The Water-Land-Energy-Food-Climate Nexus In Sardinia

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NEXUS and System Dynamics Modelling

• Land, food, energy, water and climate are linked and interconnected into a Nexus, characterized by complexity and feedbacks. An integrated management of the Nexus is critical to understand conflicts/synergies and secure efficient and sustainable use of resources, especially under climate change.

• System Dynamics Modelling (SDM) analyzes behaviour of complex systems, like reservoir water balance and resilience from a range of potential future threats

• Stocks (e.g., water in a reservoir); flows (e.g., river inflows or evaporation, energy use, ag water demand) and converters which control flow rates (e.g., evaporation rates)

• SDM splits large systems into dynamically interacting sub-systems with multiple interactions for resource availability (e.g., water, energy, land use) and uses for different sectors (e.g., agriculture, tourism, domestic)

• Modelling implemented in R, with elements evaluated at every modelling time-step

• SIM4NEXUS H2020 project (https://www.sim4nexus.eu/) and CMCC-NEXUS strategic project
NEXUS: SARDINIA

- 24,090 km²: plains (14%), hills (68%) mountains (18%)
- Mediterranean Climate with 600 ± 400 mm/yr
- Population is 1.6 million, Tourist flows (38 million overnight stays in 2007)
- Agricultural land 47% of the total area of the island, but only 7% of this area is irrigated
- Irrigation accounts for 69.4% of the water consumption, whereas urban 25.4%
- Industry only 5.2% as many industries have de-salinization plants.

- Tourism for about 17% of GDP, agriculture for 4%.
- Water requirements storage reservoirs (57% of annual demands), and on spring water or groundwater (43%).
- The region is divided in seven hydrological districts), encompassing different reservoirs and water distribution systems only partially connected between districts.
- Thus water availability, but also water demand varies spatially in the region (as well as the distribution by sector).
CMCC Nexus

Systemic approach for integrated management and governance of resources and interconnected sectors (i.e. the Water-Energy-Food-Climate-Land use-Nexus) to achieve SDGs and socio-economic demand.

Framework Integrating different NEXUS aspects (Water-Energy-Food-Land Use-Climate)

- Resource limitations/management for achieving security over multiple sectors
  - Some of these are already consolidated
  - Further expansion and collaboration to consolidate additional tools to analyze further NEXUS aspects
Integration – NEXUS

- Water supplies and water balance
- Impact of climate on water resources
- Water demand related to different sectors (agricultural, domestic/tourist, industry, etc.)
- Energy use associated to water resources
- Implication on land use
Climate impact on:

- recharge to reservoirs, evaporation rates, crop water requirements,
- touristic fluxes, cooling/heating demand
- energy production dependant on solar radiation and wind
• Land uses are primarily involved to carbon emissions and sinking,
• main drivers for crop production and livestock, and thus food security
Integration – NEXUS

Food production:
- Crop water requirement (SIMETAW)
- Crop yield
- Crop for livestock production
Integration – NEXUS

- Energy generation from different sources
- Energy consumption for different sectors
- (energy for irrigated agriculture and food production)
- Energy production from renewable sources (climate dependant)
- GHG emissions
NEXUS integration sample results

- **Monthly Minimum Environmental Flow**
- **Reservoir Water Volume (%)**
  - Sulcis
  - Tirso
  - Coghinas-Mannu-Temo
  - Liscia
  - Posada-Cedrino
  - Sud-orientale
  - Flumendosa-Campidano

- **% crop irrigated Area due to Water availability constraints**

- **Annual Average Water Volume in Reservoirs as % by WATER Districts**
NEXUS integration sample results

Electricity production by source

- Coal
- Hydropower
- PV
- Wind
- Biomass

Electricity demand by sector

- Agriculture
- Industry
- Domestic
- Service

Net Energy Emissions Trends in Sardinia, implementing widespread use of renewable resources and Land Use Land Use Change and Forestry mitigation options
# Policy coherency

Policy coherence: Analyse conflicts and synergies on resources between different policies / management rules

Bivariate matrix of policy interactions and synergetic/antagonistic effect on single resources

|     | E1 | E2 | E3 | E4 | E5 | FA1 | FA2 | FA3 | W1 | W2 | W3 | L1 | L2 | C1 | C2 | C3 | T1 | T2 | FO1 | FO2 |
|-----|----|----|----|----|----|-----|-----|-----|----|----|----|----|----|----|----|----|----|-----|-----|
| E1  |  3 | -2 |  1 |  0 |  1 | 1\-1|  1 |  0  |  0  |  0  | -2 |  0  |  2  |  1  |  0  |  0  |  0  |  2  |
| E2  |  3 |  2 |  2  |  0 |  1 |  0  |  1  |  0  |  0  |  0  | -1 |  0  |  2  |  2  |  2  |  0  |  1  |  0  |
| E3  | 0\-1|  1 |  0  |  0  |  0 |  0  |  0  |  0  |  0  |  0  |  1 |  0  |  1  |  2  |  0  |  1  |  1  |  0  |
| E4  |  2 |  2 |  0  |  0  |  1 |  1\-1|  1 | 1\-1 |  1  |  0  | -1 |  0  |  1  |  3  |  1  |  0  |  0  |  0  |
| E5  |  1 |  2 | -1  |  0 |  1  |  0  |  1  |  0  |  0  |  0  |  0  |  2  |  3  |  1  |  1  |  1  |  0  |  0  |
| FA1 |  0 |  0 |  0  |  1 |  0  |  1\-1|  2 |  1  |  0  |  0  |  0  |  2  |  2  |  1  |  0  |  1  |  0  |  2  |
| FA2 |  0 |  1 |  1 |  2 |  1 |  1  |  2 |  2  |  2  |  1  |  1 | -1 | -1 |  1  |  1  |  2  |  1  |  1  |  1  |
| FA3 |  1 |  1 |  2 |  2 |  1 |  2  |  2 |  1  |  1  |  1 | -1 | -1 |  1 | 1\-1 |  1 |  2  |  2  |  1  |  2  |
| W1  |  0 |  0 |  0 | -1 |  0 |  2  | -2 |  2  |  0  |  0 |  0 |  0 |  0 |  2 |  1 | -1  |  0  |  0  |  0  |
| W2  |  1 |  1 |  0 |  2 |  0 |  1  | -1 |  1  |  0  |  0 |  0 |  0 |  3 |  3 | -1 |  1  |  0  |  0  |  0  |
| W3  |  0 |  0 |  0 |  0 |  0 |  1  |  3 | -1 |  1 |  1 |  0 |  0 |  1 |  0 |  1 |  1 | -1 |  0  |  1  |
| L1  | -1 |  1 |  1 | -1 |  0 |  0 |  0 |  0 |  1 |  0 |  0 |  0 |  1 |  0 |  0 |  0 |  1 |  1 |  1 |
| L2  |  0 |  0 |  0 |  0 |  2 |  0 |  1 |  0 |  0 |  0 |  0 |  0 |  1 |  1 |  2 |  2 |  1\-1 |  0  |  2  |
| C1  |  3 |  3 |  1 |  2 |  3 |  2 |  1 |  1 |  1 |  0 |  0 | -1 |  0 |  1\-1 |  1 | -1 |  1 |  2 |  2 |
| C2  |  1 |  2 |  2 |  2 |  3 |  3 |  1 |  2 |  3 |  3 |  1 |  0 |  1 | 1\-1 |  3 |  1 |  2 |  2 |  2 |
| C3  |  0 |  0 |  0 |  0 |  0 |  0 |  0 |  0 |  0 |  0 |  0 |  0 |  3 |  0 |  0 |  0 |  0 |  0 |  0 |
| T1  |  1 |  1 |  0 |  0 |  2 |  1 |  1 |  2 |  1 |  2 |  2 |  0 |  1 |  1 |  1 |  2 |  1 |  2 |  2 |
| T2  |  1 |  1 |  1 |  0 |  2 |  1 |  1 |  2 |  0 |  0 |  2 |  2 |  2 |  1 |  2 |  2 |  2 |  2 |  2 |
| FO1 |  0 |  0 |  0 |  0 |  0 |  1 |  0 |  2 |  1 |  1 |  0 |  0 |  0 |  0 |  0 |  0 |  2 |  2 |  1 |
| FO2 |  1 |  0 |  0 |  0 |  1 |  2 |  0 |  1 |  0 |  1 |  1 |  2 |  1 |  1 |  2 |  2 |  1 |  0 |  2 |  2 |
Thanks