Specification of regional/local scale models and methods

Deliverable D3C.1

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Preface

The European Commission-funded FP7 project IMPRESSIONS (Impacts and Risks from High-end Scenarios: Strategies for Innovative Solutions) is an ambitious study of the risks and consequences for Europe of a runaway greenhouse effect and the options available for averting its most adverse effects. Focusing on the high-end of projections of future climate change and operating in the context of alternative development pathways for Europe, the project seeks to simulate future impacts on natural resources, land use and societal well-being in Europe during the 21st century. It attempts this using a suite of single-sector and integrated multi-sector models that simulate the dynamics of climate change impacts and adaptive management using an iterative, time-dependent approach up to 2100. The options for adaptive management, including transformative change, are guided by stakeholder-led visions of a sustainable and equitable Europe by 2100.

This deliverable reports on the specification of regional/local scale models and methods. It describes the methods and models to be applied in the three regional/local scale case studies: Scotland, Hungary and Iberia. The specification for the regional models links to other parts of the IMPRESSIONS project. Primarily this involves a relationship with the project's scenario development (WP2) since the scenarios are key inputs to the models. There are also links to WP4/5 in terms of exploring future visions, and in defining pathways of adaptive actions including transformative solutions.

Summary

Existing statistical and process-based models are being enhanced to improve the quantification of climate change impacts, adaptation and vulnerability under high-end scenarios (HES). These are being applied with new models developed to improve the representation of individual behaviour in the real world. These agent-based models simulate adaptation as a process driven by the behaviour of individual decision-makers, firms and institutions that can learn and interact with one another.

The models include interactions between different sectors, e.g. agriculture, forestry and biodiversity, and between different regions and the rest of the world, as they compete for resources such as land, water and energy. The models also allow the exploration of synergies and trade-offs between adaptation and mitigation actions, where possible, such as the potential for tree-planting to alleviate flooding as well as storing carbon.

The local/regional modelling exercise is being conducted in three study cases: Scotland, Hungary and Iberia. Context-specific, regionally relevant themes and research questions are being addressed within the three case studies and, hence, the methodological and modelling approaches differ between them. In spite of exploring different issues, a common modelling framework and set of application protocols is being applied to the local/regional modelling in order to support comparison across cases. The modelling covers both the physical and social environment providing outputs that are relevant for assessing the vulnerability of human well-being. The models will be used to explore both direct and indirect drivers of change across cases, as well as scenario and model uncertainties. The CLIMSAVE Integrated Assessment Platform (IAP) at the European scale (see Deliverable D3B.1; Holman et al. 2015) will be used to apply boundary conditions for the local/regional models. Linkages across cases and scales are also being supported by a stakeholder engagement process which ensures the relevance and saliency of the modelling exercises, and contributes to envisioning and model parameterisation.

1. Introduction

This deliverable describes the specification for model improvement and development within the regional case studies of IMPRESSIONS: Scotland, Hungary and Iberia. The objective for WP3C is to advance and apply regional scale methods and models to better quantify and understand the impacts, risks, vulnerabilities and adaptation options associated with a range of scenarios for key economic, social and environmental sectors and their cross-sectoral interactions. This document outlines the specification of methods and models within the three regional case studies which cover statistical models, detailed process-based models and complex systems approaches to capture and quantify knowledge about individual behaviour, institutional conditions and decision-making processes that underpin adaptation.

The research is ongoing, and while the general specification presented here has already been agreed, the implementation of the model improvements represents work in progress. As such, this report offers an early snapshot of the modelling activities in the IMPRESSIONS' regional case studies.

1.1. Description of Work

According to the Description of work there are three main tasks relating to D3C.1:

Task 3C.1: Development and application of climate change impacts, adaptation and vulnerability (CCIAV) methods and models within the Scottish case study
The main theme of the Scottish case study is land resource management, including links to the global scale through the food and beverage trade and its effects on land allocation. The research will combine the CLIMSAVE IAP for Scotland with Agent-Based Models (ABMs) applied to the IMPRESSIONS scenarios from WP2 to simulate emergent social and economic structures. The CLIMSAVE IAP for Scotland is a higher data resolution version of the CLIMSAVE IAP for Europe (see Deliverable D3B.1; Holman et al. 2015), including cross-sectoral interactions for urban, agriculture, forestry, biodiversity, water and coasts. A detailed, process-based model of forest resources (ForClim) will also be applied since forestry is a major sector in Scotland and policy targets exist to extend Scotland's forested area by up to 30%. The ABM approach will treat adaptation as a process underpinned by the systemic behaviour and decision-making of learning and interacting land use agents, taking account of variations between individual actors (class, ethnicity, gender, wealth and power). ABM applications will be made for sub-regions of Scotland and used in comparison with the IAP approach. The Scotland case study will involve Adaptation Scotland as this organisation leads a network of relevant private and public sector stakeholders with an interest in climate change impacts and adaptation. Stakeholder engagement will be used to develop a flexible research strategy in response to stakeholder needs (as identified in WP1) supported by Adaptation Scotland and the stakeholder facilitation of WP6A. The main outcome of the study will be new knowledge and evidence to support the implementation of the Scottish Adaptation Strategy, as well as capacity building for key decision-makers with respect to adaptive learning for coping with high-end futures.

Task 3C.2: Development and application of CCIAV methods and models within the Iberian case study
The main theme of the Iberian case study is land use and water resource management, including links to the global scale through migration from North Africa. The study will focus on socio-ecological resilience to high-end scenarios in two cross-boundary areas of Spain and Portugal, namely the Guadiana and Tagus river basins. The approach will assess changes in institutional practices and the information needed by national and local decision-makers to cope with high-end climate change, drawing on the multi-scale climate and socio-economic scenarios from WP2 and CCIAV modelling. The modelling work will simulate the interrelationships and feedbacks between key processes in

hydrology, water management, forestry, agriculture, land use, population change and migration. Specifically, an eco-hydrological river basin scale model SWIM will be applied to the Guadiana and Tagus river basins to investigate climate and land use change impacts on seasonal water availability with the focus on low flow periods and droughts under the high-end scenarios. A catchment-scale forest model (LandClim) will also be employed to simulate forest-related ecosystem service provision under the impact of a changing climate and a changing wildfire regime. A range of forest fire indices will be used to assess changes in wildfire risk at the scale of the entire river basin. Results from the global and European case studies will be used to identify boundary conditions for socio-economic drivers such as population, migration and land cover change (urban, forest, arable, grassland, etc.). The study will better quantify the risks and vulnerabilities, trade-offs and synergies, and the opportunities, costs and benefits that account for the interplay between changes in water availability, land use and the implementation of alternative policy mixes. This will lead to the identification of pathways to a resilient and sustainable future that account for social learning trajectories and path dependencies (with WP4). These outcomes will support policy decisions that foster the coping and adaptive capacities of society to high-end futures. The Portuguese Environment Agency (APA), who are in charge of all adaptation, mitigation and water policies, have agreed to participate as an influential decision-maker in the Iberian case study. The APA is also responsible for the integration and coordination of these policy areas with other sectoral policies of relevance for the case study (e.g. land use, forestry, biodiversity and nature conservation) and already works closely with other national and local decision-makers that are to be involved in the case study development. The agency is a key node in all Portuguese climate change related policies and thus, is also one of the key interfaces with Spain in any cross-boundary policy development required to deal with high-end scenarios.

Task 3C.3: Development and application of CCIAV methods and models within the Hungarian case study

The main themes of the Hungarian case study are water management, urban development, human health and well-being in two medium-sized communities, Szekszárd and Veszprém. The research will assess current and future vulnerability to climate change under high-end scenarios developed in WP2 and informed by region-specific results of CCIAV models within the two communities. Participatory approaches to increase the ownership and relevance of the process and results have been used from the very beginning to identify community specific priorities. Participatory methods with key community stakeholders at the local level and the national-level Alliance of Climate Friendly Municipalities will continue to be used throughout the case study to evaluate how high-end scenarios will drive climate change vulnerability. Indicators of elements at risk to the combined effects of climate and socio-economic change, such as critical infrastructure, zones of high-density development and elderly people, will be identified in consultation with the stakeholder groups. The spatial distribution of these indicators will be based on the climate and socio-economic scenarios provided by WP2 to create maps of exposure to high-end impacts and distinguish locations with high vulnerability (i.e. hotspots). A mixed methods approach will be used to achieve this, which combines qualitative participatory mapping processes with quantitative modelling and mapping to highlight areas where high-end scenarios are expected to have the greatest impacts. No significant integrated climate modelling activities have been undertaken in the two communities to date, so IMPRESSIONS will apply a high-resolution urban land use model (based on modifications to the RUG model). RUG simulates changes in artificial surfaces (i.e. the built environment) based on scenario assumptions for changes in spatial planning policy, population growth, economic development and societal preferences for residential locations. IMPRESSIONS will also develop a new model of human health for the local population focusing on heat-related impacts, with probabilistic methods used to assess the uncertainties associated with population projections and adaptation. Assumptions about adaptation to health impacts will be linked to the stakeholder interviews (WP1) as well as the latest evidence for housing interventions, air conditioning uptake and energy use, among other factors.

Changes in other land use classes (e.g. agriculture, forestry) and water resources will be downscaled to the study area from the continental and sub-continental model outcomes from the European case study to frame impacts at the local scale for discussion with stakeholders. This evidence base will be used to test the ability of existing development and sector strategies and adaptation plans for the two communities to reduce vulnerability by lowering exposure and increasing resilience. These results will form the basis of an assessment of the potential for adaptive governance through policy, technical measures and the efforts of different stakeholders and self-organising social networks to address both short-term emergencies and longer-term climate risk.

1.2. Case study visions

The agreed visions for the regional case studies, which this deliverable supports, are given below.

1.2.1. Scottish case study

The rural economy of Scotland is vulnerable to the impacts of climate change. This case study aims to explore risks posed by high-end climate change scenarios to land resource management sectors in Scotland, including forestry, agriculture and tourism. It focuses on possible disruption within the supply chain for food and beverage production (at the local, national and global scale); the potential implications of Scotland's reforestation targets; potential changes to tourism activity based on changes to the Scottish landscape (currently a key motivating factor for tourism to Scotland); and the possible spread of Lyme disease. The attitudes and decision-making behaviour of key Scottish stakeholders to different adaptation options for high-end climate change scenarios is being explored to improve how adaptation is represented as a learning process in agent-based models. The outcomes of the project will provide new evidence to inform the Scottish Adaptation Strategy and Land Use Strategy, and will support decision-makers to incorporate high-end climate change scenarios into their risk management strategies.

1.2.2. Iberian Case Study

The dry landscapes of southern Spain and Portugal, including the unique oak-grassland agroforestry systems known as "Dehesas" or "Montados", are vulnerable to climate change, especially due to an increase in drought frequency and intensity, and to social trends such as the declining demand for cork. The main goal of the Iberian case study is to develop transformative solutions to cope with high levels of climate change in the Tagus and Guadiana river basins, including the potential impacts of population change and migration from North Africa. In particular, the work with decision-makers will explore two types of systemic solutions: (i) Integrated River Basin Management, to explore different policy mixes at the river basin scale, including the interactions between water, energy (hydropower) and land use management, to assess how they can improve the resilience of socio-ecological systems; and (ii) Ecosystem-Based Approaches of the Dehesa/Montado to look at the conditions for improving the resilience and productivity of these ecosystems and landscapes, including how to enhance ecosystem services and the livelihoods of local people at the local scale (e.g. farm). Pathways will be identified that exploit the synergies between climate mitigation, adaptation and sustainable development.

1.2.3. Hungarian Case Study

Climate change poses multiple challenges to municipalities, with some parts of Hungary already suffering from impacts such as flooding, high summer temperatures, extreme storm events, and water shortages. The Hungarian case study will focus on testing the ability of existing overall municipal development strategies, sector strategies and adaptation plans to reduce vulnerability to high-end climate change by lowering exposure to risk and increasing resilience. Thematic models will be used to assess how high-end climate change scenarios affect urban development, agricultural land use and food self-provisioning capacity, water availability and health (heat-related morbidity and Lyme disease). The study will explore the adequacy of present adaptation measures and options for additional adaptation strategies that may be necessary for coping with high-end climate and socio-economic change in the future focusing on the roles of networks and change agents, institutional innovation and sectoral policies. This information will help relevant stakeholders and agents of change to develop effective integrated mitigation and adaptation solutions, transformative strategies and transition pathways.

1.3. Links to other work packages

The specification for regional/local model improvement and development links to other parts of the IMPRESSIONS project. WP2 will provide the integrated regional/local scale climate and socio-economic scenarios, WP4 will provide participatory adaptation and mitigation pathways, and WP5 will assess the risks, opportunities, costs and benefits, explore transformative strategies for coping with high-end scenarios and synthesise all the results into an Information Hub. Furthermore, the global (WP3A) and European (WP3B) case studies will provide boundary conditions for the three regional/local case studies in Scotland, Hungary and Iberia. In particular, the land use change projections derived from the European case study modelling, which will allocate land into arable, intensive grassland, extensive grassland, managed forest, unmanaged forest and abandoned/unmanaged land uses, on the basis of profitability within the scenario (based on yields, costs and prices) will provide an input to more detailed, process-based models of individual sectors within the regional/local case studies.

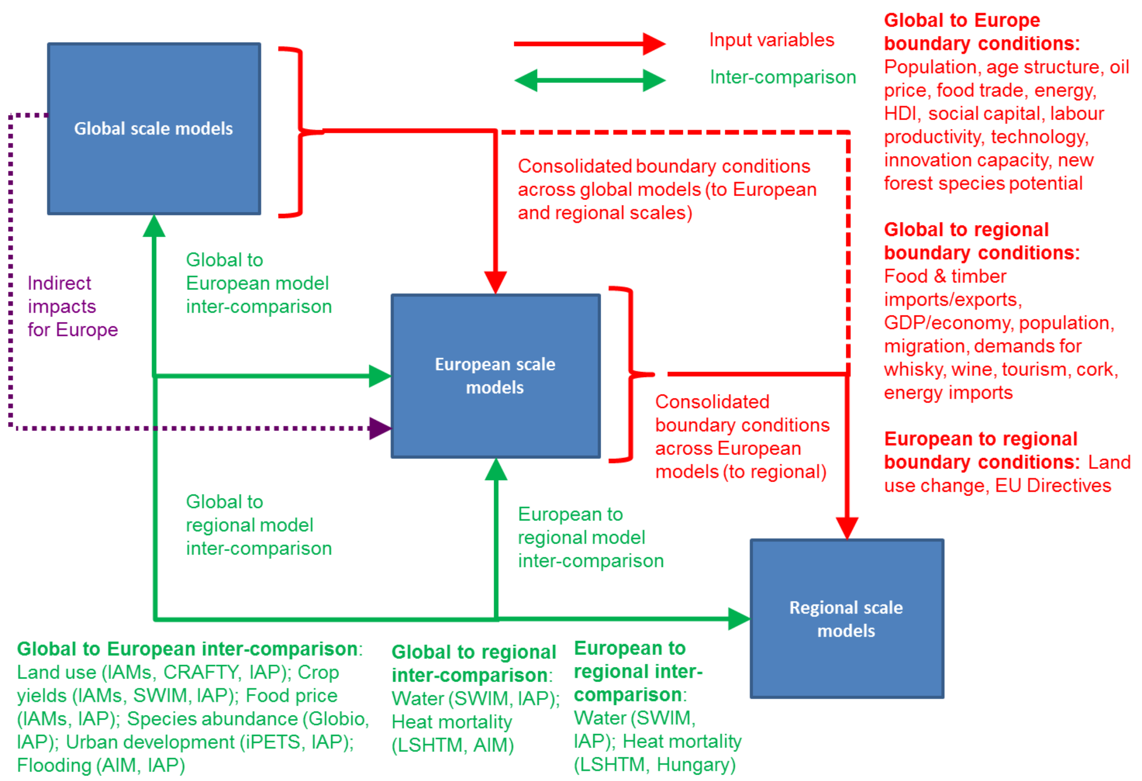

Figure 1.1: Potential cross-scale (Global-European-Regional) data transfers (shown in red) (presented at the 2nd modellers meeting held in Pisa on 30 September to 1 October 2014, based on model data dictionaries).

2. Scenarios and boundary conditions up to 2100

2.1. Climate scenarios

The climate change scenarios used in the regional case studies will be based on climate model simulations that are available from CMIP5 and CORDEX for RCP8.5 and RCP4.5 due to the focus in IMPRESSIONS on high-end climate change. Deliverable D2.1 (Kok et al. 2015) describe the process by which the limited number of climate model simulations which will be used as a core set within all IMPRESSIONS case studies were identified by WP2, based on climate model sensitivity (reflecting lower, intermediate and high-end climate change) and the availability of regional model data. Kok et al. (2015) thereby selected the following core set of climate scenarios:

- Representing high-end climate change:
  - RCP8.5 x HadGEM2-ES/RCA4
  - RCP8.5 x CanESM2/CanRCM4
  - RCP8.5 x IPSL-CM5A-MR/WRF;
- Representing intermediate climate change:
  - RCP8.5 x GFDL-ESM2M/RCA4
  - RCP4.5 x HadGEM2-ES/RCA4;
- Representing lower-end climate change:
  - RCP4.5 x GFDL-ESM2M/RCA4
  - RCP4.5 x MPI-ESM-LR/CCLM4.

2.2. Socio-economic scenarios

The socio-economic scenarios will be based on the Shared Socio-economic Pathways (SSPs) in all case studies. Early in IMPRESSIONS, the decision was taken to limit the number of SSPs to be used in the participatory process to four (SSP1, SSP3, SSP4 and SSP5) for a variety of reasons explained in Deliverable D2.1 (Kok et al. 2015). These four SSPs capture the low and high challenges to both mitigation and adaptation. In addition to the SSPs, all three case studies undertook an assessment of available relevant existing scenarios. This assessment resulted in the selection of the CLIMSAVE socio-economic scenarios for Scotland on the basis of relevancy. Conversely, for Iberia and Hungary, existing material was out of focus and/or at an inappropriate spatial and temporal resolution.

For Scotland, Kok et al. (2015) matched the four CLIMSAVE socio-economic scenarios with the four global SSPs and extended them until 2100. It proved difficult to match SSP5 (Fossil-fuelled Development) with the CLIMSAVE scenarios, so this is being developed based on the global SSP5 storyline with input from Scottish stakeholders. However, SSP1 (Sustainability) and SSP3 (Regional Rivalry) matched well and SSP4 (Inequality) matched in part, so elements of both scenario sets are being combined (Table 1).

Table 2.1: CLIMSAVE scenarios for Scotland with illustrative examples for economic, environmental and social uncertainties, and most similar SSP.

Scenario	Economic	Environmental	Social	SSP
MacTopia	Strong	Integrated	Equitable	SSP1
Mad Max	Rollercoaster volatile	Non-existent	Disparate	SSP3
Tartan Spring	Strong but weakening	Weak environmental regulation	Disparate well-being	SSP4
The Scottish Play	Gradual strong with blips	Trade-offs	Equitable	No SSP equivalent

For Iberia and Hungary, new socio-economic scenarios will be developed with stakeholders. The European SSPs will serve as boundary conditions for both case studies.

In all cases, the socio-economic scenarios include both qualitative descriptions and quantifications. Qualitative descriptions include narratives and tables that summarise trends in key elements. These products will be developed using stakeholder participatory approaches. Quantification of some key variables are available from the IIASA SSP database. These quantified variables can be used directly as model input and will define boundary conditions after downscaling. Quantification of other key model input variables is being determined through expert estimates derived from a 'Fuzzy Sets' based approach (carried out at the WP2 Wageningen workshop in January 2015; see Kok et al. 2015) and modeller expert judgment. The quantification process is ongoing.

2.3. Regional population data and downscaling

Population totals and/or age structure are required by the regional models at different levels (see Figure 1.1 for IMPRESSIONS operating scales). This will require some development, especially when it comes to population age structure and different scenario quantifications. To be consistent and precise in this approach, the population data will be made available to all models at three different scales: national, sub-national (NUTS2), and grid level. Population data already exist for age groups as well as totals at various spatial scales for European countries. However, in line with the scenario development, models in IMPRESSIONS will require population data that follow the chosen scenario quantifications, namely the four different SSPs (1, 3, 4 and 5). These data are not currently available at sub-national level, so a method is being developed for population downscaling in conjunction with a database for storing the resulting information. The outcome of this exercise will be an age-specific population database for 30 countries at the NUTS2 sub-national statistical level, for the four different SSP scenarios. The European Union statistical office Eurostat describes the NUTS2 level as "basic regions for the application of regional policies"[1]. For this reason it is considered important to use the NUTS2 level to create the scenario specific database of population information.

2.4. European boundary conditions

Results from the application of the European scale models for the IMPRESSIONS scenario framework will allow boundary conditions to be defined for the three regional/local case studies. Boundary conditions are the exogenous factors occurring at higher spatial scale levels that are used to initialise the regional/local scale models. Examples include changes in the macro-economy through the demand for food, timber and other land based commodities, e.g. wine, whisky, tourism, etc., and European scale policy change and its effects. By defining a set of European boundary conditions that are conditional on the IMPRESSIONS scenarios, the regional/local models will be applied to a common set of assumptions. This provides better scope for the comparison of the model results across the three case studies.

[1] http://ec.europa.eu/eurostat/web/nuts/overview

3. Modelling in the Scotland case study

3.1. General specification

Scotland has a population of over 5.3 million and comprises 32 local authority areas (Scottish Government Website, 2015; Figure 3.1). As part of the United Kingdom, Scotland has a relatively ambitious climate change adaptation policy, evidenced in the Climate Change Act of 2009 and the associated Climate Change Adaptation Programme and Climate Change Adaptation Framework. The Scottish Government's Climate Change Adaptation Framework provides information about the impacts and options for adaptation within Scotland. It includes a series of Sector Action Plans, which outline the government's priorities and planned adaptation actions. These plans also provide information that can be used by organisations in those sectors to familiarise themselves with the risks and opportunities of climate change.

The Scottish Government's Climate Change Adaptation Framework and associated Sector Action Plans have paved the way for substantive organisational research within the climate change arena in Scotland. Numerous organisations are currently implementing internal policy changes based on the business risks and opportunities posed by climate change. These organisations are cross-sectoral and include: government departments; non-governmental organisations; industry; research; and academic institutions. The policy changes taking place within these varied organisations are indicative of the progressive status of climate change adaptation research within Scotland.

Figure 3.1: Map showing the location of the Scottish case study within Europe (highlighted in red inside the red box; left; Google, 2015) and a detailed breakdown of the local authority areas within Scotland (right; Scottish Government website, 2015).

The HES issues to be explored in the Scottish case study centre around the attitudes and decision-making of key Scottish stakeholders for climate change adaptation. The four key themes are:

- Decision objectives (problems, goals, contexts and preferences);
- Decision support;
- Making and implementing decisions, including the use of HES projections; and
- Decision-making outcomes.

These themes have been explored in a series of interviews with key stakeholders (through WP1), and will be further explored in a follow-up survey, as well as in a series of participatory stakeholder workshops (through WP6A). The purpose of the three stakeholder workshops is to:

- Link the CLIMSAVE Scottish scenarios to the SSPs and explore the implications of HES for Scotland;
- Review modelling results on impacts and vulnerability, develop a vision, and identify adaptation and mitigation pathways (and policies) for the RCP x SSP scenarios; and
- Review model outcomes, refine pathways with risks, opportunities, resilience and transformability, and develop action plans and 'empowering' narratives.

Exploration of the implications of HES within Scotland will be supported by a series of inter-connected modelling approaches. An overview of the different models to be included and their linkages is presented in Figure 3.2. Further details of each of the modelling frameworks are provided in subsequent sections.

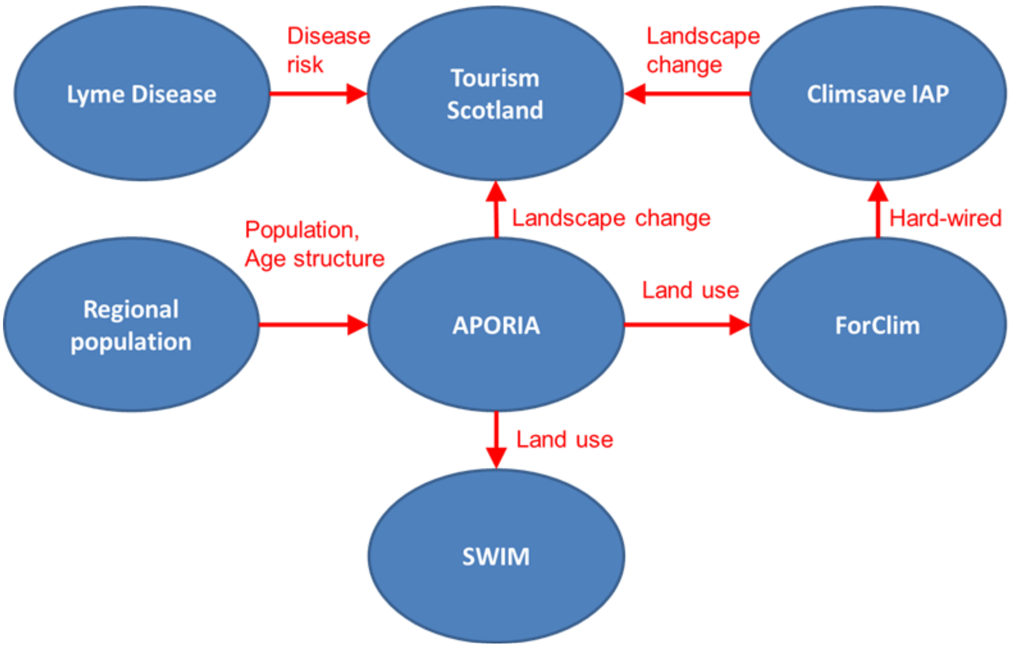

Figure 3.2: The models applied in the Scottish case study and their inter-linkages.

3.2. Tourism modelling

The tourism industry is an important contributor to the Scottish economy. While scenery and landscape is a dominant factor motivating summer (JJA) tourism to Scotland (Visit Scotland, 2012), the landscape is projected to change substantially over the coming century, influenced both directly and indirectly by climate change.

The tourism model is a new model in the process of development. The model will use a ranking system of tourists' perceptions of landscapes (both current and visualisations of change – an example is shown in Figure 3.3), determined using social survey methods. The social survey will be based on visualisations of future climate analogues and contingent ranking to explore the potential impacts of climate change-related landscape change on Scottish tourism. The climate analogues were established using the regional climate model HIRHAM5 (driven by the global climate model EC-EARTH at the boundaries and with RCP8.5 forcing).

Figure 3.3: An illustration of a "before" (right) and "after" (left) photo of a Scottish landscape, having been altered using photoshop to show potential changes due to climate change.

The focus of the model is on the late 21st century (2070s-2100s), and on changes to the natural environment (e.g. drying, changing water levels, changed vegetation, etc.). Projected changes will encompass existing Scottish Government targets in, for example, reforestation. Outcomes of the model will include qualitative (changing tourist perceptions) and quantitative (projected changes in visitor numbers) descriptors of HES impacts on tourism. Furthermore, the model will potentially explore the opportunity to output the changing value to tourism, or income derived from tourism (in terms of economic spend).

3.3. Agricultural land use modelling

Modelling the response of agricultural land use to HES in Scotland will make use of the Aporia modelling framework (Murray-Rust et al. 2014). Aporia was developed to aid the creation of agent-based land-use models, at multiple locations with unique socio-economic contexts, by local experts and academics without extensive coding and software engineering experience (Figure 3.4). Through configuration of Aporia, researchers can investigate a variety of research questions, such as: How does the relative influence of social factors versus economic and environmental factors guide on-farm crop rotation selection and the provision of ecosystem services? What is the degree of subsidy adoption among farm households and how effective are subsidies in achieving their economic or environmental goals? And, under what conditions is marginal land taken out of (or put into) agricultural production?

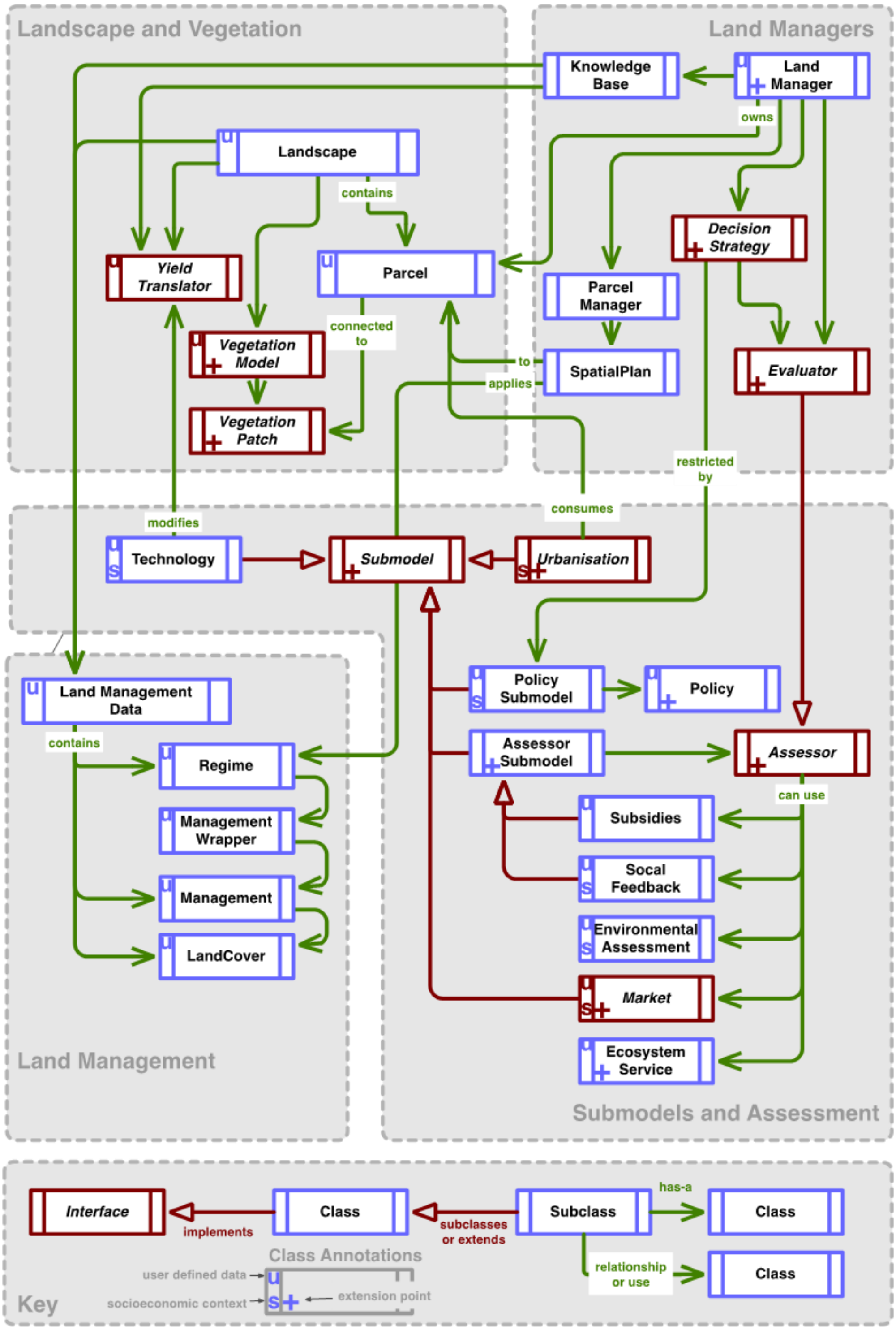

Figure 3.4: The Aporia framework for agricultural land use modelling (after Murray-Rust et al. 2014).

Aporia will be applied to Scotland using existing social survey data about Scottish farmers to parameterise a range of farmer agents within the model. The model will be tested against available data and compared with other land use modelling approaches, *viz*. the CLIMSAVE IAP. Climate and socio-economic scenarios will then be applied to the model to understand how the Scottish agricultural system will respond to HES. The benefit of the agent-based modelling approach is that it is explicit about the role of human behaviour and decision-making in underpinning climate adaptation processes. This provides a counter-point to the indicator-based approach of the CLIMSAVE IAP.

3.4. Water modelling

The Soil and Water Integrated Model (SWIM) is a process-based deterministic eco-hydrological model, developed from two earlier models: SWAT and MATSALU as described in Krysanova et al. (1998, 2000). SWIM operates at the river basin scale based on an assemblage of numerical representations of physical processes of the hydrological cycle and other related processes (vegetation/crop growth, nutrient cycling, and erosion). These physical processes are mathematically interpreted and parameterised, to form the four main modules of the model: the soil hydrological cycle, the groundwater system, biogeochemical processes and plant growth processes (represented schematically in Figure 3.5). SWIM operates on a daily time step and uses climatic, land use, topographic, crop and soil datasets as input files.

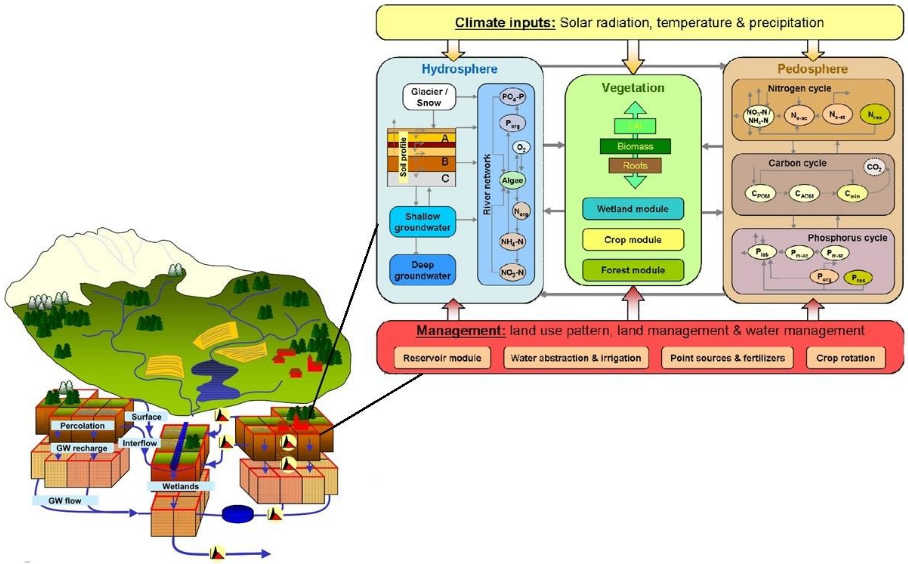

Figure 3.5: SWIM model schematic representation.

The topographical map of a catchment serves as a basis to create a sub-basin map, which is later intersected with land use and soil maps, to identify so-called HRU's – Hydrological Response Units – within each sub-basin, with a unique combination of land use and soil type. Identical HRUs, i.e. those with the same land use and soil types in a sub-basin, are assumed to have the same hydrological "behaviour" and are later combined into hydrotope classes within each sub-basin. The components of the hydrological cycle, nutrient cycling and sediment loads are calculated at the HRU level and lateral flows are aggregated for sub-basins. The lateral flows of water, nutrients and sediments are then routed through the basin, using a conceptual representation of the open channel hydraulics based on the Muskinghum method, taking into account transmission losses.

The hydrological modelling is being applied to the Tay River catchment driven by the HES to address the impact on water resources within the Scottish case study. The SWIM model has been set-up, calibrated and validated for the Tay catchment up to the Ballathie gauge. SWIM will be used to investigate the potential impacts of the HES on river discharge using the data sets of projected climatic change, described in Section 2.1, and land use change scenarios, e.g. afforestation, generated by the agent-based Aporia model (see Section 3.3) and/or the CLIMSAVE IAP (see Section 3.7). The consequences of changes in river discharge will be inferred from these model results, e.g. irrigation water availability, flooding, ecological status and water quality. Additionally, a model inter-comparison exercise is planned between the SWIM model and the global and European scale models, e.g. WaterGAP (global), rIAM (Europe) and the Scottish CLIMSAVE IAP, in terms of their representation of river discharge and crop yields, as well as simulated impacts.

3.5. Forest modelling

Increasing the amount of forested land in Scotland is an attractive option for carbon offsetting and as a way to increase timber production. HES for Scotland will likely benefit woody tree growth as most tree species are limited by cold temperatures. The dynamic forest stand model ForClim is being used to simulate forests stands on a 5 km grid for the whole of Scotland, to identify locations with the highest potential tree growth and timber production under HES.

ForClim is a cohort-based dynamic vegetation model that was developed to analyse successional pathways of various forest types (Bugmann and Solomon 2000, Shao et al. 2001). Based on the theory of patch dynamics, tree development (growth), establishment and mortality are simulated with an annual time step on small areas (“patches”); while the influence of climate and ecological processes is taken into consideration using a minimum of ecological assumptions. No interaction is assumed between trees of adjacent patches, i.e. the successional pattern at larger scales (forest stand to landscape) is obtained by averaging the simulation results from many patches (Bugmann 2001). ForClim is composed of four independent sub-models on weather (computes relevant bioclimatic variables), water (computes an annual site-specific drought index), plant (calculates establishment, growth and mortality of trees on the forest patch) and management (simulates several cutting/harvesting and thinning techniques defined by the type (e.g. clear cutting, ‘plentering’), frequency and intensity of management operations (Figure 3.6).

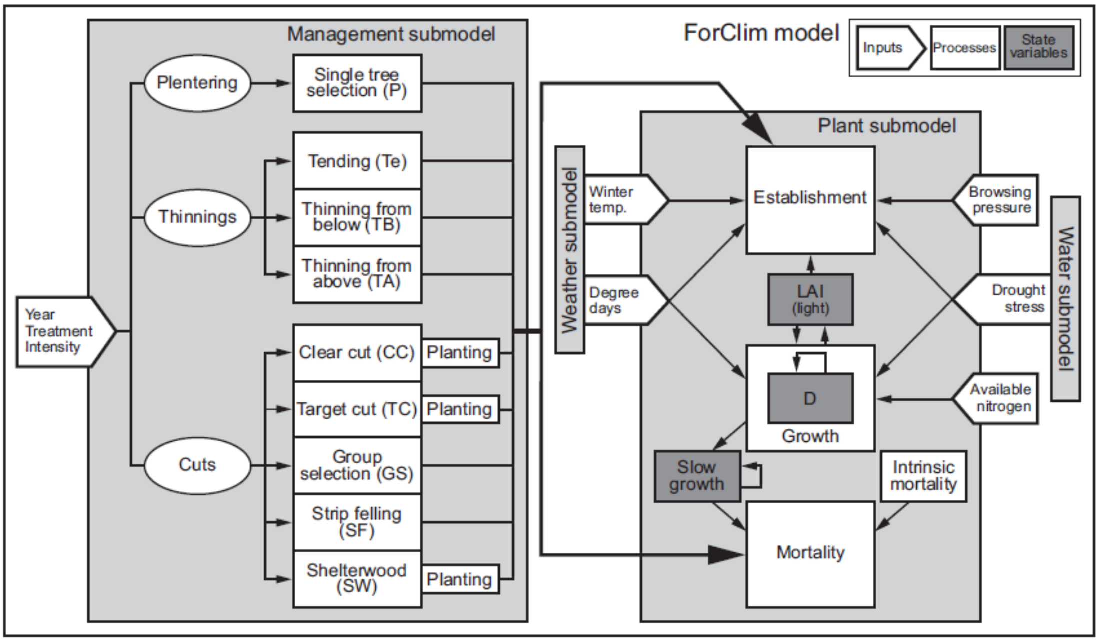

Figure 3.6: Structure of the ForClim model with sub-models management, plant, weather and water (Rasche et al. 2011).

ForClim is being used in the Scottish case study to simulate potential natural forests as well as managed even-aged monocultures. For managed forests, this includes species that are currently grown in Scottish plantations (e.g. *Picea sitchensis*, *Pinus sylvestris*) as well as some potentially new species, which might be more productive under future warmer climatic conditions (e.g. *Pseudotsuga menziesii*). The goal is to identify the species and locations where re-foresting efforts should focus in the future.

3.6. Lyme disease modelling

Lyme disease is the most prevalent vector-borne disease in Europe that is transmitted by ticks. In 2011 there were 229 cases reported in Scotland[2] (incidence rates of 4.36 per 100,000 inhabitants). The annual peak period is from July to September and the main endemic region is the Highlands, while the incidence number in Tayside is also rising (Slack et al. 2011). To support adaptive disease management, the modelling work focuses on the biophysical disease risk in the case study area, i.e. the density of infectious ticks. The specific objectives are: (i) to propose a novel spatio-temporal model for tick population ecology and pathogen transmission, by integrating the influence of temperature and heterogeneous landscape; and (ii) to apply the model to predict the seasonality of Lyme disease risk across the Scottish landscape under HES.

The Lyme disease risk (LYR) model is developed using a cellular automata approach. The environment is represented in a two-dimensional, rectilinear grid (1 km^2). During each successive discrete time step (one week), the states of cells are updated simultaneously following the transition rules that have been applied to the current configuration. In this model, cells are stated at different layers to represent the population distribution of ticks and host animals and the configuration of the environment. Transition rules concerning tick development, pathogen transmission and host population dynamics are based on previous studies (Li et al. 2012, Li et al. 2014). Additional transition rules are included on the influence of temperature on tick population dynamics and the seasonality of host population and movement. The model framework is presented in Figure 3.7. The model requires a land cover map as input and the initial host distribution that is generated using the actual land cover and species distribution data, spatial disaggregation methods and information from the literature. Weekly temperatures are included as a series of georeferenced grids to reflect local-level spatio-temporal heterogeneity.

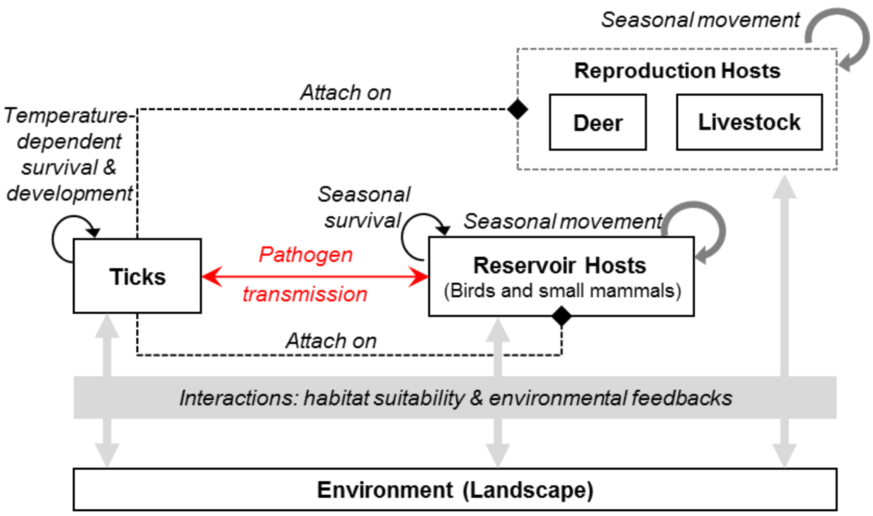

Figure 3.7: The LYR model framework: interactions between ticks, hosts, pathogens and landscape.

[2] Health Protection Scotland: Lyme disease, 10 year dataset. http://www.documents.hps.scot.nhs.uk/giz/10-year-tables/lyme.pdf

Under HES, the LYR model predicts the joint effects of temperature change, which directly influences tick and pathogen population dynamics, and land use change that shapes the suitability of habitats and the distribution of ticks.

3.7. Cross-sectoral modelling using the CLIMSAVE IAP

The CLIMSAVE Integrated Assessment Platform (IAP) is a unique interactive exploratory tool that contains a series of linked meta-models and databases (Figure 3.89) to allow users to explore the complex issues surrounding impacts, adaptation and vulnerability to climate change at regional and European scales. Two versions of the tool have been developed: a European version and a Scottish version (to test the application of the methodology at the regional scale). The tool provides sectoral and cross-sectoral insights within a facilitating, rather than predictive or prescriptive, software environment. The power of the tool lies in its holistic framework (multi- and cross-sectoral, climate and socio-economic change (Figure 3.8) and is intended to complement, rather than replace, the use of more detailed sectoral tools used by sectoral professionals and academics.

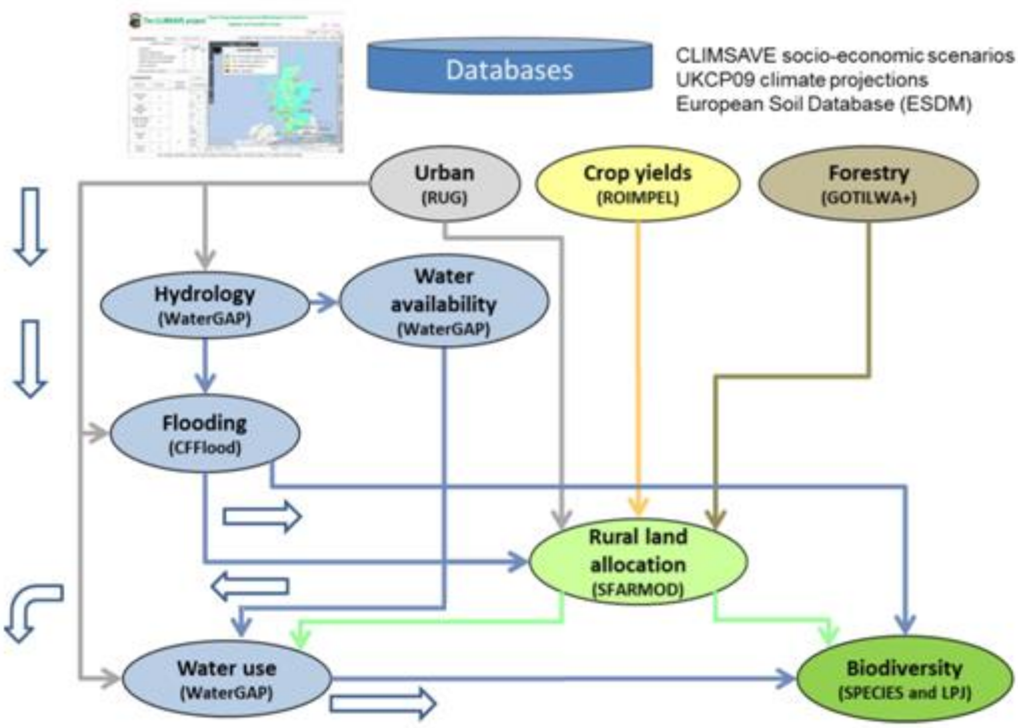

Figure 3.8: Simplified schematic showing the structure of the linked models within the Scottish CLIMSAVE IAP.

As such, the CLIMSAVE IAP is not intended to provide detailed local predictions, but to assist stakeholders in developing their capacity to address regional scale issues surrounding climate change. Outputs from the CLIMSAVE IAP will be used in the inter-model comparisons, informing boundary conditions, the tourism modelling and the vulnerability and coping capacity assessment. The CLIMSAVE IAP will be updated to include the new RCPxSSP scenarios and applied to HES.

3.8. Vulnerability and coping capacity modelling

Vulnerability and coping capacity will be evaluated for Scotland using the CLIMSAVE IAP, updated with the new RCPxSSP scenarios. The CLIMSAVE IAP approach to vulnerability mapping evaluates the spatially-variable impacts of future scenarios on human well-being. To do so it breaks vulnerability down into three key elements: (i) the severity of the impact itself; (ii) the level of adaptation in place to reduce the impact; and (iii) the extent to which humans are able to draw on their available resources (both tangible and societal) to cope with the impacts that remain, i.e. the "coping capacity". Vulnerability occurs where the level of impact following adaptation is greater than society's ability to cope.

This concept is shown schematically in Figure 3.9 for computing vulnerability of residual impacts, i.e. impact following adaptation, although vulnerability can be computed both before and after adaptation within the IAP. The extent to which human well-being is affected by the potential or residual impact depends on: (i) the "lower coping threshold" (the level of impact below which the impacts on human well-being can be considered negligible); (ii) the "upper coping threshold" (the level of impact above which society is unable to cope, no matter how resource rich it is); and, (iii) the "coping range" (the zone between the two thresholds). The "coping range" or coping capacity reflects the resources that are available to society and is derived as a function of human, social, financial and manufactured capital. Natural capital is not included in the coping capacity since it is calculated directly by the IAP.

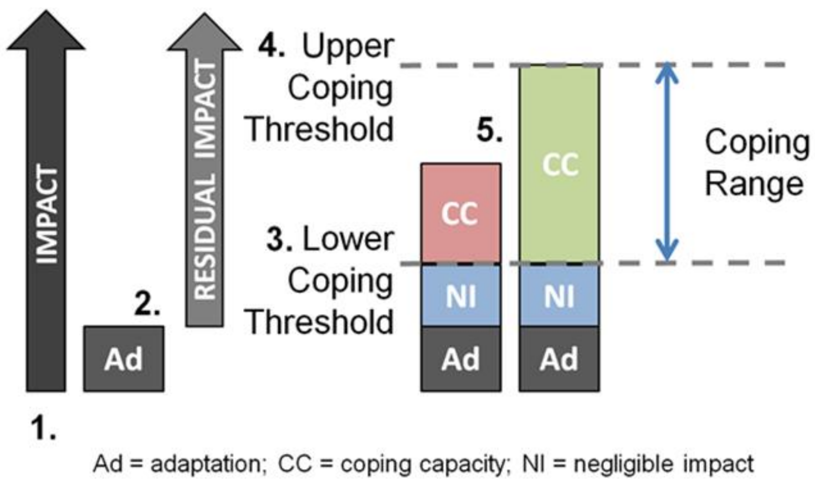

Figure 3.9: Schematic overview of the CLIMSAVE vulnerability approach.

Vulnerability will be assessed for a cross-section of ecosystem service categories: (i) food supply (provisioning service); (ii) water exploitation index (provisioning service); (iii) people affected by a 1:100 year flood event (regulating service); (iv) a biodiversity index (supporting service); (iv) a land use intensity index (to represent cultural/aesthetic services); and (vi) a land use diversity index (to represent multi-functionality). Upper and lower coping thresholds were selected for each of these indicators/indices to enable a vulnerability index to be calculated at the grid cell level as:

- "Not vulnerable, negligible impact" (no significant impact);
- "Not vulnerable, coping" (impact is less than the coping capacity);
- "Vulnerable, not coping" (coping capacity is insufficient to deal with the impact); and
- "Vulnerable, impossible to cope" (the impact is greater than the upper coping threshold).

The total vulnerable area and number of vulnerable people under HES will be calculated at the Scottish scale using the two vulnerable classes and by summing the area and population of cells identified as vulnerable. Cross-sectoral aggregate vulnerability is calculated by counting the number of vulnerable sectors in each grid cell.

4. Modelling in the Hungary case study

4.1. General specification

The Hungarian case study aims to assess the impacts, risks, vulnerability and adaptation options associated with HES and socio-economic scenarios at the local scale in Hungary. By combining participatory methods with quantitative analysis, the assessment will explore locally relevant challenges and adaptation options in the agricultural, water management, urban development, and health sectors in close and early interaction with local decision-makers and other key stakeholders of two medium-sized communities, Veszprém and Szekszárd (Figure 4.1).

Quantitative analysis will be supported by thematic modelling focused on the priorities identified by stakeholders and mentioned above. The Aporia agent-based model is being used to simulate how local stakeholders and institutions interact in determining patterns of rural land use and the capacity for food production and self-provisioning under high-end climate and socio-economic scenarios. Furthermore, a series of integrated models will be developed (Figure 4.2) to study the impacts of HES on urban land use (RUG), regional water management (SWIM), Lyme disease risk (LYR) and institutional capacity to cope with heat stress events (HEAT STRESS model).

Combining the above research with a participatory approach, will ensure that local stakeholders play a central role in all phases of the project: from identifying key areas of interest, through supporting data collection and assisting model calibration, to developing shared visions for a sustainable future and related pathways of harmonised adaptation and mitigation strategies and actions.

Figure 4.1: Location of the two communities of Veszprém and Szekszárd in Hungary.

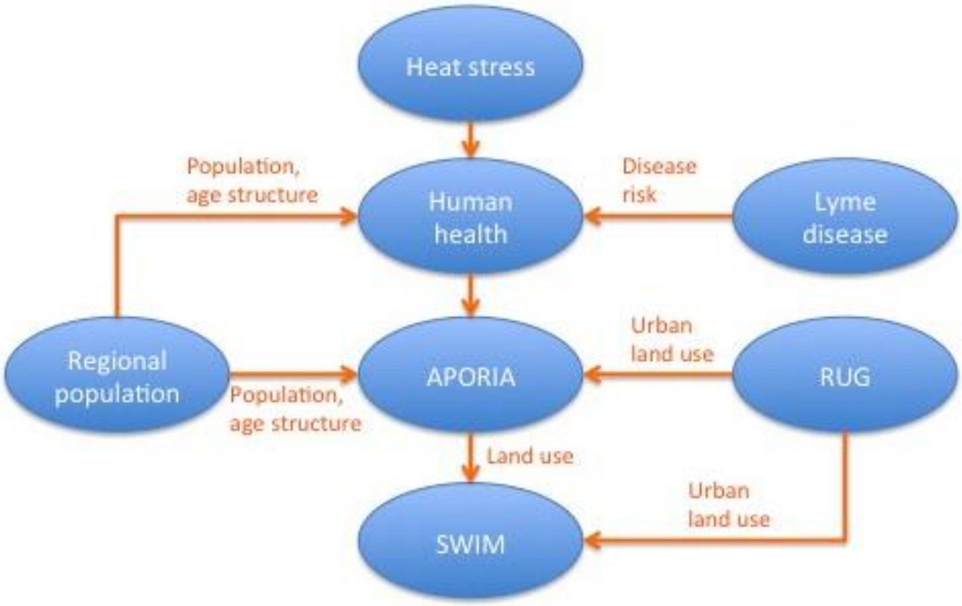

Figure 4.2: Structure of the linkages between the thematic models in the Hungarian case study.

4.2. Urban land use modelling

The urban model is being developed from the regional urban growth (RUG) model used in the RegIS2 project (study area: East Anglia and the North West England in the UK). In RUG, the pattern of urbanised area is driven by regional-level, economic-demographics and cell-level residential potential. The resident density in the urbanised area is driven by cell-level residential preferences (externalities, i.e., social benefits and environmental quality, and accessibility) and regional-level restrictions (economic developments and land use policies). The new model follows RUG's basic assumptions, with a number of extensions: (i) neighbourhood effects for residential preferences (or externalities) are included; (ii) externalities are being tested for three different aspects: social, economic and environmental, based on different sub-classes of artificial land cover; and (iii) life stages of the population are being included, since people at different life stages have different preferences for social, economic and environmental amenities.

The model requires inputs for regional level, economic-demographics (e.g. population with age structure, GDP, household size, etc.), land cover configuration, transport network maps and a range of policy masks to promote/constrain urban development in certain areas. The model has a decadal time step and predicts future patterns of cell-level proportions of sub-classes of artificial area and distribution of age-structured populations.

Extreme weather events (EWEs) under HES are short-lived, localised and difficult to predict. There is insufficient evidence to support the assumption that people make residential location decisions that avoid EWEs (Vari et al. 2003, Black et al. 2011, Fielding 2011). However, we hypothesise that residential dynamics are a consequence of long-term EWE impacts. Thus, long-term EWEs may decrease agricultural production, destroy infrastructure and damage economics in high risk areas, leading to job losses, land abandonment and the migration of the population to more favourable places. In other words, long-term EWEs damage GDP (e.g. Brown et al. 2013) and consequently influence urban development and the population distribution. We will consider how this hypothesis could be represented in the urban land use model as a GDP damage function.

4.3. Agricultural land use modelling

In Hungary, total agricultural and food production decreased by 19.43% and agricultural production per capita by 6.25% from 1997 to 2012. The National Statistical Office (KSH) also indicated a 17.51% decrease in agricultural land from 1990 to 2013. In a country of significant agro-ecological potential and a tradition of agricultural production both for self-provisioning and export, such reductions have become cause for concern. This modelling study will investigate how local food production can be maintained and expanded under HES. With this general aim in mind, a number of case-specific research questions can be asked: (i) Can local food production be maintained under HES with currently dominant land management practices? How? (ii) Can adaptation in land management practices help maintain and expand food production under HES? How can these practices diffuse to producers in the study areas? and, (iii) To what extent can agricultural land conversions (e.g. afforestation, urbanisation, abandonment) affect agricultural production? Will these effects be amplified under HES? How can these effects be mitigated?

Sustainable food production depends on a land manager's decisions about implementing sustainable agricultural land use practices and preserving agricultural landscapes. The agent-based agricultural land use model (Aporia) is being used to connect the representation of human behavioural processes to simulations of the biophysical environment focusing on agricultural (or other) land use systems (see Section 3.3). In Aporia, land managers (e.g. farmers, forest managers) are represented as agents who can make decisions about land use actions based on their relative weighting of a range of individual, social, economic, environmental and political factors. These multi-contextual factors are subject to change under HES based on quantitative and/or qualitative evidence. Aporia will be used to evaluate the aggregate effect of these changes on agricultural land use patterns at the landscape scale. The model will be run with annual time-steps. At each time step, an agent assesses his/her parcels and makes decisions about whether to assign a new land management strategy or to convert the parcel into another land use type. The simulated output is projected, long-term changes in agricultural land use patterns and food production under different HES.

4.4. Lyme disease modelling

While the Lyme disease (LYR) modelling in Scotland focuses on the biophysical risk (Section 3.6), its application in Hungary focuses more on the exposure and pathogen spill-over risks at the human-tick interface. The main reason for this design is the relatively low tick infection rate (4.44%; Egyed et al. 2012), but the high disease incidence rate (12.3 per 100,000 habitants on average between 1998 and 2008 (Zöldi et al. 2013), which suggests that human risk activities may have an important role in shaping the pathogen spill-over and therefore disease patterns.

The main objective is to map the contact possibilities between ticks and people for the whole of Hungary. A human layer is being integrated into the biophysical model described in Section 3.6, for which human population distributions will be provided by the RUG model (Section 4.2). A previous model of forest leisure trips (Li et al. 2015) is being simplified to simulate residents' leisure or professional activities in forested areas. Thus, people are represented as agents in the model that can make their own decisions on selecting forests to visit.

Under HES, the model projects the long-term effects of land cover change that shapes the tick habitat (hazard risk) and land use/residential change that alters the spatial patterns of human risk activities (exposure risk) and, hence, human-tick contact possibilities (spill-over risk).

[3] Land area of Hungary by land use categories, 1853–2013, https://www.ksh.hu/docs/eng/agrar/html/tabl1_3_1.html

4.5. Heat-related mortality modelling

The modelling of heat-related mortality risks will follow the approach developed for the European case study. This model quantifies heat-related mortality under assumptions of climate change, population growth and ageing, and urban change for the following three age-groups: 0-64, 65-74, 75+ as risk increases greatly with age. The model will use inputs of population from the RUG model (see Section 4.2), which will be used to estimate future age-specific mortality for Hungary. Population attributable mortality will be based on the method used by Vardoulakis et al. (2014).

Mortality data for Budapest is being gathered as the populations of Veszprém and Szekszard are too small to provide meaningful estimates of the temperature-mortality function. New exposure response functions are being developed based on the model developed by Gasperrini et al. (2010). This method better characterises the population response at the extreme end of the (exposure) temperature distribution, in order to capture the uncertainty in assessing impacts under HES.

The model will be run for the WP2 HES for specific years up to 2100. The possibility of developing a probabilistic model is being investigated through a test case based on London where probabilistic data is already available. The approach can then be applied to Hungary if the probabilistic information becomes available later in the project. The decision-maker interviews for Hungary undertaken as part of WP1 will be analysed to determine relevant assumptions about adaptation to heat-related health impacts, such as air conditioning uptake.

4.6. Vulnerability and coping capacity assessment

The impact of high-end climate change on vulnerability will be studied in the specific thematic contexts covered by the models. Changes in climate-related stress factors such as droughts, heat waves and extreme events will be introduced into the various thematic models and their potential impacts on the regional socio-ecological system will be studied. Stakeholders will be exposed to quantitative projections to map the potential adequacy of their adaptive capacities and to identify areas where significant vulnerabilities due to inadequate coping capacities under the given stress regime are expected to arise. Coping capacity will be computed using a similar approach to the Scottish case study through an index of human, social, manufactured and financial capital (see Section 3.8). Options for expanded technical, behavioural and institutional responses and adaptation measures and other structural changes at the local, regional or national level will be identified. Scenarios will be used to situate vulnerability and adaptation projections in a broader context and to engage stakeholders in identifying adaptation options that are robust across a range of integrated RCPxSSP futures.

5. Modelling in the Iberia case study

5.1. General specification

The Iberian Peninsula river basins are among the European basins most likely to be affected by climate change, especially under HES. The Tagus and the Guadiana river basins (Figures 5.1 and 5.2) are two of the five international river basins shared between Portugal and Spain and this poses distinct challenges for the coordination of social-ecological systems. Water scarcity is likely to be aggravated by the traditional focus on irrigation - the main source of water demand on both sides of the river basin - as well as by growing urban water demand and large-scale water transfers.

Climate change is expected to greatly increase water-resource management challenges in the drier south of the Iberian Peninsula (EEA, 2012), so significant institutional and agent transformations are needed to cope with the impending warming future. Sectors such as agriculture, forestry, energy and nature conservation may become more vulnerable to activities carried out upstream of the river basin. There is an increasing need for holistic, integrated, multi-scale and trans-boundary solutions, which require improved coordination between different political, legal and institutional settings and actions.

Figure 5.1: The Tagus river Basin.

Figure 5.2: The Guadiana River basin.

This work will be linked to the results gathered during the first Iberian stakeholder workshop where, amongst other issues, the following were addressed in relation to HES in Iberia:

(1) *Policy and Governance:*

- Implications for the implementation and communication of the regional and national adaptation plans;
- Prospects for policy coordination between the Portuguese and Spanish regions and national authorities faced with HES (e.g. main opportunities, strategies and difficulties);
- Options and mechanisms (including information, communication and public participation) to improve existing cooperation between shared river basins faced with HES;
- Effects of the implementation of EU Directives (Water Framework Directive, Energy, climate and conservation policies) in such coordination (e.g. regarding water transfers).

(2) *Economic and technological development:*

- Impact of HES on economic growth and opportunities for job creation (e.g. tourism, services, technology, energy, industry, construction and agriculture);
- Opportunities and constraints for the development of low-carbon resilient technologies in Portugal and Spain;
- Changes in energy production structures in Iberia (e.g. hydro and nuclear in shared river basins).

(3) *Social:*

- Population and migration dynamics, including rural abandonment and changes in urban dynamics under HES;
- Effects on social systems, such as health, mobility, education systems, etc.

The modelling work will focus on the Tagus River Basin and will use two complementary approaches (see Figures 5.3 and 5.4):

- The SWIM model is being applied to the Tagus river basin to simulate different options for Integrated River Basin Management (including water, energy and land use management) and to identify the conditions that could improve the resilience of the socio-ecological system under HES. A particular focus will be given to extreme events such as long and severe drought episodes and to the exploration of different management options considering different political priorities (e.g. hydro-electric or agricultural production targets; maintenance of ecological flows). Indicators of the effectiveness of different options/ pathways will explored including: (i) water availability; (ii) crop yields (possibly including biofuel); (iii) hydropower production; (iv) land use (e.g. % of forested area); (v) biodiversity (linking with the Globio model applied in the global case study).

- The LandClim model is being used at the farm level (max 10.000ha) in selected areas of the Tagus basin to assess the resilience of Dehesa systems to forest fires and droughts. The effectiveness of changes in tree composition (*Quercus suber*, *Q. ilex* and *Olea europaea*, Almond trees), tree density and landscape structure (i.e. creation of lake systems) will be tested. Where available, ecophysiological data will be incorporated into LandClim to better evaluate the effects of prolonged and/or more intense drought periods and of increased fire intensity and frequency on tree growth and survival. Indicators of the effectiveness of different options/pathways will include: (i) production of cork (and potentially, production of acorn and olives); (ii) livestock production (pigs, sheep, deer, cows); and (iii) biodiversity conservation.

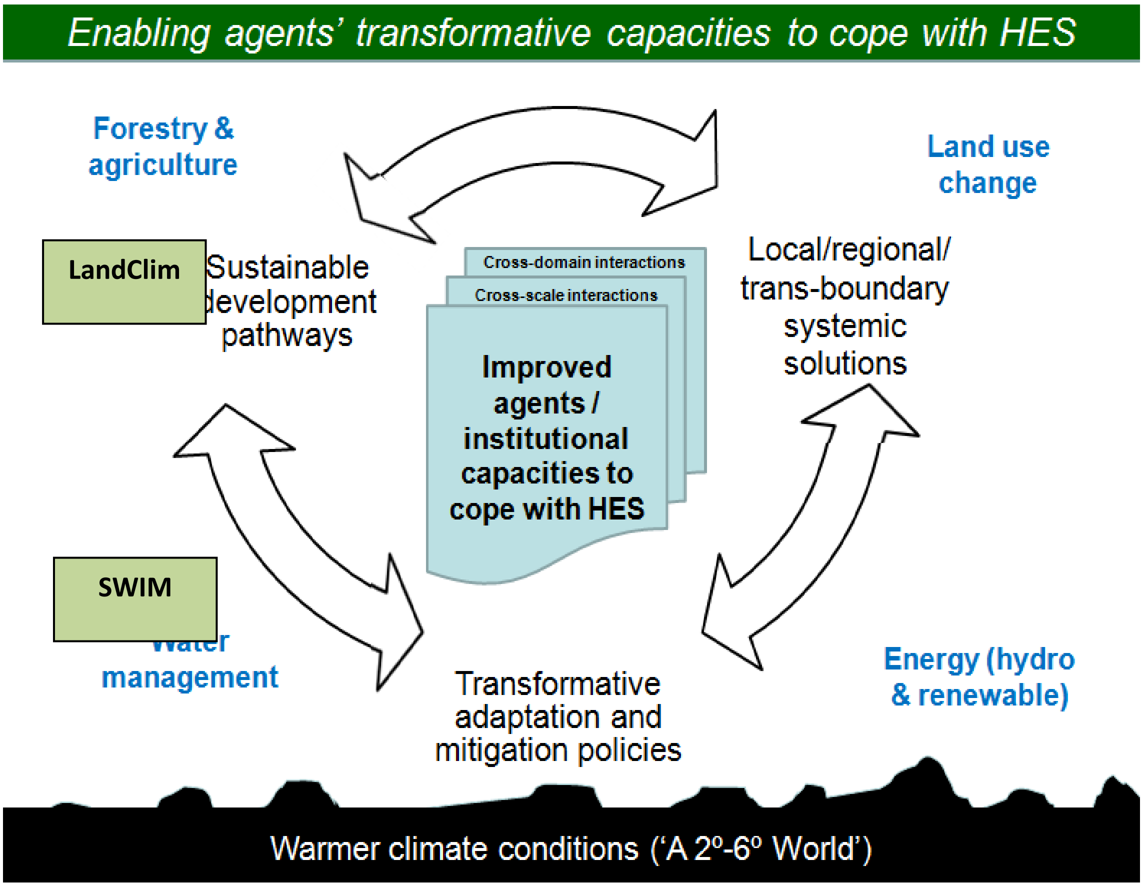

Figure 5.3: The Iberian models and their interactions.

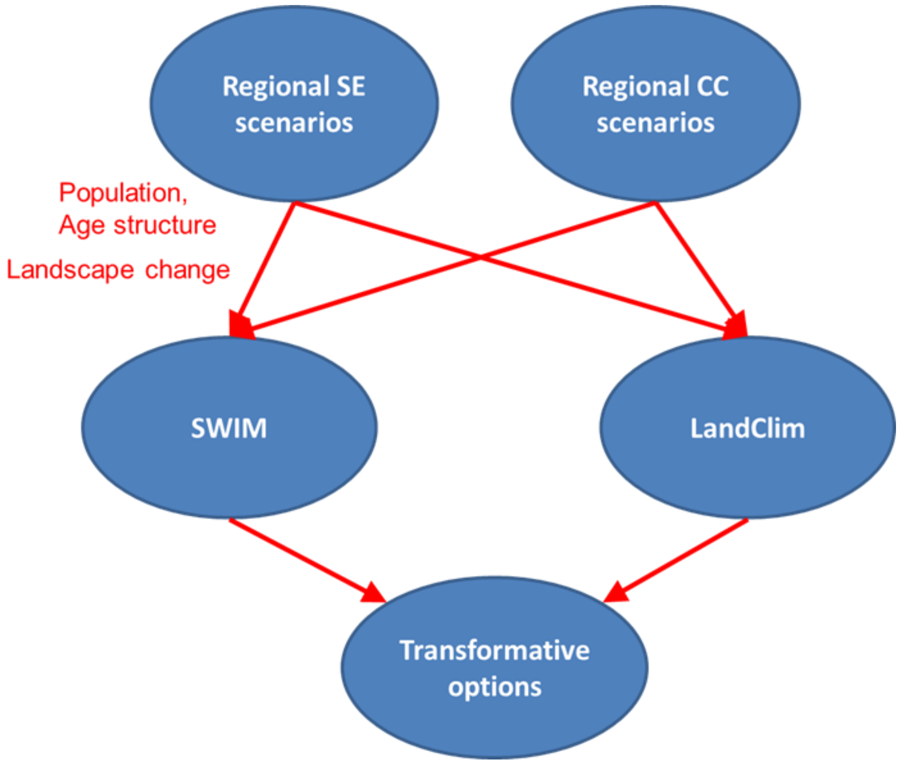

Figure 5.4: Connections between the Iberian models.

5.2. Water modelling

The SWIM model is being applied to address the impacts of HES within the Tagus River Basin. For a description of the SWIM model, please refer to Section 3.4 of the Scottish case study. The SWIM model has been set up, calibrated and validated for the Tagus River Basin up to the Santarem gauge, including a specific calibration for fifteen large reservoirs in the catchment. To assess projected changes, the calibrated model will be driven by the socio-economic scenarios and climate change scenarios described in Section 2.1. The socio-economic scenarios will represent potential changes in the landscape, such as development of the Tagus-Segura inter-basin transfer, construction of new reservoirs to meet hydropower and water supply demands, and new water transfers. SWIM will help to explore and validate different River Basin Management options, with different policy targets such as those related to: (i) hydropower production; (ii) agricultural production; (iii) water availability; (iv) environmental targets; and (v) treaties between Portugal and Spain. This will help to improve the resilience of the Tagus River, as a complex socio-hydrological system, under HES. A model-inter-comparison is also planned for this basin, as described in Section 3.4 for the Tay Basin.

5.3. Forest modelling

The Iberian Peninsula has several managed forested landscapes, which offer a range of goods and services to the population. The forest landscape model, LandCLIM, is being used to explore a sample landscape near Lisbon (Charneca), which is a complex mosaic of many different land uses. Specifically related to forests, this includes pine forests, olive plantations, natural wooded areas and montado (or dehesa). The montado forested landscape is the most dominant land cover in this area. Oak trees are used to produce cork and acorns, while the semi-open nature of these trees allows for high grass production, which is used for livestock grazing. These landscapes are expected to have strong responses to HES.

LandClim (Figure 5.5; Schumacher et al. 2004) is a spatially-explicit forest landscape model that was developed to assess the importance of climatic effects, forest disturbances (such as fire) and management on historical and future forest dynamics. It consists of a local vegetation model (based on ForClim; see Section 3.5) that simulates forest succession, and a landscape model that simulates processes such as fire, wind, forest pest outbreaks, forest management and seed dispersal. LandClim simulates forest dynamics at time scales from tens to thousands of years and at large spatial extents (e.g. 30 km²) at a relatively fine scale (grid cells of 25m x 25m).

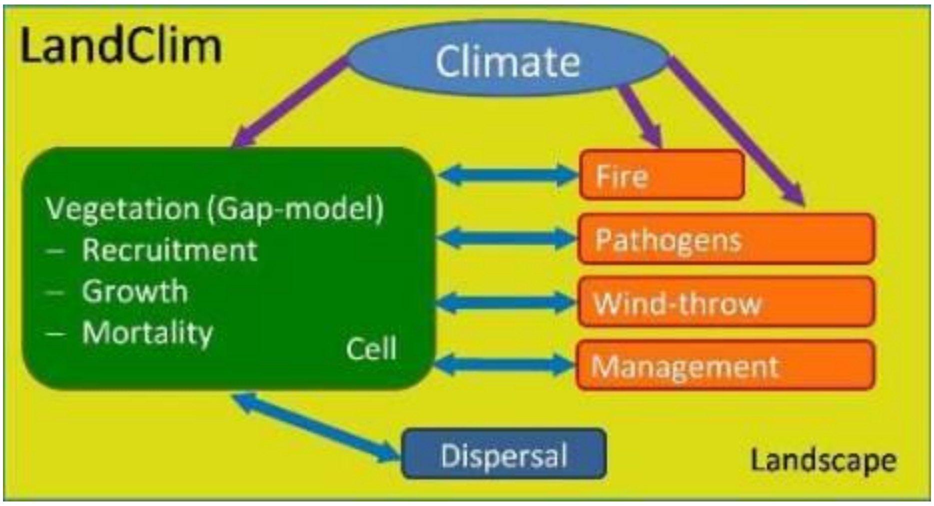

Figure 5.5: Schematic of the LandClim model.

LandClim is being used to simulate the range of tree-based land uses (e.g. montado, pine and olive plantations, and natural forests) under current climate and under various climate change scenarios. The main issues that are being investigated are how trees will respond to increasing droughts (both in duration and severity) and increasing fires (both in intensity and extent). LandClim is also being used simulate forest and pasture management, and to assess how management could be used to mitigate the potential impacts of HES (e.g. planting more fire-tolerant and/or drought-tolerant species, protecting seedlings from grazing). Preliminary simulations under current climate conditions have been performed and LandClim is able to adequately capture current vegetation.

5.4. Transformative options and the role of stakeholders

The call for transformative options and the need for close engagement of stakeholders in developing them derives from the realisation that conventional or incremental measures will probably not be sufficient to cope with the potential consequences of HES in Iberia. Hence, it is now crucial to explore in a participatory way how to improve the most efficient options and mechanisms for institutional cooperation and policy learning in Iberia. This will yield not only reduced emissions targets (mitigation) or improved responses to impacts of the impending near-future (adaptation), but above all, will be able to generate completely new forms of social-ecological system interactions (transformation).

The ambition is to study the conditions and processes that enable relevant agents (including policy-makers, trans-boundary institutions and local organisations) to develop and implement integrated solutions, and to build transformative capacities aligned with sustainable pathways to cope with HES in Iberia, with a special focus given to the Tagus and Guadiana river basins. To give a concrete example, as a result of the successful first Iberian Workshop carried out in Lisbon in June 2015, an invitation was issued to the members of the Iberian team to organise a high-end policy retreat meeting with key policy-makers of the Andalusian Government in Autumn 2015 to further explore the implementation of transformative policy options in that region.

5.5. Vulnerability assessment

Vulnerability and coping capacity in the Iberian case study will be evaluated by: (i) testing existing policies and management practices under HES; and (ii) assessing how different transformative options can increase resilience to avoid vulnerability to HES. An integrated solution-based comparative approach of the two river basins will be used to study the state of implementation and how to improve the resilience of the European Water Framework Directive under HES. Constraints and opportunities posed by mainstreaming climate change in Integrated River Basin Management (IRBM) will be analysed. Furthermore, a series of nested examples of integrated solutions will be studied at the local level, mainly Ecosystem-Based Adaptation (EBA), which also takes account of other integrated and innovative options and practices dealing with adaptation, mitigation and sustainable development (e.g. at the farm level). The goal is to explore the conditions, options and leverage points for enhancing the resilience (avoiding vulnerability) of the overall system and individual agents to HES.

6. Conclusions and timetable

This report has outlined the specification for regional/local model improvement and development within the three regional case studies of IMPRESSIONS based in Scotland, Hungary and Iberia. The specification will support the delivery of the objective for WP3C of advancing and applying regional scale methods and models to better quantify and understand impacts, risks, vulnerabilities and adaptation options associated with a range of scenarios for key economic, social and environmental sectors and their cross-sectoral interactions.

A timetable for implementing the modelling specification and improvement is outlined in Table 6.1.

Table 6.1: Major tasks and milestones for the regional modelling work.

Task / Milestone	Date
D3C.1: Specification of regional/local scale models and methods	June 2015
1st stakeholder workshop in Scotland to finalise the socio-economic scenario development	September 2015
3rd IMPRESSIONS modellers meeting to discuss progress and integration across case studies	December 2015
2nd stakeholder workshop in Scotland (modelling results on impacts and vulnerability needed)	April 2016
2nd stakeholder workshop in Hungary (modelling results on impacts and vulnerability needed)	June 2016
Preliminary regional/local case study outputs provided to WP4 (milestone 15)	June 2016
2nd stakeholder workshop in Iberia (modelling results on impacts and vulnerability needed)	September 2016
3rd stakeholder workshop in Scotland (modelling of adaptation and mitigation actions needed)	April 2017
3rd stakeholder workshop in Hungary (modelling of adaptation and mitigation actions needed)	June 2017
D3C.2: Regional/local scale model applications	July 2017
3rd stakeholder workshop in Iberia (modelling of adaptation and mitigation actions needed)	September 2017

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