Report on the outcomes of a Virtual Mobility 'Synthesis of WG1 and WG2 Outputs'

COST Action CA22144
SUSTAINABLE USE OF SALT-AFFECTED LANDS (SUSTAIN)
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Table of Contents

List of Figures

1. Introduction

The document aims to combine WG1 and WG2 results into a scientific base which supports WG3 activities that evaluate ecosystem services and study social-economic aspects of salt-affected land management. The synthesis unites soil and water salinity research from WG1 with plant tolerance and adaptation mechanisms from WG2 to enable the conversion of biophysical evidence into ecological and economic valuation systems.

The Action relies on WG1 to study abiotic salinity aspects through soil monitoring techniques and spatial and temporal property analysis and biochemical soil component assessment. The research of WG2 builds on WG1 by studying how living organisms adapt to salt conditions through plant tolerance mechanisms and nutritional changes and possible cultivation methods. The combination of these two knowledge domains stands as a fundamental requirement. The development of strong socio-economic models through WG3 becomes impossible when researchers lack understanding of soil and water salinity evolution (WG1) and plant physiological and nutritional responses (WG2). The synthesis acts as a vital connection which unites scientific knowledge of biophysical systems with economic assessment methods.

2. Summary of WG1 outputs

WG1 investigates the physical and biochemical properties of saline soils and waters through Deliverables D1.1–D1.4 which contain their documented outputs.

The traditional methods of salinity monitoring through electrical conductivity (ECe) and soil sampling and ion balance measurements remain vital but their spatial reach and financial costs remain limited. The predictive power of salinity monitoring has improved through the implementation of remote sensing technologies and machine learning models. The combination of DRASTIC indices with Random Forest and ANN models generates more detailed groundwater vulnerability maps than previous methods. The main challenge arises from the absence of standardized monitoring protocols between case studies which hinders the ability to merge databases.

The research shows that salinity exists in the environment exists at multiple time periods and spatial dimensions. The research conducted by WG1 demonstrates that scientists need to monitor salinity patterns through both short-term seasonal observations and long-term decadal studies to track groundwater changes and salt deposition. The research requires metadata systems which handle data at different spatial levels from individual field sites to complete landscape areas.

Remote sensing technologies including multispectral and hyperspectral imaging and GIS-based salinity mapping and in-situ sensors have proven to be the most promising tools for this research. The technologies help identify problems early but need validation through field measurements to function effectively.

WG1 has developed metadata frameworks which organize data about salinity measurements and their corresponding monitoring techniques and soil biochemical data. The open-access platform described in Deliverable D1.3 receives metadata collection for future integration with WG2 and WG3.

3. Summary of WG2 outputs

WG2 investigates plant responses to salinity through physiological and biochemical and molecular studies which result in outputs that appear in Deliverables D2.1–D2.8.

Plants use three main defense mechanisms to handle salt stress which include maintaining ion balance through Na^+/K^+ regulation and using proline and soluble sugars for osmotic adjustment and activating antioxidant defense systems to fight oxidative stress. The research shows how transporters and stress-responsive genes function under molecular control.

The nutritional value of Salicornia and Suaeda maritima halophytes remains stable or increases when they grow under salt-rich environments. The lipidomic analysis shows that was conducted showed that phospholipids and glycolipids with omega-3 fatty acids increased in concentration which enhances food nutritional value. The research demonstrates that halophytes serve two purposes by providing both stress tolerance and nutritional value for human consumption.

WG2 research identifies breeding targets for salt tolerance through the analysis of physiological traits and molecular markers which include ion exclusion and root architecture. The combination of traditional breeding methods with genomic technology enables scientists to develop new cultivars with enhanced characteristics.

Experimental research shows that planting halophytes with conventional crops in mixed fields creates a protective effect against oxidative stress which leads to stable crop yields. The research conducted by WG2 demonstrates that Salsola soda and Portulaca oleracea and other underutilized crops show potential to expand agricultural diversity in salt-affected regions. The database development in D2.7 focuses on creating a resource that includes multiple species for broader agricultural applications.

4. Cross-cutting findings

The combined assessment of WG1 and WG2 outputs shows multiple specific areas of commonality and beneficial connections which need resolution to achieve successful integration with WG3 valuation work.

Soil heterogeneity and plant responses: WG1 research shows that salinity levels in the environment show significant spatial and temporal variations because groundwater levels and soil salt deposits change substantially during different seasons (e.g., case studies from irrigated plains and semi-arid basins). The observed patterns from WG2 research help explain why plants react differently throughout the same agricultural field. The controlled saline conditions enhance lipid production in halophytic plants Salicornia and Suaeda maritima but conventional crops experience yield instability in diverse soil environments.The essential connection between WG1 soil heterogeneity metadata and WG2 plant trait data enables complete understanding of productivity trade-offs under salinity conditions.

The combination of monitoring techniques with plant trait information for analysis: WG1 research validated multiple methods for salinity detection which include traditional ECe measurements and ion ratio analysis and biochemical soil property assessment as well as GIS-based mapping and machine learning algorithms (Random Forest, ANN, TreeNet).WG2 research established three essential plant tolerance mechanisms which include ion homeostasis and antioxidant defense and nutritional adaptation mechanisms. The two data streams exist in an incomplete state of connection between them. The current practice of separating field salinity maps from plant biochemical response measurements at different spatial scales represents a significant knowledge gap that needs integration in WG3.

Long-term and multi-scale integration faces substantial knowledge deficits: WG1 research demonstrates that soil salinity needs continuous monitoring because its levels change throughout different seasons. The research findings from WG2 stem from brief experimental studies conducted in controlled environments and greenhouses. The current research lacks extended field experiments which unite soil-water observation with plant growth measurements. The evaluation of ecosystem services in WG3 becomes challenging because socio-economic models need extended multi-year data sets that show environmental patterns and agricultural outcomes at landscape scales.

Microorganisms and rhizosphere interactions: The research from WG1 and WG2 shows that biological systems play a crucial role in controlling how plants respond to salinity stress. The biochemical processes of soils under salinity stress receive emphasis in WG1 outputs through their examination of organic matter reduction and microbial nutrient cycling. WG2 research shows that PGPR bacteria and mycorrhizal fungi and seaweed extracts enhance plant tolerance to salt stress when used as growth promoters. The research shows that root–soil–microbe networks present an underresearched connection which could establish a link between biophysical knowledge and ecosystem service assessment in WG3.

Practical synergies for WG3: The evaluation of halophyte performance in WG2 and soil remediation potential in WG1 reveals commonalities between provisioning and regulating ecosystem services. For example, the combination of halophyte cultivation enables farmers to obtain marketable biomass while simultaneously decreasing soil salt levels.The practice of growing different crops together leads to better ecological diversity and system stability but it might decrease immediate crop production levels. The discovered synergies match exactly what WG3 requires to develop Total Economic Value (TEV) frameworks and create business models for saline agriculture.

To conclude, the combination of WG1 and WG2 research outputs shows that the two groups have already generated matching and overlapping data which will support WG3 when integrated. The analysis of soil heterogeneity reveals why plants perform differently while monitoring techniques can link with plant characteristics and halophyte cultivation systems deliver two-fold benefits for service provision and regulation. The current research faces essential challenges because it lacks both extended timeframes for data collection and effective connections between soil measurements and plant characteristics. The integration of these knowledge gaps will enable WG3 to transition from working with isolated data points toward creating strong socio-economic assessments and comprehensive meta-analyses.

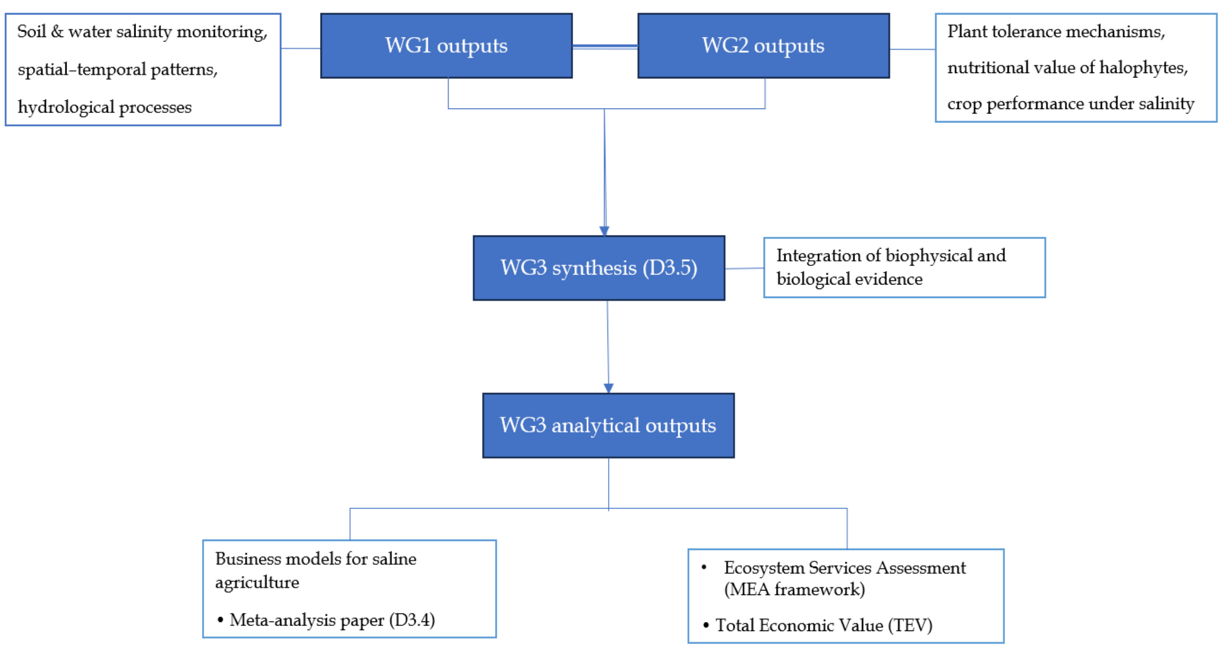

Figure 1.Conceptual framework of WG3 synthesis integrating WG1 and WG2 outputs Source: Dafku Z., 2025

5. Implications for WG3

The implementation of some activities in WG3 needs the integration of WG1 and WG2 outputs to establish a comprehensive understanding of environmental and agricultural impacts from salinity changes. The combination of WG1 soil and water data with WG2 plant response information enables WG3 to perform a complete assessment of ecosystem services and their economic worth, and the economic potential of salt affected lands

WG3 requires the integration of WG1 and WG2 outputs because it enables researchers to understand the complete environmental and agricultural effects of salinity. The combination of WG1 soil and water data with WG2 plant response information enables WG3 to perform comprehensive assessments of ecosystem services and their economic value(ecosystem service categories are presented according to the Millennium Ecosystem Assessment framework, 2005).

Provisioning services: WG3 can determine realistic food and biomass production levels in saline environments through the combination of WG1 soil and water salinity data with WG2 plant growth and nutritional quality evidence. The assessment includes both conventional crops and the edible halophytes Salicornia and Suaeda maritima which serve dual purposes for food security and emerging market opportunities.

Regulating services: WG1 research findings about salinity patterns and groundwater behavior and soil chemical properties link with WG2 results showing halophyte salt extraction abilities and soil structure enhancement. The combined research enables WG3 to determine the economic value of regulating services which include soil restoration and water purity preservation and reduced land deterioration.

Cultural services: The Mediterranean region already uses several halophyte species in its food traditions while these plants are gaining popularity in gourmet and health-focused markets. The combination of WG1 data about plant growth locations with WG2 information about nutritional value and cultural significance enables WG3 to determine cultural service values including dietary diversity and culinary heritage and local identity preservation.

Economic valuation: The economic assessment of Total Economic Value (TEV) becomes possible through the integration of WG1 metadata about soil salinity thresholds and hydrological patterns with WG2 data regarding plant tolerance characteristics and yield performance and nutritional content. The analysis of WG3 enables the evaluation of economic trade-offs between immediate yield reductions and extended soil conservation efforts and the identification of combined advantages from biodiversity protection and emerging business prospects.

On the other hand, the economic value of salt-affected lands emerges as a key finding when WG1 and WG2 research outputs are integrated. Sustainable production and diversified livelihoods become possible through the transformation of present degraded resources which include soils and waters. *For example:*

Alternative crops and new markets: Salicornia and Suaeda species thrive in saline soils to produce valuable products which can be used in food production and pharmaceuticals and cosmetics manufacturing. Agro-ecological services with economic value can be developed through halophyte cultivation because it enhances soil quality which boosts future agricultural value and decreases land degradation expenses.

Tourism and cultural markets:

The traditional Mediterranean use of halophytes in food preparation and cultural heritage can be transformed into specialized food businesses and environmentally friendly tourism activities.

Circular economy opportunities:

The by-products from halophyte biomass production serve as animal feed while also enabling bioenergy and bio-based material creation which enhances resource utilization efficiency.

WG3 can establish economic value of salt-affected lands through environmental evidence from WG1 and plant performance data from WG2 to show sustainable management creates valuable economic landscapes from previously considered marginal areas.

6. Conclusions and next steps

The combined outputs from WG1 and WG2 create a complete understanding of saltwater environments and plant survival mechanisms through their complementary research findings. WG1 and WG2 synthesis work together to establish the ecological framework which WG3 needs to develop its valuation systems. WG1 delivers abiotic indicators which include salinity thresholds and groundwater levels and soil chemistry while WG2 delivers biotic responses through plant traits and nutritional quality and halophyte performance. The combined data from these two groups establishes the necessary biophysical evidence needed for socio-economic assessment.

WG3 can convert these outputs into economic values through the Total Economic Value (TEV) framework. The economic value of provisioning services includes crop yield and nutritional benefits and soil remediation and the cultural value of using halophytes in cooking.

The synthesis work provides vital evidence for the meta-analysis paper which focuses on uniting worldwide knowledge about salinity management and valuation (D3.4). The current synthesis directly feeds into D3.5 as it converts WG1 and WG2 outputs into formats that WG3 can use for the implementation of the activities.

Next steps include:

The synthesis development will continue through joint work with WG1 and WG2 leaders to develop a complete and unified synthesis that combines their research findings.

Share a short synthesis document (ppt or document) which serves as input for Deliverable D3.5.

The collected and organized data from this report will serve as essential material for creating a meta-analysis paper focusing on the integration of soil salinity monitoring approaches (WG1) with plant tolerance traits and nutritional responses (WG2) to support socio-economic valuation of salt-affected lands.

7. References

The synthesis incorporates peer-reviewed articles (listed below) together with information obtained from WG1 and WG2 meetings in Poznań (Poland) and webinars conducted by the two Working Groups, and the email correspondence included both WG1 and WG2 leaders, vice-leaders as well as other members.

Millennium Ecosystem Assessment (MEA). (2005). *Ecosystems and Human Well-being: Synthesis*. Island Press.

Karabulut, A. I., Nacar, S., Yesilnacar, M. I., Cullu, M. A., & Bayram, A. (2025). Predictive Analytics and Soft Computing Models for Groundwater Vulnerability Assessment in High-Salinity Regions of the Southeastern Anatolia Project (GAP), Türkiye. *Water*, *17*(13), 1855. https://doi.org/10.3390/w17131855

Witzel, K., Motos, J.R.A., Atay, E. *et al*. Leveraging microorganisms and biostimulants: mitigating salinity stress in crops with agricultural biologicals. *Plant Soil* (2025). https://doi.org/10.1007/s11104-025-07578-1