesticides	100		110	120	100	105	105	115	95
Energy	100		85	95	120	130	100	110	130

ALFEIOS RIVER BASIN

1. Ladhon Dam - HPS

2. Flokas Dam – HPS
- Irrigation canal

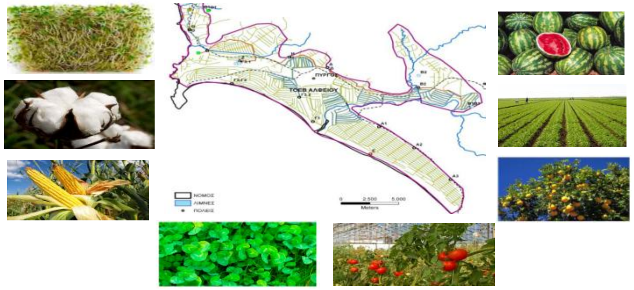




ALFEIOS RIVER BASIN

Flokas Irrigation canal:

- **Primary sector – agriculture:** significant source of employment and commercial activity



- **Present irrigated area:** 50-60% (**12,250** ha)
- **Irrigation period:** Mid April to Mid October
- **Main Crop pattern:** Alfalfa (16%), Maize (43%), Citrus (14%), Cotton (9), Watermelons (8%), Tomatoes (4%), Potatoes (3%), Olive Trees (3%)
- **Irrigation systems:** Surface, drip irrigation and sprinklers
- **Irrigation canal losses:** 20-30%

INPUT VARIABLES

- **Technical, economic and social input parameters for crop pattern of Flokas irrigation canal:**

  - Min and Max Crop Production (kg/ha)
  - Min and Max Selling price (€/kg)
  - Min and Max Cost of Production (€/kg)
  - Min and Max Subsidies (€/ha)

- **Estimation of Min and Max Net Farmer Income (€/m^3)**

CROP WATER REQUIREMENTS

- **CROPWAT 8.0 FAO software:**

  - **Reference Evapotranspiration:** Penman-Monteith method based on climatic data of Pyrgos station (1946-2006)

  - **Effective Rain:** USDA-SCS method based on rainfall data of Pyrgos station (1946-2006) --- Normal, Dry and Wet Year

  - **Crop and soil data:** based on FAO and local data

Normal Hydrologic Year	Cotton	Alfalfa	Maize	Citrus	Watermelon	Tomato	Potato	Olive Trees
Total irrigation water demand m^3 CROPWAT	3.734.169	7.895.448	16.236.530	4.405.013	2.357.317	1.357.316	803.288	682.229
Min real total irrigation water demand m^3	8.343.626	17.940.747	36.572.020	9.074.353	5.081.087	2.901.734	1.794.043	1.333.044
Max real total irrigation water demand m^3	12.739.776	28.304.314	56.733.790	13.594.060	7.668.320	4.327.511	2.736.793	1.888.267

WATER – YIELD RELATIONSHIP

- **Simple Linear Relationships between crop yield and water supply:**
  - based on **FAO paper No. 33** (Doorenbos and Kassam, 1979)
  - valid for water deficits up to 50%

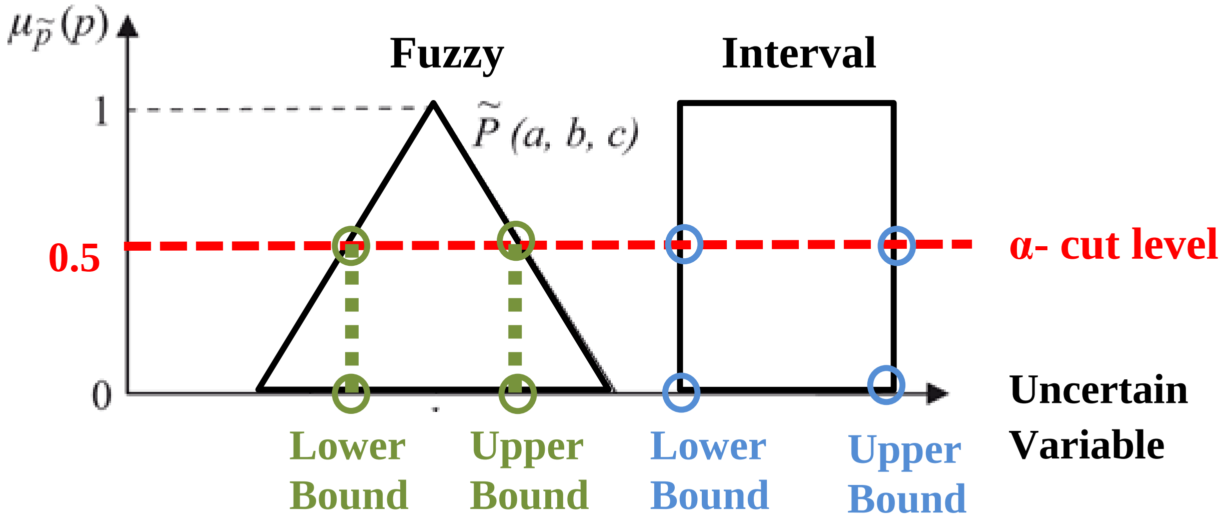
- **Estimation of crop yield reduction under water stress conditions based on:**
  - **maximum crop water requirements** ET_{pot}^{C}
  - **actual crop water availability** ET_{real}^{C}
  - **maximum and actual crop yield** y_{max} **and** y_{actual}
  - **annual yield response factors** k_y

$$\left(1-\frac{y_{actual}}{y_{\max}}\right)=k_y\times\left(1-\frac{ET_{real}^{C}}{ET_{pot}^{C}}\right) \Rightarrow y_{actual}=y_{\max}\times\left(1-k_y\times\left(1-k_r\right)\right)$$

With $k_r=\left(\frac{ET_{real}^{C}}{ET_{pot}^{C}}\right)$

OPTIMAL WATER ALLOCATION

- **Fuzzy-boundary interval - stochastic programming** (Li et al., 2010):
  - Linear optimization problem
  - **Uncertainty** as: **(a)** probability distribution, **(b)** possibility distribution, **(c)** interval
  - **Fuzzy numbers:** converted into fuzzy boundary interval through associated α-cut levels



OPTIMAL WATER ALLOCATION

- **Uncertain variables: (a)** favourable (X_{ij}^+) **& (b)** unfavourable (X_{ij}^-)

- **Two solution methods implying different risk attitudes of decision makers considering system uncertainties:**
  1. "***Risk-Prone***" or "***Optimistic***"
  2. "***Risk-adverse***" or "**Pessimistic**"

- **Solving for each solution type and α-cut level:**

  2^n deterministic submodels corresponding to all combinations of lower & upper bound value for *n* fuzzy-interval variables

- **For each solution type:** $f^{\alpha}_{opt} = \{f_{min}^{\alpha}, f_{max}^{\alpha}\}$,

  where $f_{min}^{\alpha}=\min\{f_1,f_2,.., f_{2^n}\}$

  $f_{max}^{\alpha}=\max\{f_1,f_2,.., f_{2^n}\}$

OPTIMISATION PROBLEM

(A) Objective function:

Maximise Total Benefit: Benefit(HPLadhon) - Penalty(SpillLadhon) +

Benefit(Irrigation+Extra) - Penalty(IrrigationShortage) +

Benefit(HPFlokas) - Penalty(SpillFlokas)

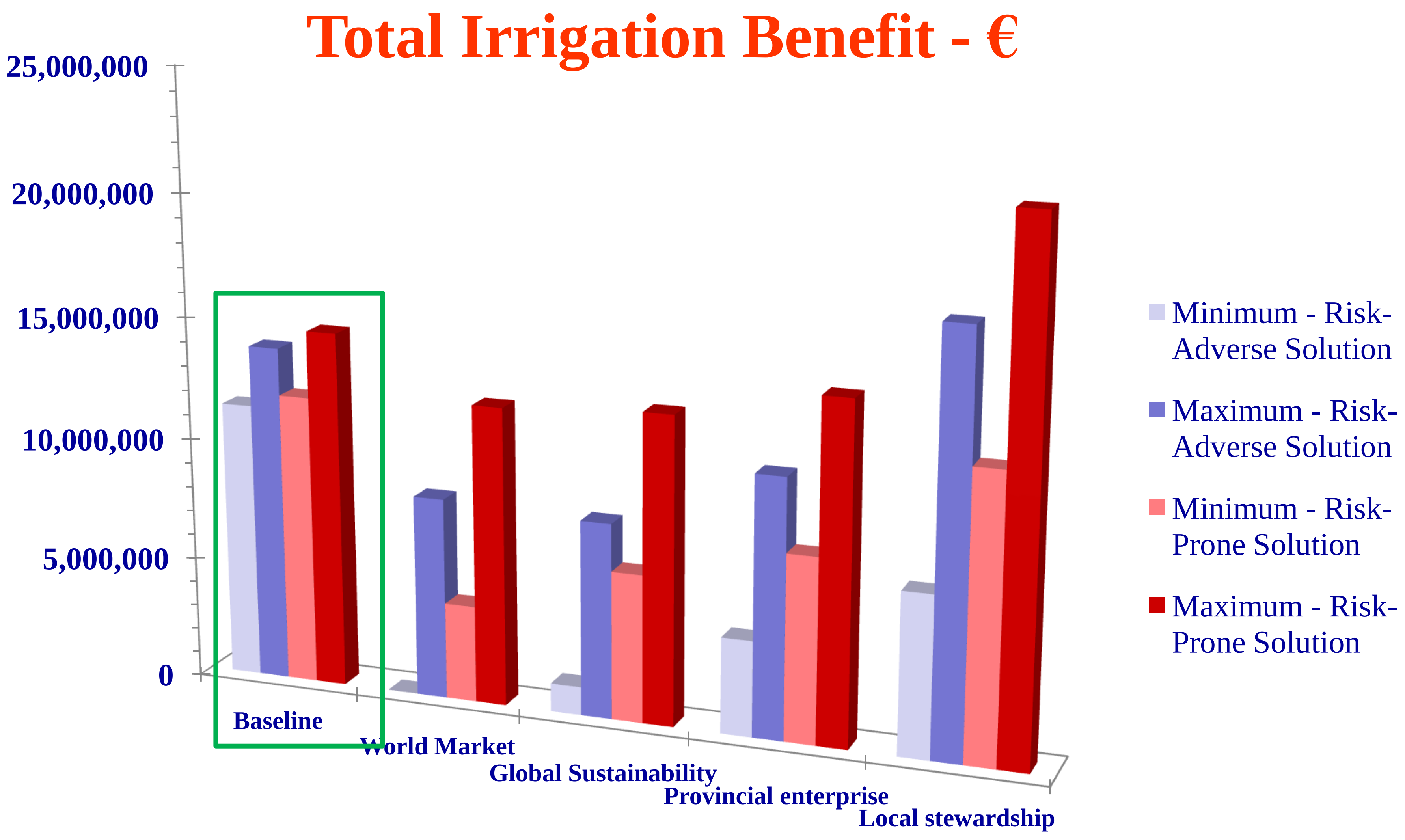
(B) Constraints: 1. Ladhon:

- Water Volume Mass Balance
- Min & Max pumping capacity
- Min & Max reservoir storage capacity
- Evaporation: linear F(average reservoir storage(t))

2. Flokas: (Degree of Ladhon Contribution to Flokas)

- Water Volume Mass Balance
- Min & Max pumping capacity & storage capacity
- Fish ladder flows & Min environmental flows

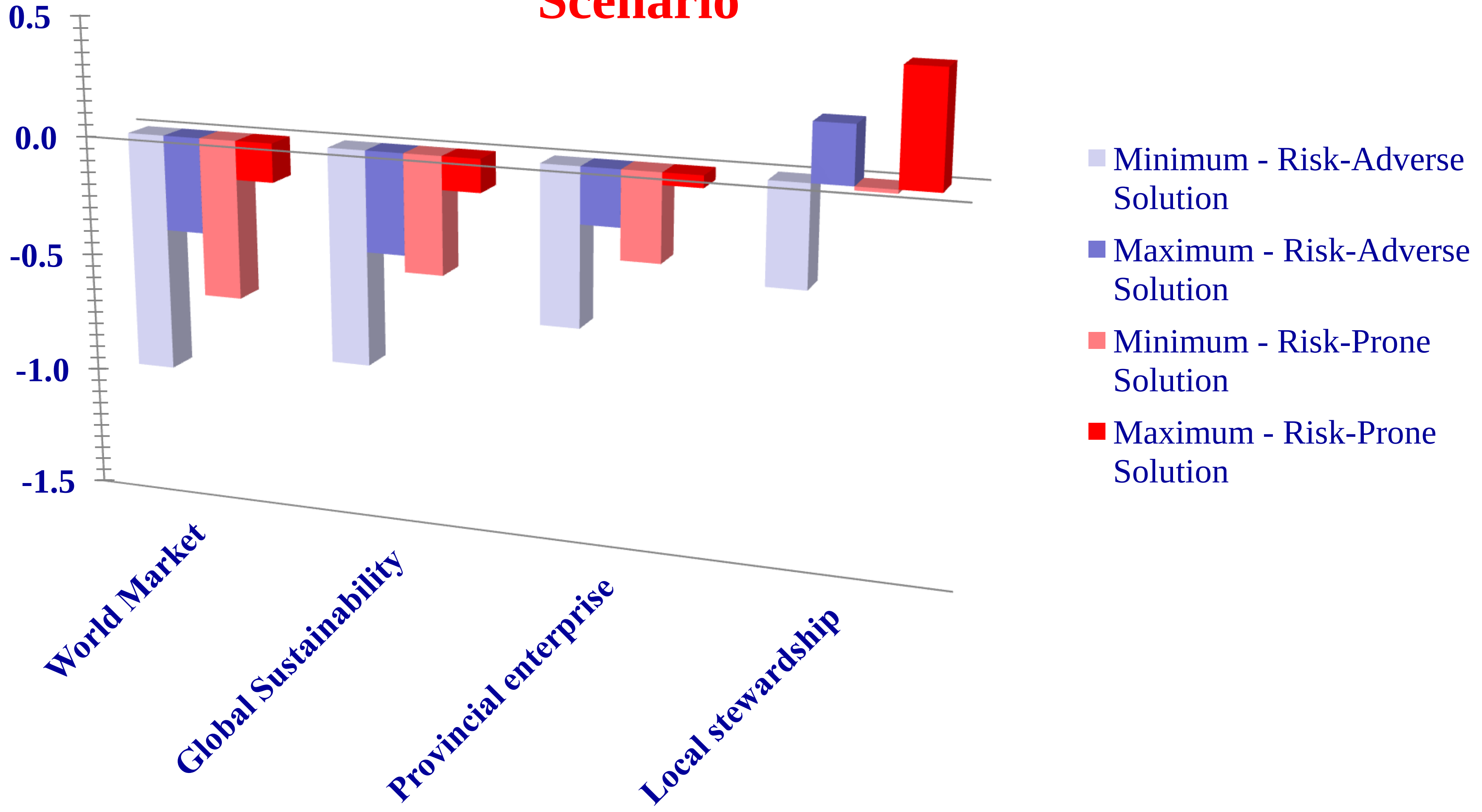
RESULTS



Total Irrigation Benefit - €
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
Baseline
World Market
Global Sustainability
Provincial enterprise
Local stewardship
Minimum - Risk-Adverse Solution
Maximum - Risk-Adverse Solution
Minimum - Risk-Prone Solution
Maximum - Risk-Prone Solution

RESULTS

% Change of Irrigation Benefit compared to Baseline Scenario



RESULTS & CONCLUSIONS

- **Irrigation Benefits of "*Baseline Scenario*":** between "***Provincial Enterprise***" and "***Local Stewardship***"
  - **Agriculture in Greece:**
    - strong social character and protectionism
    - **BUT:** with a decreasing trend due to reforms of Common Agricultural Policy

- **Highest reduction of agricultural income: "*World Market Scenario*":**
  - Subsidies play balancing role for most crops!
  - Existence of small family farms: weak competitors to stronger agricultural markets (U.S.A., Brasil)

- **Agricultural income increases: from "*Global Sustainability Scenario*" towards "*Local Stewardship Scenario*"**

When you bend down and look at the waters of the Alfeios river near Olympia, their clarity is such that your face and soul are mirrored in them...

The nature becomes here spirit. The clarity of waters becomes clarity of thought ...

Panayiotis Kanellopoulos (1902-1986)

Professor of Sociology, Prime Minister of Greece

Thank you for your attention!