SIM4NEXUS

WP7: D7.7
RESEARCH ARTICLES INVENTORY
M1-M48

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PROJECT	Sustainable Integrated Management FOR the NEXUS of water-land-food-energy-climate for a resource-efficient Europe (SIM4NEXUS)
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DELIVERABLE	WP7: D7.7 Research articles inventory M1-M48
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REVIEWER	
COMMENTS	The order of scientific contributions listed in this document is oriented along the chronology of publication dates and therefore does not match the list in the Communications Monitoring Report (D7.13) based on the order of reports.

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1.0	Tobias Conradt	09-May-2020	M1-M48 COMPLETED FOR FINAL REVIEW
1.1	Tobias Conradt	16-June-2020	REMOVED A DOELMAN ET AL. 2019 PAPER

Contents

Introductory Remarks

Scientific journal articles, colloquially just called "papers", are the most authoritative means of conveying actual research progress -- at least among the scientific community. In many countries the fate of academic careers is closely connected to the number and frequency of first-authored publications. Personal bibliometric scores like the h-index (Hirsch 2005) are now easily calculated and closely followed by digital means. A much older German proverb has it "Wer schreibt, der bleibt!" (He who writes, stays [in business].)

The high esteem of scientific publications is rooted in a rigid quality control, the peer review process: Journal editors send the manuscript to third-party researchers of the same discipline (the peers, on no account direct colleagues of the authors) for review. Writing reviews from time to time is therefore a moral commitment for any author. These review reports, usually from two independent sources, inform the editor's decision to accept or reject the paper or – the common case – to request a revision. The review comments are then forwarded anonymously to the authors. When the revised manuscript has been submitted, the reviewers are sometimes asked back for their comments, and occasionally a second correction loop is exercised until the editor greenlights the work for publication. Utilizing online dissemination, some journals also extend the trilateral correspondence between authors, editors and reviewers by an open discussion phase in which the entire scientific community is invited to further comment and help improve the final publication.

This time-consuming procedure is not well known outside the scientific community which might be a reason for challenging the special value of this slow and generally target-group confined communication channel -- even within SIM4NEXUS, project partners were teased whether they would "just take the money and write articles" (instead on focusing on scheduled deliverables deemed more important). Another indication of scientific literature output not being among the commonly internalised objectives of the project consortium was the friendly acknowledgment of an initiative for a special issue presented by the WP7 coordinators at the Athens project meeting in March 2018: Not a single contribution had ever been suggested for such a dedicated SIM4NEXUS collection.

Indeed, the traditional culture of scientific progress communication hardly matches nowadays preference for dynamic just-in-time information throughput, and there are already respective zones of disintegration in the scientific sphere. Some journals (competing for bibliometric scores

like individuals, cf. Koutsoyiannis & Kundzewicz 2007) seem to have dropped quality checks altogether: Mind the 2020 spring flood of hastily published COVID-19 papers with uncertain or even contradicting results. This development is not limited to medicine. It is also related to the shift from printed, subscription-based journals to open-access online journals charging per article. Previously scientific quality had been an important selling point, now the publishing interest of authors equipped with open access budgets is to be served in the first place, and journals adopt to the market (Beall 2013). Even a number of SIM4NEXUS publications reported here have been published under at least questionable quality standards, though this might not have happened on purpose as sources collected by Frandsen (2019) suggest; there is an unfathomable abyss of journals to choose from and despite serious efforts (e.g. Grudniewicz et al. 2019) still no common definition for predatory journals exists.

Nevertheless -- what will most probably remain from SIM4NEXUS in just one or two decades? Will there still be someone learning something from the serious game developed in the project? This is not impossible, but it would require a steady long-term maintenance of software (adopting to new technology standards) and input data (shifting the virtual time frame) – not very likely. Will people still read SIM4NEXUS tweets and other news items about the project? Hardly. However, unless a continental long-term blackout disrupts the Internet, all the literature representing the scientific project output will remain accessible and occasionally attract researchers for decades without any further effort. Three branches of research can be distinguished in the portfolio of SIM4NEXUS publications that will for sure grow further:

- Descriptions and discussions of the Nexus concept, as realised in this project and elsewhere, with many suggestions for applications and further development (Laspidou et al. 2017, 2018, 2020, Sušnik et al. 2018, Brouwer et al. 2018b, Hülsmann et al. 2019, Cremades et al 2019)
- Nexus-inspired research, practical applications of the concept on global (e.g. Brouwer et al. 2018, Arvesen et al. 2018, Mercure et al. 2018, Martinez et al. 2018, Sušnik 2018) and regional (Trabucco et al. 2018, Laspidou et al. 2019, Papadopoulou et al. 2020) domains

- Research about interactions and trade-offs between single Nexus components without reference to the Nexus as such (e.g. Weindl et al. 2017a,b, Hesslerová et al. 2018, Humpenöder et al. 2018, Masia et al. 2018, Martinez & Blanco 2019, Gerten et al. 2020)

The impact of the knowledge gathered here can be viewed in terms of citations: First-hand references already outnumber the original SIM4NEXUS research articles by an order of magnitude. This leaves no doubt that SIM4NEXUS ideas from research papers have already spread into many other minds and will subsequently reverberate in- and outside the scientific community for many years to come.

REFERENCES

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Frandsen, T. F. (2019) Why do researchers decide to publish in questionable journals? A review of the literature. Learned Publishing 32 (1) 57–62. https://doi.org/10.1002/leap.1214

Hirsch, J. E. (2005) An index to quantify an individual's scientific research output. Proceedings of the National Academy of Sciences of the United States of America (PNAS) 102 (46) 16569–16572. https://doi.org/10.1073/pnas.0507655102

Koutsoyiannis, D. & Z. W. Kundzewicz (2007) Editorial—Quantifying the impact of hydrological studies. Hydrological Sciences Journal 52 (1) 3–17. https://doi.org/10.1623/hysj.52.1.3

Outcomes and deliverables

Deliverables and milestones

Deliverable/milestone	Due	Initiated	In progress	Completed	Final delivery date
D7.7 Research articles inventory M1-M48	M48			X	May 2020

Indicators

Task	Product/ activity	Effort indicator			Impact indicator		
		Name	Target	Reached	Name	Target	Reached
7.3	Scientific publications	Publications published + submitted	10	32+	No. of estimated users	5000	N/A
					No. of citations	N/A	392

There is no means to count the actual users of scientific publications. As a replacement metric for measuring the impact, the cumulative number of citations as counted by the Web of Science™ on 6 May 2020 is given.

Citations rose sharply over the last year of the project, there had been only 117 in May 2019. Considering the time lags inherent to scientific publishing, more than 500 citations can be expected before the end of 2020.

Points for review

- None

The Inventory

- Names of Authors affiliated to SIM4NEXUS partner institutions are written in bold.
- Publication dates do not consider online pre-releases unless stated otherwise.
- Open Access (OA) status refer to the access conditions of the original journal publications (gold OA). As OA was mandatory for all publications issued in the framework of SIM4NEXUS, independent releases of the accepted manuscripts are regularly accessible through online repositories wherever gold OA is not provided (green OA). The responsibility for green OA is with the authors, so they should be approached for information about the actual repository links if these cannot be easily found via search engine.
- Citation numbers have been retrieved from the Web of Science™ (Clarivate Analytics, formerly ISI) on 6 May 2020. This was the final of the regular surveys for the citation metrics of the quarterly Communications Monitoring Report (D7.13).

Publications in M1–M12 (June 2016–May 2017)

Jan Pokorný (ENKI), Petra Hesslerová (ENKI), Hanna Huryna (ENKI), David Harper		
August 2016	Open Access: No	Number of citations: N/A
Indirect and Direct Thermodynamic Effects of Wetland Ecosystems on Climate		
Vymazahl, J. (eds) Natural and Constructed Wetlands, pp 91–108. Springer, Cham. HTTPS://DOI.ORG/10.1007/978-3-319-38927-1_7		

Abstract: This chapter deals with a largely unrecognised service of wetlands – their role in regulating air temperature through evapotranspiration. We explain quantitatively how solar energy striking the earth's surface is dissipated by water (expressed in energy units (W m−2)) in three processes: dissolution-precipitation of salts, disintegration-recombination of the water molecule in biological processes and evapotranspiration-condensation. The direct effect of wetlands on regional climate, through reduction of temperature gradients and the role of water vapour and clouds in lowering the passage of solar radiation are then described. We quantify the huge upsurge of sensible heat (warm air) that must have occurred after the drainage of wetlands in the northern hemisphere over the past 260 years. The radiative forcing that was caused by the increase in greenhouse gases in the atmosphere over the same period (from 1 to 3 W m−2 from 1750 to the present day) is markedly lower than radiative forcing caused by wetland drainage and indeed, is too small to measure. The amounts of carbon dioxide, methane and water vapour in atmosphere and their dynamics are compared. We question the meaning of 'average temperature' as the criterion of climate change in terms of thermodynamics. We show temperature differences in the present-day cultural landscape, on a clear sunny day, in thermovision pictures: wetlands and forests are up to 20 °C cooler than drained surfaces. We argue that persisting with the dogma of climate change caused by the greenhouse effect alone results in society ignoring the most important functions of natural vegetation, manifest through their direct effect on climate and water cycling. This facilitates further wetland drainage and deforestation. We believe that it is now essential to support and restore natural vegetation structures, like wetlands and forests, in order to make any serious reduction in climate warming.

Publications in M13–M24 (June 2017–May 2018)

C. Laspidou (UTH), M. Witmer (PBL), L.S. Vamvakeridou (UNEXE), X. Domingo (EURECAT), F. Brouwer (WUR-LEI), M. Howells (KTH), J. Susnik (IHE Delft), M. Blanco (UPM), M. Bonazountas (EPSILON), M. Fournier (ACT), M.P. Papadopoulou (NTUA)

September 2017	Open access: Yes	Number of citations: N/A

The water-land-food-energy-climate Nexus for a resource efficient Europe

Online proceedings of the 15th International Conference on Environmental Science and Technology (CEST 2017), Rhodes, Greece, 31 August to 2 September 2017, Nr. 768, 5 pp. HTTPS://CEST2017.GNEST.ORG/SITES/DEFAULT/FILES/PRESENTATION_FILE_LIST/CEST2017_00768_ORAL_PAPER.PDF

Abstract: A novel methodology for addressing policy inconsistencies and knowledge gaps that hinder the transition to a greater resource efficiency Europe is proposed. We focus on the integration of all different sectors that interact and influence each other, namely the water-energy-food-land use-climate nexus" and we develop tools for identifying and quantifying their complex interlinkages under the influence of climate change. In order to achieve this, we employ a series of sophisticated models (referred to as "thematic models"), each of which addresses a different nexus dimension, or a combination of a few, while none addresses all nexus dimensions in an integrative manner. We use dynamic systems modeling and other complexity science techniques in order to "merge" different thematic model outputs in a single coherent result, which is presented to the user in an easy-to-comprehend Serious Game environment. This way, the effect of policies that are designed to affect one field (nexus dimension) on others can be quantified and simulated, thus informing policy-makers for the unintended consequences of their policies, reducing uncertainties, covering knowledge gaps and leading to a resource efficient Europe faster.

Isabelle Weindl, Benjamin Leon Bodirsky, Susanne Rolinski, Hermann Lotze-Campen, Christoph Müller, Jan Philipp Dietrich, Miodrag Stefanović, Sybill Schaphoff, Alexander Popp (All authors affiliated to PIK)

November 2017 | Open Access: No | Number of citations: 4

Livestock production and the water challenge of future food supply: Implications of agricultural management and dietary choices

Global Environmental Change 47, 121–132
HTTPS://DOI.ORG/10.1016/J.GLOENVCHA.2017.09.010

Abstract: Human activities use more than half of accessible freshwater, above all for agriculture. Most approaches for reconciling water conservation with feeding a growing population focus on the cropping sector. However, livestock production is pivotal to agricultural resource use, due to its low resource-use efficiency upstream in the food supply chain. Using a global modelling approach, we quantify the current and future contribution of livestock production, under different demand- and supply-side scenarios, to the consumption of "green" precipitation water infiltrated into the soil and "blue" freshwater withdrawn from rivers, lakes and reservoirs. Currently, cropland feed production accounts for 38% of crop water consumption and grazing involves 29% of total agricultural water consumption (9990 km3 yr−1). Our analysis shows that changes in diets and livestock productivity have substantial implications for future consumption of agricultural blue water (19–36% increase compared to current levels) and green water (26–69% increase), but they can, at best, slow down trends of rising water requirements for decades to come. However, moderate productivity reductions in highly intensive livestock systems are possible without aggravating water scarcity. Productivity gains in developing regions decrease total agricultural water consumption, but lead to expansion of irrigated agriculture, due to the shift from grassland/green water to cropland/blue water resources. While the magnitude of the livestock water footprint gives cause for concern, neither dietary choices nor changes in livestock productivity will solve the water challenge of future food supply, unless accompanied by dedicated water protection policies.

Isabelle Weindl, Alexander Popp, Benjamin Leon Bodirsky, Susanne Rolinski, Hermann Lotze-Campen, Anne Biewald, Florian Humpenöder, Jan Philipp Dietrich, Miodrag Stefanović (All authors affiliated to PIK)

December 2017 | Open Access: No | Number of citations: 9

Livestock and human use of land: Productivity trends and dietary choices as drivers of future land and carbon dynamics

Global and Planetary Change 159, 1–10
HTTPS://DOI.ORG/10.1016/J.GLOPLACHA.2017.10.002

Abstract: Land use change has been the primary driving force of human alteration of terrestrial ecosystems. With 80% of agricultural land dedicated to livestock production, the sector is an important lever to attenuate land requirements for food production and carbon emissions from land use change. In this study, we quantify impacts of changing human diets and livestock productivity on land dynamics and depletion of carbon stored in vegetation, litter and soils. Across all investigated productivity pathways, lower consumption of livestock products can substantially reduce deforestation (47–55%) and cumulative carbon losses (34–57%). On the supply side, already minor productivity growth in extensive livestock production systems leads to substantial CO2 emission abatement, but the emission saving potential of productivity gains in intensive systems is limited, also involving trade-offs with soil carbon stocks. If accounting for uncertainties related to future trade restrictions, crop yields and pasture productivity, the range of projected carbon savings from changing diets increases to 23–78%. Highest abatement of carbon emissions (63–78%) can be achieved if reduced consumption of animal-based products is combined with sustained investments into productivity increases in plant production. Our analysis emphasizes the importance to integrate demand- and supply-side oriented mitigation strategies and to combine efforts in the crop and livestock sector to enable synergies for climate protection.

Floor Brouwer (WUR-LEI), Georgios Avgerinopoulos (KTH), Dora Fazekas (CE), Chrysi Laspidou (UTH), Jean-Francois Mercure (RU), Hector Pollitt (CE), Eunice Pereira Ramos (KTH) Mark Howells (KTH)

January 2018	Open Access: Yes	Number of citations: 20

Energy modelling and the Nexus concept

Energy Strategy Reviews 19, 1–6
HTTPS://DOI.ORG/10.1016/J.ESR.2017.10.005

Abstract: The Nexus concept is the interconnection between the resources energy, water, food, land and climate. Such interconnections enable to address trade-offs and seek for synergies among them. Several policy areas (e.g. bio-based economy, circular economy) increasingly consider the Nexus concept. Ignoring synergies and trade-offs between energy and natural flows, can generate misleading modelling outcomes. Several modelling tools are available to address energy and the Nexus. Based on six such models, this paper aims to support the design and testing of coherent strategies for sustainable development. Model improvements would be achieved by comparing model outcomes and including a common baseline.

Anders Arvesen, **Gunnar Luderer (PIK), Michaja Pehl (PIK), Benjamin Leon Bodirsky (PIK),** Edgar G. Hertwich

January 2018 | Open Access: No | Number of citations: 19

Deriving life cycle assessment coefficients for application in integrated assessment modelling

Environmental Modelling & Software 99, 111–125
https://doi.org/10.1016/j.envsoft.2017.09.010

Abstract: The fields of life cycle assessment (LCA) and integrated assessment (IA) modelling today have similar interests in assessing macro-level transformation pathways with a broad view of environmental concerns. Prevailing IA models lack a life cycle perspective, while LCA has traditionally been static- and micro-oriented. We develop a general method for deriving coefficients from detailed, bottom-up LCA suitable for application in IA models, thus allowing IA analysts to explore the life cycle impacts of technology and scenario alternatives. The method decomposes LCA coefficients into life cycle phases and energy carrier use by industries, thus facilitating attribution of life cycle effects to appropriate years, and consistent and comprehensive use of IA model-specific scenario data when the LCA coefficients are applied in IA scenario modelling. We demonstrate the application of the method for global electricity supply to 2050 and provide numerical results (as supplementary material) for future use by IA analysts.

Florian Humpenöder, Alexander Popp, Benjamin Leon Bodirsky, Isabelle Weindl, Anne Biewald, Hermann Lotze-Campen, Jan Philipp Dietrich, David Klein, Ulrich Kreidenweis, Christoph Müller, Susanne Rolinski and Miodrag Stevanovic (All authors affiliated to PIK)

February 2018 | Open Access: Yes | Number of citations: 12

Large-scale bioenergy production: how to resolve sustainability trade-offs?

Environmental Research Letters 13, 024011 (15 pp)

HTTPS://DOI.ORG/10.1088/1748-9326/AA9E3B

Abstract: Large-scale 2nd generation bioenergy deployment is a key element of 1.5°C and 2°C transformation pathways. However, large-scale bioenergy production might have negative sustainability implications and thus may conflict with the Sustainable Development Goal (SDG) agenda. Here, we carry out a multi-criteria sustainability assessment of large-scale bioenergy crop production throughout the 21st century (300 EJ in 2100) using a global land-use model. Our analysis indicates that large-scale bioenergy production without complementary measures results in negative effects on the following sustainability indicators: deforestation, CO2 emissions from land-use change, nitrogen losses, unsustainable water withdrawals and food prices. One of our main findings is that single-sector environmental protection measures next to large-scale bioenergy production are prone to involve trade-offs among these sustainability indicators—at least in the absence of more efficient land or water resource use. For instance, if bioenergy production is accompanied by forest protection, deforestation and associated emissions (SDGs 13 and 15) decline substantially whereas food prices (SDG 2) increase. However, our study also shows that this trade-off strongly depends on the development of future food demand. In contrast to environmental protection measures, we find that agricultural intensification lowers some side-effects of bioenergy production substantially (SDGs 13 and 15) without generating new trade-offs—at least among the sustainability indicators considered here. Moreover, our results indicate that a combination of forest and water protection schemes, improved fertilization efficiency, and agricultural intensification would reduce the side-effects of bioenergy production most comprehensively. However, although our study includes more sustainability indicators than previous studies on bioenergy side-effects, our study represents only a small subset of all indicators relevant for the SDG agenda. Based on this, we argue that the development of policies for regulating externalities of large-scale bioenergy production should rely on broad sustainability assessments to discover potential trade-offs with the SDG agenda before implementation.

Janez Sušnik (IHE Delft), Chengzi Chew (DHI), Xavier Domingo (EURECAT), Simone Mereu (UNISS), Antonio Trabucco (UNISS), Barry Evans (UNEXE), Lydia Vamvakeridou-Lyroudia (UNEXE), Dragan A. Savić (UNEXE), Chrysi Laspidou (UTH), Floor Brouwer (WUR-LEI)

February 2018	Open Access: Yes	Number of citations: 18

Multi-Stakeholder Development of a Serious Game to Explore the Water-Energy-Food-Land-Climate Nexus: The SIM4NEXUS Approach

Water 10 (2) 139 (21 pp)
HTTPS://DOI.ORG/10.3390/W10020139

Abstract: Water, energy, food, land and climate form a tightly-connected nexus in which actions on one sector impact other sectors, creating feedbacks and unanticipated consequences. This is especially because at present, much scientific research and many policies are constrained to single discipline/sector silos that are often not interacting (e.g., water-related research/policy). However, experimenting with the interaction and determining how a change in one sector could impact another may require unreasonable time frames, be very difficult in practice and may be potentially dangerous, triggering any one of a number of unanticipated side-effects. Current modelling often neglects knowledge from practice. Therefore, a safe environment is required to test the potential cross-sectoral implications of policy decisions in one sector on other sectors. Serious games offer such an environment by creating realistic 'simulations', where long-term impacts of policies may be tested and rated. This paper describes how the ongoing (2016–2020) Horizon2020 project SIM4NEXUS will develop serious games investigating potential plausible cross-nexus implications and synergies due to policy interventions for 12 multi-scale case studies ranging from regional to global. What sets these games apart is that stakeholders and partners are involved in all aspects of the modelling definition and process, from case study conceptualisation, quantitative model development including the implementation and validation of each serious game. Learning from playing a serious game is justified by adopting a proof-of-concept for a specific regional case study in Sardinia (Italy). The value of multi-stakeholder involvement is demonstrated, and critical lessons learned for serious game development in general are presented.

Sara Masia (IHE Delft), Janez Sušnik (IHE Delft), Serena Marras (UNISS), Simone Mereu (UNISS), Donatella Spano (UNISS), Antonio Trabucco (UNISS)

February 2018 | Open Access: Yes | Number of citations: 4

Assessment of Irrigated Agriculture Vulnerability under Climate Change in Southern Italy

Water 10 (2) 209 (19 pp)
https://doi.org/10.3390/w10020209

Abstract: Climate change in Mediterranean countries is anticipated to have a strong impact on water availability by exacerbating drought conditions and water scarcity. In this context, efficient irrigation practices are becoming essential for sustaining crop production. This work assesses vulnerability of irrigated agriculture for six irrigation districts and their associated reservoirs in Mediterranean areas across Italy under climate change (1976–2005 versus 2036–2065; RCP 4.5 and 8.5), evaluating changes in irrigation requirements, evaporation from reservoirs, and the availability of freshwater supplies. Irrigation requirements are estimated through a crop water model (SIMETAW_R) integrated into a GIS platform, while inflows to reservoirs are hydrologically modelled as partitioning of precipitation contributing to runoff. Results are aggregated into indicators that show the general decreasing resilience and increasing vulnerability of irrigated agriculture under climate change conditions in each case study. The highest percentage of allowable water losses for irrigation is estimated in the Cuga-Alto Temo system, during the prolonged drought period, to be able to satisfy irrigation demand for less than a year. Climate change may only partially affect irrigation in resilient systems, in which storage capacity and the water level entering into the reservoir are considerably higher than the water distribution volumes.

Jean-Francois Mercure (RU, CE), Hector Pollitt (CE), Neil R. Edwards, Philip B. Holden, **Unnada Chewpreecha (CE),** Pablo Salas, Aileen Lam, **Florian Knobloch (RU),** Jorge E. Vinuales

April 2018 | Open Access: Yes | Number of citations: 20

Environmental impact assessment for climate change policy with the simulation-based integrated assessment model E3ME-FTT-GENIE

Energy Strategy Reviews 20, 195–208
https://doi.org/10.1016/j.esr.2018.03.003

Abstract: A high degree of consensus exists in the climate sciences over the role that human interference with the atmosphere is playing in changing the climate. Following the Paris Agreement, a similar consensus exists in the policy community over the urgency of policy solutions to the climate problem. The context for climate policy is thus moving from agenda setting, which has now been mostly established, to impact assessment, in which we identify policy pathways to implement the Paris Agreement. Most integrated assessment models currently used to address the economic and technical feasibility of avoiding climate change are based on engineering perspectives with a normative systems optimisation philosophy, suitable for agenda setting, but unsuitable to assess the socio-economic impacts of realistic baskets of climate policies. Here, we introduce a fully descriptive, simulation-based integrated assessment model designed specifically to assess policies, formed by the combination of (1) a highly disaggregated macro-econometric simulation of the global economy based on time series regressions (E3ME), (2) a family of bottom-up evolutionary simulations of technology diffusion based on cross-sectional discrete choice models (FTT), and (3) a carbon cycle and atmosphere circulation model of intermediate complexity (GENIE). We use this combined model to create a detailed global and sectoral policy map and scenario that sets the economy on a pathway that achieves the goals of the Paris Agreement with >66% probability of not exceeding 2 °C of global warming. We propose a blueprint for a new role for integrated assessment models in this upcoming policy assessment context.

Nikolaos Mellios (UTH), Jason F. L. Koopman (WUR-LEI), Chrysi Laspidou (UTH)

May 2018 | Open Access: Yes | Number of citations: N/A

Virtual Crop Water Export Analysis: The Case of Greece at River Basin District Level

Geosciences 8 (5) 161 (15 pp)
https://doi.org/10.3390/geosciences8050161

Abstract: An analysis of virtual crop water export through international trade is conducted for Greece, downscaled to the River Basin District (RBD) level, in order to identify critical "hotspots" of localized water shortage in the country. A computable general equilibrium model (MAGNET) was used to obtain the export shares of crops and associated irrigation water was calculated for all major crops in Greece. A distinction between virtual crop water locally consumed and traded internationally was made for all Greek RBDs. Cotton was identified as a large water consumer and virtual water exporter, while GR08 and GR10 were identified as the RBDs mostly impacted. The value of virtual water exported was calculated for all crop types and fruits and vegetables were identified as the crop most beneficial, since they consume the least water for the obtained value.

Pilar Martinez, Maria Blanco, Bente Castro-Campos (All authors affiliated to UPM)

May 2018 | Open Access: Yes | Number of citations: 8

The Water–Energy–Food Nexus: A Fuzzy-Cognitive Mapping Approach to Support Nexus-Compliant Policies in Andalusia (Spain)

Water 10 (5) 664 (17 pp)
https://doi.org/10.3390/w10050664

Abstract: Water, energy and food are essential resources for economic development and social well-being. Framing integrated policies that improve their efficient use requires understanding the interdependencies in the water–energy–food (WEF) nexus. Stakeholder involvement in this process is crucial to represent multiple perspectives, ensure political legitimacy and promote dialogue. In this research, we develop and apply a participatory modelling approach to identify the main interlinkages within the WEF nexus in Andalusia, as a starting point to developing a system dynamic model at a later stage. The application of fuzzy cognitive mapping enabled us to gain knowledge on the WEF nexus according to opinions from 14 decision-makers, as well as contributing to raising awareness and building consensus among stakeholders. Results show that climate change and water availability are key drivers in the WEF nexus in Andalusia. Other variables with significant interlinkages within the WEF nexus are food production, irrigated agriculture, energy cost, socio-economic factors, irrigation water use, environmental conservation, and farm performance indicators. The scenario analysis reveals the interdependencies among nexus sectors and the existence of unanticipated effects when changing variables in the system, which need to be considered to design integrated policies.

Publications in M25–M36 (June 2018–May 2019)

Janez Sušnik		
June 2018	Open Access: Yes	Number of citations: 9
Data-driven quantification of the global water-energy-food system		
Resources, Conservation and Recycling 133, 179–190 https://doi.org/10.1016/j.resconrec.2018.02.023		

Abstract: There is increasing interest in the global water-energy-food (WEF) system and potential system trajectories, especially considering growing concerns over resource exploitation and sustainability. Previous studies investigating different aspects of this system have a number of shortcomings, meaning it is difficult to identify system-wide tradeoffs, and makes comparison difficult. A global analysis of the WEF system linked to gross domestic product (GDP) growth is presented, integrating the four sectors into a coherent analysis and modelling framework. GDP was included as previous related work demonstrates a link between GDP and each WEF sector. A system dynamics modelling approach quantifies previously qualitative descriptions of the global WEF-GDP system, while a Monte-Carlo sampling approach is adopted to characterise national-level variability in resource use. Correlative and causal analysis show links of varying strength between sectors. For example, the GDP-electricity consumption sectors are strongly correlated while food production and electricity consumption are weakly correlated. Causal analysis reveals that 'correlation does not imply causation'. There are noticeable asymmetries in causality between certain sectors. Historical WEF-GDP values are well recreated. Future scenarios were assessed using seven GDP growth estimates to 2100. Water withdrawals in 2100 and food production in 2050 are close to other estimations. Results suggest that humanity risks exceeding the 'safe operating space' for water withdrawal. Reducing water withdrawal while maintaining or increasing food production is critical, and should be decoupled from economic growth. This work provides a quantitative modelling framework to previously qualitative descriptions of the WEF-GDP system, offering a platform on which to build.

Ilje Pikaar, Silvio Matassa, **Benjamin L. Bodirsky (PIK), Isabelle Weindl (PIK), Florian Humpenöder (PIK),** Korneel Rabaey, Nico Boon, Michele Bruschi, Zhiguo Yuan, Hannah van Zanten, Mario Herrero, Willy Verstraete, **Alexander Popp (PIK)**

June 2018 | Open Access: No | Number of citations: 10

Decoupling Livestock from Land Use through Industrial Feed Production Pathways

Environmental Science and Technology 52 (13) 7351–7359
https://doi.org/10.1021/acs.est.8b00216

Abstract: One of the main challenges for the 21st century is to balance the increasing demand for high-quality proteins while mitigating environmental impacts. In particular, cropland-based production of protein-rich animal feed for livestock rearing results in large-scale agricultural land-expansion, nitrogen pollution, and greenhouse gas emissions. Here we propose and analyze the long-term potential of alternative animal feed supply routes based on industrial production of microbial proteins (MP). Our analysis reveals that by 2050, MP can replace, depending on socio-economic development and MP production pathways, between 10–19% of conventional crop-based animal feed protein demand. As a result, global cropland area, global nitrogen losses from croplands and agricultural greenhouse gas emissions can be decreased by 6% (0–13%), 8% (−3–8%), and 7% (−6–9%), respectively. Interestingly, the technology to industrially produce MP at competitive costs is directly accessible for implementation and has the potential to cause a major structural change in the agro-food system.

Tomoko Hasegawa, Shinichiro Fujimori, Petr Havlík, Hugo Valin, **Benjamin Leon Bodirsky (PIK), Jonathan C. Doelman (PBL),** Thomas Fellmann, Page Kyle, **Jason F. L. Koopman (WUR-LEI), Hermann Lotze-Campen (PIK),** Daniel Mason-D'croz, Yuki Ochi, Ignacio Pérez Domínguez, **Elke Stehfest (PBL),** Timothy B. Sulser, **Andrzej Tabeau (WUR-LEI),** Kiyoshi Takahashi, Jun'ya Takakura, **Hans Van Meijl (WUR-LEI), Willem-Jan van Zeist (PBL),** Keith Wiebe, Peter Witzke

July 2018	Open Access: Yes	Number of citations: 35

Risk of increased food insecurity under stringent global climate change mitigation policy

Nature Climate Change 8, 699–703
HTTPS://DOI.ORG/10.1038/S41558-018-0230-X

Abstract: Food insecurity can be directly exacerbated by climate change due to crop-production-related impacts of warmer and drier conditions that are expected in important agricultural regions. However, efforts to mitigate climate change through comprehensive, economy-wide GHG emissions reductions may also negatively affect food security, due to indirect impacts on prices and supplies of key agricultural commodities. Here we conduct a multiple model assessment on the combined effects of climate change and climate mitigation efforts on agricultural commodity prices, dietary energy availability and the population at risk of hunger. A robust finding is that by 2050, stringent climate mitigation policy, if implemented evenly across all sectors and regions, would have a greater negative impact on global hunger and food consumption than the direct impacts of climate change. The negative impacts would be most prevalent in vulnerable, low-income regions such as sub-Saharan Africa and South Asia, where food security problems are already acute.

Chrysi S. Laspidou (UTH), Dimitrios, T. Kofinas (UTH), Nikolaos K. Mellios (UTH), Maria Witmer (PBL)

August 2018 | Open Access: Yes | Number of citations: N/A

Modelling the Water-Energy-Food-Land Use-Climate Nexus: The Nexus Tree Approach

Proceedings 2 (11) 617 (7 pp)
https://doi.org/10.3390/proceedings2110617

Abstract: The United Nations Food and Agriculture Organization (FAO) has established the Water-Energy-Food Nexus, implying that the three commodities are inextricably linked forming a complex system of interrelations. Perceiving water, energy and food as a system variable with dependencies rather than a singularity suggests an approach of a more holistic view that can offer a sustainable plan for managing resources. In this article, the already established three-way Nexus is expanded to include two more dimensions, namely land use and climate and a framework for modelling the interlinkages among these dimensions is presented.

Antonio Trabucco (UNISS), Janez Sušnik (IHE Delft), Lydia Vamvakeridou-Lyroudia (UNEXE), Barry Evans (UNEXE), Sara Masia (IHE Delft), Maria Blanco (UPM), Roberto Roson (UB), Martina Sartori (UB), Eva Alexandri (CE), Floor Brouwer (WUR-LEI), Donatella Spano (UNISS), Alfonso Damano (U Cagliari), Andrea Virdis (ENAS), Giovanni Sistu (ENAS), **Daniele Pulino (UNISS),** Vania Statzu (U Cagliari), **Fabio Madau (UNISS),** Elisabetta Strazzera (U Cagliari), **Simone Mereu (UNISS)**

August 2018 | Open Access: Yes | Number of citations: N/A

Water-Food-Energy Nexus under Climate Change in Sardinia

Proceedings 2 (11) 609 (8 pp)
https://doi.org/10.3390/proceedings2110609

Abstract: 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. The Nexus perspective is applied to Sardinia, as regional case study, to better understand and improve integrated resource management and relevant policy initiatives. Vulnerability of Sardinia Nexus is assessed under several climate projections by articulated balances of resources (water, energy) availability and sustainable development goals, at regional and sub-regional scales, accounting for demands and conflicts among key economic sectors (agriculture, hydro-power, tourism).

Petra Hesslerová (ENKI), Hanna Huryna (ENKI), Jan Pokorný (ENKI), Jan Procházka (U S Bohemia)

September 2018 | Open Access: No | Number of citations: 2

The effect of forest disturbance on landscape temperature

Ecological Engineering 120, 345–354
HTTPS://DOI.ORG/10.1016/J.ECOLENG.2018.06.011

Abstract: Since the 1990s, the territory of the Šumava National Park (Czech Republic) has faced significant changes in land cover, especially deforestation, in conjunction with several bark beetle disturbances and hurricane Kyrill in 2007. The aim of the study is to review the hydrological and climatic function of the forest and deforestation impacts on the landscape temperature. As a case study, surface temperature changes of the selected area of Šumava National Park from the satellite Landsat thermal data is presented from 1991 to 2016. At the sites with decayed forest, the surface temperature increased by 2–4 °C. Images from ground temperature measurements illustrate extreme temperature differences (~35 °C) at locations where dead wood has not been removed; in the live forest, they are around 5 °C. Further, we show the increase in air temperature is associated with the decay of forest stands, including snow melting. The duration of the permanent snow cover on the mountaintops with the growing forest in the last four years is, on average, 11 days longer than the areas with decayed forest. The results show that the increase in surface temperature in the large area causes changes in the local climate and hydrological regime. These changes may have a negative impact on the surrounding ecosystems, including the Šumava wetlands and peat bogs belonging to the Ramsar sites.

Marco Springman, Michael Clark, Daniel Mason-D'Croz, Keith Wiebe, **Benjamin Leon Bodirsky (PIK),** Luis Lassaletta, Wim de Vries, Sonja J. Vermeulen, Mario Herrero, Kimberly M. Carlson, Malin Jonell, Max Troell, Fabrice DeClerck, Line J. Gordon, Rami Zurayk, Peter Scarborough, Mike Rayner, Brent Loken, Jess Fanzo, H. Charles J. Godfray, David Tilman, **Johan Rockström (PIK)**, Walter Willett

October 2018	Open Access: Yes	Number of citations: 201

Options for keeping the food system within environmental limits

Nature 562, 519–525
doi: HTTPS://DOI.ORG/10.1038/S41586-018-0594-0

Abstract: The food system is a major driver of climate change, changes in land use, depletion of freshwater resources, and pollution of aquatic and terrestrial ecosystems through excessive nitrogen and phosphorus inputs. Here we show that between 2010 and 2050, as a result of expected changes in population and income levels, the environmental effects of the food system could increase by 50–90% in the absence of technological changes and dedicated mitigation measures, reaching levels that are beyond the planetary boundaries that define a safe operating space for humanity. We analyse several options for reducing the environmental effects of the food system, including dietary changes towards healthier, more plant-based diets, improvements in technologies and management, and reductions in food loss and waste. We find that no single measure is enough to keep these effects within all planetary boundaries simultaneously, and that a synergistic combination of measures will be needed to sufficiently mitigate the projected increase in environmental pressures.

Malgorzata Blicharska (UU), Claudia Teutschbein (UU)		
December 2018	Open Access: Yes	Number of citations: N/A
Utmaningar för naturvård i et multi-sektorssystem **[Environmental Conservation Challenges in a multi-sector system]**		
Biodiverse 23 (4) 16-17 http://www.biodiverse.se/app/uploads/2018/12/Biodiverse-4_2018_181204__low.pdf#page=16 English translation: http://www.biodiverse.se/articles/environmental-conservation-challenges-in-a-multi-sector-system/		
Abstract: Many sectors in society are involved in nature conservation issues, like agriculture, forestry and land-use planning. Coherence on a political level between these sectors is getting more and more important, not only to avoid conflict, but also to discover and develop synergies between the sectors. In our study, we see that nature conservation could be a tool for strengthening other sectors.		

Floor Brouwer (WUR-LEI), Lydia Vamvakeridou-Lyroudia (UNEXE), Eva Alexandri (CE), Ingrida Bremere (BEF), Matthew Griffey (SWW), Vincent Linderhof (WUR-LEI)

December 2018 | Open Access: Yes | Number of citations: 3

The Nexus Concept Integrating Energy and Resource Efficiency for Policy Assessments: A Comparative Approach from Three Cases

Sustainability 10 (12) 4860 (18 pp)
doi: https://doi.org/10.3390/su10124860

Abstract: As the world increasingly runs up against physical constraints of energy, land, water, and food, there is a growing role for policy to reduce environmental pressures without adversely affecting increases in prosperity. There is therefore a need for policy makers to understand the potential trade-offs and/or synergies between the uses of these different resources, i.e., to encompass the water–energy–food–land nexus for policy and decision making, where it is no longer possible to ignore the limitations in land availability and its links to other natural resources. This paper proposes a modelling approach to help to assess various policies from a nexus perspective. The global macro-econometric model (E3ME) explores a low-carbon transition through different sets of energy and climate policies applied at different spatial scales. The limitations of the E3ME model in assessing nexus interactions are discussed. The paper also argues and offers an explanation for why no single traditional or classic model has the potential to cover all parts of the nexus in a satisfactory way, including feedback loops and interactions between nexus components. Other approaches and methodologies suitable for complexity science modelling (e.g., system dynamics modelling) are proposed, providing a possible means to capture the holistic approach of the nexus in policy-making by including causal and feedback loops to the model components. Based on three case studies in Europe, the paper clarifies the different steps (from policy design towards conceptual model) in modelling the nexus linkages and interactions at the national and regional levels. One case study (The Netherlands) considers national low-carbon transitions at national level. Two other case studies (Latvia and southwest UK) focus on how renewable energy may impact the nexus. A framework is proposed for the generic application of quantitative modelling approaches to assess nexus linkages. The value of the nexus concept for the efficient use of resources is demonstrated, and recommendations for policies supporting the nexus are presented.

Chrysi S. Laspidou, Nikolaos Mellios, Dimitris Kofinas (All authors affiliated to UTH)

February 2019 | Open Access: Yes | Number of citations: 2

Towards Ranking the Water–Energy–Food–Land Use–Climate Interlinkages for Building a Nexus Conceptual Model with a Heuristic Algorithm

Water 11 (2) 306 (12 pp)
https://doi.org/10.3390/w11020306

Abstract: The concept of the Water–Energy–Food nexus (WEF), as documented by the United Nations Food and Agriculture Organization (FAO), suggests that the three resources are thoroughly interrelated, shaping a complicated web of interlinkages. Perceiving the three commodities as an interdependent variable system, rather than isolated subsystems is a step towards a more holistic approach, and thus a prerequisite to introducing a sustainable scheme for better managing resources. In this work, the well-documented WEF nexus is broadened to a five-dimensional nexus, also involving land use and climate. A methodology for drawing the interrelations among the five dimensions and unreeling the complicated system of direct and indirect interlinkages is given. The intensity of interlinkages among nexus components is initially assessed through a three-point typology with interlinkage scoring corresponding to resource use in Greece. The typology is used and is further expanded to quantify successfully all interlinkages among nexus components with a proposed heuristic algorithm. Results are used to create the cross-interlinkage matrix that identifies food as the most influencing resource and water as the resource mostly influenced by other nexus elements. Results show that indirect interlinkages of multiple resources can be very significant and should not be ignored when planning nexus-coherent policy initiatives and investments in different sectors, in order to promote resource efficiency.

Jan Philipp Dietrich, Benjamin Leon Bodirsky, Florian Humpenöder, Isabelle Weindl, Miodrag Stefanović, Kristine Karstens, Ulrich Kreidenweis, Xiaoxi Wang, Abhijeet Mishra, David Klein, Geanderson Ambrósio, Ewerton Araujo, Amsalu Woldie Yalew, Lavinia Baumstark, Stephen Wirth, Anastasis Giannousakis, Felicitas Beier, David Meng-Chuen Chen, Hermann Lotze-Campen, Alexander Popp (All authors affiliated to PIK)

April 2019 | Open Access: Yes | Number of citations: 2

MAgPIE 4 – a modular open-source framework for modelling global land systems

Geoscientific Model Development 12, 1299–1317
https://doi.org/10.5194/gmd-12-1299-2019

Abstract: The open-source modeling framework MAgPIE (Model of Agricultural Production and its Impact on the Environment) combines economic and biophysical approaches to simulate spatially explicit global scenarios of land use within the 21st century and the respective interactions with the environment. Besides various other projects, it was used to simulate marker scenarios of the Shared Socioeconomic Pathways (SSPs) and contributed substantially to multiple IPCC assessments. However, with growing scope and detail, the non-linear model has become increasingly complex, computationally intensive and non-transparent, requiring structured approaches to improve the development and evaluation of the model.

Here, we provide an overview on version 4 of MAgPIE and how it addresses these issues of increasing complexity using new technical features: modular structure with exchangeable module implementations, flexible spatial resolution, in-code documentation, automatized code checking, model/output evaluation and open accessibility. Application examples provide insights into model evaluation, modular flexibility and region-specific analysis approaches. While this paper is focused on the general framework as such, the publication is accompanied by a detailed model documentation describing contents and equations, and by model evaluation documents giving insights into model performance for a broad range of variables.

With the open-source release of the MAgPIE 4 framework, we hope to contribute to more transparent, reproducible and collaborative research in the field. Due to its modularity and spatial flexibility, it should provide a basis for a broad range of land-related research with economic or biophysical, global or regional focus.

Elke Stehfest (PBL), Willem-Jan van Zeist (PBL), Hugo Valin, Petr Havlik, **Alexander Popp (PIK),** Page Kyle, **Andrzej Tabeau (WUR-LEI),** Daniel Mason-D'Croz, Tomoko Hasegawa, **Benjamin L. Bodirsky (PIK),** Katherine Calvin, **Jonathan C. Doelman (PBL),** Shinichiro Fujimori, **Florian Humpenöder (PIK), Hermann Lotze-Campen (PIK), Hans van Meijl (WUR-LEI),** Keith Wiebe

May 2019 | Open Access: Yes | Number of citations: 6

Key determinants of global land-use projections

Nature Communications 10, 2166(10 pp)
https://doi.org/10.1038/s41467-019-09945-w

Abstract: Land use is at the core of various sustainable development goals. Long-term climate foresight studies have structured their recent analyses around five socio-economic pathways (SSPs), with consistent storylines of future macroeconomic and societal developments; however, model quantification of these scenarios shows substantial heterogeneity in land-use projections. Here we build on a recently developed sensitivity approach to identify how future land use depends on six distinct socio-economic drivers (population, wealth, consumption preferences, agricultural productivity, land-use regulation, and trade) and their interactions. Spread across models arises mostly from diverging sensitivities to long-term drivers and from various representations of land-use regulation and trade, calling for reconciliation efforts and more empirical research. Most influential determinants for future cropland and pasture extent are population and agricultural efficiency. Furthermore, land-use regulation and consumption changes can play a key role in reducing both land use and food-security risks, and need to be central elements in sustainable development strategies.

Publications in M37–M48 (June 2019–May 2020)

Pilar Martinez (UPM), Maria Blanco (UPM)		
September 2019	Open Access: Yes	Number of citations: 0
Sensitivity of Agricultural Development to Water-Related Drivers: The Case of Andalusia (Spain)		
Water 11 (9) 1854 (21 pp) doi: https://doi.org/10.3390/w11091854		
Abstract: Future agricultural development will be challenged by the impacts of climate change on water, which are expected to be particularly strong in southern European regions. Thus, exploring interrelations between agriculture and water under climate change is essential to frame informed policies that ensure sustainable water management while enhancing food production. Nevertheless, studies that address future agriculture development focus on climate-induced changes in crop productivity and often disregard the water dimension. In this research, we have conducted a sensitivity analysis of agricultural development to drivers of water use in Andalusia in 2050 based on outcomes from the CAPRI-Water model. The results from the analysis show that water cost is the most determinant factor in shaping agricultural land, offsetting the impact of the driver of water availability. In contrast, irrigation water use is driven not only by water cost but also by irrigation efficiency. The magnitude of the sensitivity to these drivers differs significantly across crops. Policies aimed at improving resource use efficiency can contribute to strengthening the resilience and adaptation capacity of future agricultural systems to climate change. To achieve this goal, the policies must consider crop sensitivity to irrigation costs and the potential rebound effect.		

Stephan Hülsmann, **Janez Sušnik (IHE Delft)**, Karsten Rinke, Simon Langan, Dianneke van Wijk, Annette B. G. Janssen, Wolf M. Mooij

October 2019 | Open Access: No | Number of citations: 2

Integrated modelling and management of water resources: the ecosystem perspective on the nexus approach

Current Opinion in Environmental Sustainability 40, 14–20
https://doi.org/10.1016/j.cosust.2019.07.003

Abstract: Addressing challenges of water, energy and food security, nexus approaches towards resources management are being developed and starting to be implemented. However, the ecosystem perspective, essential for sustainable resources management, has been identified as a missing element within earlier nexus assessments. With regard to water they have mainly focused on the allocation to different sectors and users, while ecosystem services were rarely explicitly addressed. Existing aquatic ecosystem models are capable of quantifying a wide range of ecosystem services, but have thus far not been comprehensively used in a nexus context. Recent developments in aquatic ecosystem modelling approaches provide opportunities to achieve the sought integration of ecosystem services in the nexus approach. Therefore, we argue for a stronger role of aquatic ecosystem models in nexus assessments.

Roger Cremades, Hermine Mitter, Nicu Constantin Tudose, Anabel Sanchez-Plaza, Anil Graves, Annelies Broekman, Steffen Binder, Carlo Giupponi, Phoebe Koundouri, Muhamad Bahri, Sorin Cheval, Jörg Cortekar, Yamir Moreno, Oscar Melo, Katrin Karner, Cezar Ungurean, Serban Octavian Davidescu, Bernadette Kropf, **Floor Brouwer (WUR-LEI)**, Mirabela Marin

November 2019	Open Access: Yes	Number of citations: 2

Ten principles to integrate the water-energy-land nexus with climate services for co-producing local and regional integrated assessments

Science of The Total Environment 693, 133662 (9 pp)
https://doi.org/10.1016/j.scitotenv.2019.133662

Abstract: The water-energy-land nexus requires long-sighted approaches that help avoid maladaptive pathways to ensure its promise to deliver insights and tools that improve policy-making. Climate services can form the foundation to avoid myopia in nexus studies by providing information about how climate change will alter the balance of nexus resources and the nature of their interactions. Nexus studies can help climate services by providing information about the implications of climate-informed decisions for other economic sectors across nexus resources. First-of-its-kind guidance is provided to combine nexus studies and climate services. The guidance consists of ten principles and a visual guide, which are discussed together with questions to compare diverse case studies and with examples to support the application of the principles.

Detlef P. Van Vuuren (PBL), David L. Bijl, Patrick Bogaart, **Elke Stehfest (PBL)**, Hester Biemans, Stefan C. Dekker, **Jonathan C. Doelman (PBL)**, **David E. H. J. Gernaat (PBL)**, **Mathijs Harmsen (PBL)**

December 2019 | Open Access: No | Number of citations: 0

Integrated scenarios to support analysis of the food–energy–water nexus

Nature Sustainability 2, 1132–1141
https://doi.org/10.1038/s41893-019-0418-8

Abstract: The literature emphasizes the important relationships between the consumption and production of food, energy and water, and environmental challenges such as climate change and loss of biodiversity. New tools are needed to analyse the future dynamics of this nexus. Here, we introduce a set of model-based scenarios and associated Sankey diagrams that enable analysis of the relevant relationships and dynamics, as well as the options to formulate response strategies. The scenarios show that if no new policies are adopted, food production and energy generation could further increase by around 60%, and water consumption by around 20% over the period 2015–2050, leading to further degradation of resources and increasing environmental pressure. Response strategies in terms of climate policies, higher agricultural yields, dietary change and reduction of food waste are analysed to reveal how they may contribute to reversing these trends, and possibly even lead to a reduction of land use in the future.

Dieter Gerten (PIK), Vera Heck (PIK), Jonas Jägermeyr (PIK), Benjamin Leon Bodirsky (PIK), Ingo Fetzer, Mika Jalava, Matti Kummu, **Wolfgang Lucht (PIK), Johan Rockström (PIK), Sibyll Schaphoff (PIK), Hans Joachim Schellnhuber (PIK)**

January 2020 | Open Access: No | Number of citations: 3

Feeding ten billion people is possible within four terrestrial planetary boundaries

Nature Sustainability 3, 200–208
https://doi.org/10.1038/s41893-019-0465-1

Abstract: Global agriculture puts heavy pressure on planetary boundaries, posing the challenge to achieve future food security without compromising Earth system resilience. On the basis of process-detailed, spatially explicit representation of four interlinked planetary boundaries (biosphere integrity, land-system change, freshwater use, nitrogen flows) and agricultural systems in an internally consistent model framework, we here show that almost half of current global food production depends on planetary boundary transgressions. Hotspot regions, mainly in Asia, even face simultaneous transgression of multiple underlying local boundaries. If these boundaries were strictly respected, the present food system could provide a balanced diet (2,355 kcal per capita per day) for 3.4 billion people only. However, as we also demonstrate, transformation towards more sustainable production and consumption patterns could support 10.2 billion people within the planetary boundaries analysed. Key prerequisites are spatially redistributed cropland, improved water–nutrient management, food waste reduction and dietary changes.

Chrysaida-Aliki Papadopoulou (NTUA), Maria P. Papadopoulou (NTUA), Chrysi Laspidou (UTH), Stefania Munaretto (PBL), Floor Brouwer (WUR-LEI)

January 2020 | Open Access: Yes | Number of citations: 1

Towards a Low-Carbon Economy: A Nexus-Oriented Policy Coherence Analysis in Greece

Sustainability 12 (1) 373 (22 pp)
https://doi.org/10.3390/su12010373

Abstract: The sustainable management of natural resources under climate change conditions is a critical research issue. Among the many approaches emerged in recent times, the so-called 'nexus approach' is gaining traction in academic and policy circles. The nexus approach presupposes the analysis of bio-physical, socio-economic and policy interlinkages among sectors (e.g., water, energy, food) for the identification of integrated solutions and the support of policy decisions. Ultimately, the nexus approach aims to identify synergies and trade-offs among the nexus dimensions. Concerning policy, the nexus approach focuses on policy coherence, i.e., the systematic identification and management of trade-offs and synergies between policies across sectors. This paper investigates the coherence between policies on the water-land-energy-food-climate nexus in Greece. The systematic analysis of policy documents led to the elicitation of nexus-related policy objectives and instruments. Then, the coherence among objectives and between objectives and instruments was assessed using the methodology proposed by Nilsson et al. A stakeholder (trans-disciplinary) orientation was adopted and the need to incorporate stakeholders' recommendations as to policy coherence assessment was highlighted. Overall, the findings revealed that climate and food/agricultural policies represent critical future priorities in Greece by stimulating progress in other nexus-related policies (energy, water, land policies) and being positively influenced by them.

Chrysi S. Laspidou (UTH), Nikolaos K. Mellios (UTH), Alexandra E. Spyropoulou (UTH), Dimitrios Th. Kofinas (UTH), Maria P. Papadopoulou (NTUA)

May 2020 | Open Access: Yes | Number of citations: 0

Systems thinking on the resource nexus: Modeling and visualisation tools to identify critical interlinkages for resilient and sustainable societies and institutions

Science of The Total Environment 717, 137264 (18 pp)
https://doi.org/10.1016/j.scitotenv.2020.137264

Abstract: Achieving the UN Sustainable Development Goals depends on using resources efficiently, avoiding fragmentation in decision-making, recognising the trade-offs and synergies across sectors and adopting an integrated Nexus thinking among policymakers. Nexus Informatics develops the science of recognising and quantifying nexus interlinkages. Nexus-coherent solutions enhance the effect of policymaking in achieving adequate governance, leading to successful strategic vision and efficient resource management. In this article, we present the structure of a System Dynamics Model—the Nexus_SDM—that maps sector-specific data from major databases (e.g., EUROSTAT) and scenario models (e.g., E3ME-FTT OSeMOSYS and SWIM) for the national case study of Greece. Disaggregation algorithms are employed on annual national-scale data, turning them into detailed spatial and temporal datasets, by converting them to monthly values spread among all 14 River Basin Districts (RBDs). The Nexus_SDM calculates Nexus Interlinkage Factors and quantifies interlinkages among Water, Energy, Food, Built Environment, Natural Land and greenhouse gas (GHG) emissions. It simulates the nexus in the national case study of Greece as a holistic multi-sectoral system and provides insights into the vulnerability of resources to future socio-economic scenarios. It calculates the link between crop type/area, irrigation water and agricultural value, revealing which crops have the highest agricultural value with the least water and crop area. It demonstrates that fossil fuel power generation and use of oil for transportation are responsible for the most GHG emissions in most RBDs and presents projections for years 2030 and 2050. The analysis showcases that to move from a general nexus thinking to an operational nexus concept, it is important to focus on data availability and scale. Advanced Sankey and Chord diagrams are introduced to show distribution of resource use among RBDs and an innovative visualisation tool is developed, the Nexus Directional Chord plot, which reveals Nexus hotspots and strong interlinkages among sectors, facilitating stakeholder awareness.

Florian Knobloch (RU), Steef V. Hanssen (RU), Aileen Lam, **Hector Pollitt (CE),** Pablo Salas, **Unnada Chewpreecha (CE), Mark A. J. Huijbregts (RU), Jean-Francois Mercure (RU, CE)**

In press, online March 2020 | Open Access: Yes | Number of citations: 0

Net emission reductions from electric cars and heat pumps in 59 world regions over time

Nature Sustainability (2020, in press)
https://doi.org/10.1038/s41893-020-0488-7

Abstract: The electrification of passenger road transport and household heating features prominently in current and planned policy frameworks to achieve greenhouse gas emissions reduction targets. However, since electricity generation involves using fossil fuels, it is not established where and when the replacement of fossil-fuel-based technologies by electric cars and heat pumps can effectively reduce overall emissions. Could electrification policies backfire by promoting their diffusion before electricity is decarbonized? Here we analyse current and future emissions trade-offs in 59 world regions with heterogeneous households, by combining forward-looking integrated assessment model simulations with bottom-up life-cycle assessments. We show that already under current carbon intensities of electricity generation, electric cars and heat pumps are less emission intensive than fossil-fuel-based alternatives in 53 world regions, representing 95% of the global transport and heating demand. Even if future end-use electrification is not matched by rapid power-sector decarbonization, it will probably reduce emissions in almost all world regions.

Submitted Manuscripts Not Yet Published

Lotte van den Heuvel (UU), Malgorzata Blicharska (UU), Sara Masia (IHE Delft), Janez Sušnik (IHE Delft), Claudia Teutschbein (UU)		
Under review (May 2020)	Open Access: N/A	Number of citations: N/A
Ecosystem services in the Swedish water-energy-food-land-climate nexus: anthropogenic pressures and physical interactions		
Ecosystem Services		

Abstract: Traditionally, challenges of natural resource management have been addressed with a sectoral policy approach. However, it is increasingly recognised that different sectors are interconnected in a complex and mutually interacting system. A nexus approach is proposed to identify synergies and trade-offs between sectors and to foster the sustainable and efficient use of resources, particularly in light of climate change. The nexus approach has led to studies identifying interactions between policy objectives across nexus sectors, but the physical interactions between nexus sectors that can be the result of policy interactions, have received less attention. Nevertheless, such interactions can have severe consequences for the environment, affecting ecosystems and the services they provide. Integrating the nexus approach and the ecosystem service concept may help to better understand pressures and impacts related to a resource nexus and to address trade-offs. In this study, literature and expert assessment are used to analyse the water-energy-food-land-climate nexus in Sweden through the lens of the ecosystem services concept to gain insights into interactions between the nexus sectors. By demonstrating how anthropogenic pressures originating from the nexus sectors affect ecosystem functions and services, this paper serves as a foundation to further inform policy-making (within and outside Sweden) when considering the water-energy-food-land-climate nexus.

End of D7.7.