

Chapter 11

Who Knows Best? The Role of Stakeholder Knowledge in Land Use Models—An Example from Doñana, SW Spain

R.J. Hewitt, V. Hernández Jiménez, L. Román Bermejo and F. Escobar

Abstract Participatory processes are increasingly used for understanding human-environment interaction problems and for developing common strategies for land resource management. These approaches are particularly important in areas where resources are shared by many stakeholders and yet there is no general agreement about how these resources should be managed. In many of these cases, detailed quantitative information about human-environment interaction problems (e.g. land degradation, erosion, water contamination etc.) is available to scientific institutions and land managers, but not easily accessible to other stakeholders. Conversely, key information, such as historical evolution of the landscape in the locality or the probable drivers of historic land change is often embedded informally in stakeholder communities but may not be accessible via conventional knowledge sharing pathways (scientific literature, reports, directives, policy briefs etc.). Land use models, in which qualitative and quantitative data can be combined at multiple levels and scales, provide an ideal bridge between highly detailed quantitative knowledge available from scientific stakeholders, and informal or unstructured knowledge about dynamics, evolution and change held by other parts

R.J. Hewitt (✉) · V. Hernández Jiménez · L. Román Bermejo
Observatorio para una Cultura del Territorio, Madrid, Spain
e-mail: richard.hewitt@observatorioculturayterritorio.org

V. Hernández Jiménez
e-mail: vero.hj@observatorioculturayterritorio.org

L. Román Bermejo
e-mail: lara.rb@observatorioculturayterritorio.org

R.J. Hewitt
Information and Computational Sciences Group,
James Hutton Institute, Aberdeen, Scotland, UK

F. Escobar
Department of Geology, Geography and Environmental Sciences,
University of Alcalá, Alcalá de Henares, Spain
e-mail: francisco.escobar@uah.es

of the stakeholder community. Many essential land use modeling activities, traditionally carried out by a single scientist in front of a computer, such as map comparison and subdivision or aggregation of land use categories, may in fact be better accomplished by working in groups with key stakeholders. Involvement of stakeholders in basic model decisions not only makes for a better model, it may also increase stakeholder confidence in the model and makes it more likely that the results of the model will be applied. We argue, with reference to the recent participatory modeling work undertaken in Doñana, south-west Spain, that stakeholder information can be incorporated into land use models by engaging stakeholders as model co-developers, and structuring activities, where possible, so as to include their knowledge directly as parameters and variables. A participatory land use model is thus conceived as a cycle of alternating analytical and discursive activities from which useful results may be obtained, but which does not presuppose an optimum or “right answer”, or prioritize scientists’ knowledge above other kinds of knowledge available to the community.

Keywords Participatory modeling · Land use change · Stakeholder · Knowledge co-generation · Doñana

1 Introduction

The Doñana natural area is an internationally renowned coastal dune and marshland ecosystem of outstanding importance for biodiversity at the mouth of the Guadalquivir River in South West Spain (Fig. 1). Intensive agriculture and tourism have transformed the economy of the area over the last 60 years but have led to severe degradation of ecosystems and habitats, including the loss of large areas of wetland. In response to these serious threats, Doñana has been the subject of major conservation efforts since the 1960s, and today enjoys diverse statutes of protection (National Park, Natural Park, UNESCO world natural heritage site, amongst others). These conservation efforts have undoubtedly been highly successful in preventing, for example, further wetland habitat loss, expansion of invasive species such as eucalyptus and urban development along the coast. The natural area remains, nonetheless, highly threatened, and continues to decay. This is principally because the highly intensive land uses in the watershed of the Guadiamar River, which supplies the Doñana marshes, are incompatible with the maintenance of pristine natural habitat downstream. However, since the wider watershed is not included in the protected area, land use is not subject to strict controls. Yet while many stakeholders might be unwilling to suspend business-as-usual in the watershed, few would regard the loss of Doñana as an acceptable price to pay. For this reason, there is a strong case for dialogue about land use in the watershed involving all the relevant actors (policy makers, farmers, conservationists, tourism representatives etc.), with a view to securing a more sustainable future.



Fig. 1 Location of study area

This chapter presents the results of a participatory scenario modeling cycle in which a range of land use futures were explored for Doñana for the year 2035. The aim of the modeling process was threefold:

- (1) To bring together key stakeholders from different sectors with different and (sometimes opposing) perspectives and engage them in a shared discussion about Doñana's future.
- (2) To enable knowledge co-generation and social learning between stakeholders about land use changes to facilitate transition to a more sustainable model of development for the area.
- (3) To push the boundaries of participatory modeling by increasing model transparency and inclusiveness and reducing the model's dependence on researchers' decisions.

To achieve these aims, detailed input from key stakeholders obtained through a series of workshops was used to parameterize, calibrate and critically evaluate a Cellular Automata (CA) model of land use change in the Guadiamar river watershed. Despite the strong emphasis on social learning and knowledge co-generation, as opposed to enhancing the accuracy of model simulations, the model meets all commonly accepted metrics for assessment of goodness-of-fit. Nonetheless, we argue that integration of qualitative and quantitative data through a participatory process leads to a better model, and that acceptance by stakeholders should be considered a valid criterion for determining a "successful model".

2 Test Areas and Data Sets

The study area corresponds approximately to the watershed of the Guadiamar River (Fig. 1). The principal data sets used in the work were the 1:25,000 scale vegetation cover and land use map series developed by the Government of Andalusia and freely available for download from the website of the regional government environmental information service, REDIAM. Other information necessary for model calibration included topographic relief, municipal boundaries, rivers and water-courses, and natural protected areas, all downloaded from the REDIAM website. For detailed information regarding these datasets, see:

<http://www.juntadeandalucia.es/medioambiente/site/rediam/>.

3 Methodology and Practical Application to the Data Sets

3.1 Cellular Automata Models of Land Use Change

The model employed in this research is a Cellular Automata (CA) based land use model. CA models integrate mathematical theories of self-reproduction in automata

(Von Neumann and Birks 1966) and stochasticity (Ulam 1952) with the 2 dimensional cellular-grid or raster cartographic space familiar to present-day users of Geographical Information Systems (GIS). The concept of a dynamic geographical cellular automata was proposed by Tobler (1979) and developed during the 1990s by researchers interested in modeling urban growth and change (e.g. White and Engelen 1993; Batty and Xie 1994; Clarke et al. 1997; Phipps and Langlois 1997). Well-known examples of CA modeling frameworks include SLEUTH (Clarke et al. 1997) and members of the Metronamica family such as SimLucia (White et al. 2000) and Xplorah (Van Delden et al. 2008). CA modeling systems aim to simulate the aggregate behaviour of multiple change agents by developing land use transition rules and testing these rules against data. For this application, we used the well-known modeling software Metronamica, developed by White and collaborators (e.g. White and Engelen 1993; White et al. 2000). Detailed methodological description of the functioning of the model is published in the user guide (RIKS 2012) and will not be repeated here.

When using the model, the first step is to introduce a GIS raster map representing land use at a given moment in time (t_n). Cells can change from one land use to another over the course of a time sequence ($t_1, t_2, t_3, \dots, t_n$) on the basis of the relationship between their own land use and the land use of the cells that are immediately adjacent or in proximity, known as the cell neighbourhood (N). However, the potential of each cell to transition is not determined exclusively by its neighbourhood, and Accessibility (A) (i.e. the influence of lines of communication such as transport, irrigation, and electricity network) must also be taken into account. A cell's transition potential also takes into account Suitability (S) or the biophysical eligibility (e.g. rainfall, slope) of each land area for a particular use, and Zoning (Z), the current legislative and planning restrictions (for example, protected areas, urban spatial plans). Finally, since human activity in the landscape is not purely deterministic, a stochastic parameter is added (v). This type of model is referred to as an N,A,S,Z Cellular Automata model or NASZCA (Hewitt et al. 2014).

To calibrate the model, parameter values for the N, A, S, and Z blocks are set and the model is run from an initial map t_1 (1956 in this case) to a second date n time steps (i.e. years) forward for which a map is available for comparison (1999 in this case). This second map is referred to as t_2 . The number of cells which are to be allocated for each land use at each time step t_n is known as the *demand*. Once the total number of cells corresponding to land use demand has been allocated to all suitable locations at model time step t_n , the next step ($t_n + 1$) is computed from t_n and so on until time t_2 is reached. The time period between t_1 and t_2 is known as the calibration period. If data are available, the use of a third period t_3 known as the validation period, subsequent to t_2 , is recommended. In this case, the most recent available land use map, the map for 2007, was used for validation.

To validate the land use model, the rules developed to simulate land change evolution between t_1 and t_2 (the calibration period) were applied to t_3 . Successful replication of land-change tendencies at both t_2 and t_3 against accepted benchmarks reinforces the main assumption of the model, i.e. that the past change processes being modelled will hold true in the future. Once calibration and validation have

Table 1 Calibration milestones and their relationship to individual simulations evaluated by stakeholders (Workshop 2, Activity 1) in bold

Milestone number:	Simulation run:	Calibrationsub-step
1	1	Simple neighbourhood rules only (benchmark model)
2	5	Calibrate neighbourhood rules
3	11	Add Accessibility
4	15	Adjust Accessibility Parameters
5	21	Add Suitability
6	23	Add Zoning
7	34	Adjust Suitability Parameters
8	35	Adjust Neighbourhood parameters

been carried out successfully, the model is considered to be ready to generate simulation for future dates. Calibration and assessment of the quality of the calibration was a continuous and iterative process managed around a series of milestones relating to the determination of parameters for the key model drivers, N,A,S, Z. Attaining a calibration milestone required experimentation with different parameter settings, major adjustments were recorded with a unique simulation number (Table 1).

Assessment of the model's goodness-of-fit was undertaken using three types of assessment: (1) visual inspection, in which stakeholders played a key part (see results of Workshop 2); (2) cell-by-cell comparison measures using the kappa simulation statistic K_{sim} (van Vliet et al. 2011); and (3) map pattern and structure evaluation through the clumpiness statistic, derived from the Fragstats package (McGarigal et al. 2002) and implemented in the Map Comparison Kit (MCK) software, developed by Alex Hagen-Zanker for the Netherlands Environment Assessment Agency (Visser and De Nijs 2006).

3.2 *The Participatory Modeling Process*

A geographical land use model is a useful tool for integrating qualitative and quantitative data (Fig. 2).

Land use models are sometimes thought of as purely quantitative tools, in that they are based on numerical inputs and outputs. However, they also contain abundant qualitative information (e.g. land use category decisions, study area decisions, transition rules etc.) that is essential to their successful operation. Often these qualitative inputs are decided in a subjective or arbitrary way by the researcher, who may not always have detailed knowledge of the study area at hand, and, in many cases, it may be more appropriate to consult with, and directly elicit information from, the appropriate stakeholder, especially if the model is intended for use outside the scientific community. However stakeholder contributions to

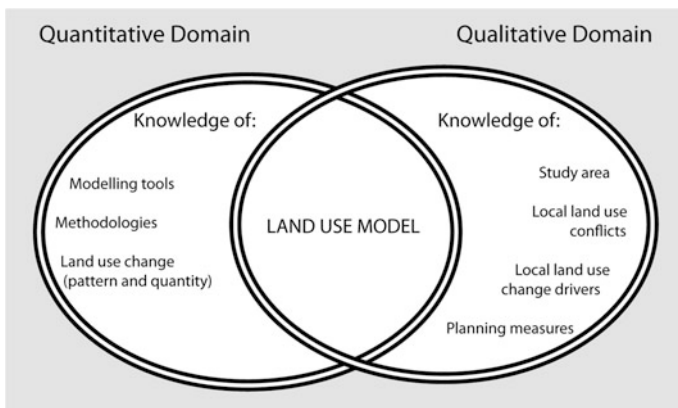


Fig. 2 A land use model as the intersection of quantitative and qualitative knowledge domains

models need not be limited to qualitative data, but can also include approximate or estimated *quantitative* data. For example, in the modeling case study presented here, stakeholders estimated suitability of terrain for each land use through a scoring procedure linked to a numerical value. While such approaches are clearly subjective, they can be surprisingly accurate, especially if the task is carefully matched to areas of stakeholder knowledge. Farmers, for example, are likely to be adept at accurately valuing terrain suitability or estimating areal quantities for crop types.

On the one hand it is likely that the successful incorporation of local stakeholders' knowledge will improve the model. For example, in this case, analysis of land use dynamics by stakeholders allowed researchers to differentiate between land use change due to the degradation of natural areas and land use change as a result of deliberate policy. One example was the elimination of eucalyptus plantations, the cause of which was not evident prior to the participatory process (Hewitt et al. 2014). By including stakeholders in the modeling procedure as co-developers, the applicability, utility and validity of the model is likely to be enhanced by promoting a sense of ownership and developing trust in the modeling procedure and model outputs among the stakeholder community as a whole (Voinov et al. 2016). In the model presented here, stakeholders were involved in model development from the very beginning of the process through three one-day workshops held in the study area between February 2012 and September 2013, during the key phases of model development; workshop 1; parameterisation, workshop 2: calibration; workshop 3; evaluation. The stakeholders who participated in the workshops are listed in Table 2. With respect to the process of stakeholder identification, we were very fortunate in that a team of researchers from the socio-ecosystems laboratory of the Madrid Autonomous University were already active in the area, and kindly shared their extensive list of contacts with us.

Table 2 Workshop participants by sector. In addition 3–4 researchers attended each workshop in the capacity of workshop coordinators

Stakeholder, by sector	WS1	WS2	WS3
<i>Science</i>			
Researcher, Autonomous University of Madrid	Yes	Yes	Yes
Researcher and University Lecturer, University of Seville	Yes	Yes	Yes
Researcher, Doñana Biological Station (National Scientific Institute)	Yes	Yes	Yes
<i>Agriculture</i>			
Director, federation of rice farmers, Seville	Yes	Yes	Yes
Representative, young farmers agricultural association (ASAJA)	Yes	Yes	Yes
Representative, Andalusian Farmers and Livestock keepers union, Huelva division	No	Yes	Yes
<i>Tourism</i>			
Tourism representative, Doñana natural area	No	Yes	Yes
<i>Local policy makers</i>			
Moguer Municipal council, Environment technician	Yes	No	Yes
Representative Doñana 21 Foundation	Yes	Yes	Yes
Almonte Municipal council, Environment technician	No	No	Yes
<i>Regional policy makers</i>			
Regional administration, environmental research division	No	Yes	Yes
Regional administration, environmental research division	No	Yes	Yes
<i>Natural area managers</i>			
Autonomous Body for National parks, head of project monitoring	Yes	Yes	No
Director, Doñana Natural Area	Yes	Yes	yes
Sub-director, Doñana Natural Area	Yes	No	No
Director of Conservation, Doñana Natural Area	Yes	No	No
Director of Public Use, Doñana Natural Area	Yes	Yes	Yes
Guide, Doñana Natural Area	No	No	Yes
Monitoring division, Doñana Natural Area	Yes	Yes	Yes
<i>Environmentalists</i>			
Ex- Ecologistas en acción (Environmental group)	Yes	No	Yes
World Wildlife Fund	No	No	Yes

Through these three workshops, the stakeholder community undertook a wide range of model co-development tasks at each major stage of the modeling process (Table 3). They helped to define the study area, the database and land use categories to use in the model, and they reclassified the land use data set to determine the most important land use dynamics for modeling their region. They provided information about the effect of the different biophysical factors on each land use category, evaluated the goodness-of-fit of simulations during the model calibration phase and estimated land use demand for the model scenarios. Finally, they explored the model results, developed a prioritized list of indicators for environmental monitoring on the basis of the model outputs and evaluated the applicability and utility

of the model as well as the overall success of the participatory process. Note that, while “stakeholders” have been treated as separate to “researchers” in the preceding text in order to emphasize their participation in modeling decisions usually carried out by researchers alone, the researcher is of course a stakeholder. Although it is evident that the researchers, as organisers of the process, have greater power over the information than other stakeholders, we attempted to balance this by presenting, in detail, prior to each workshop, the way in which the information we obtained had been used. This is important in order to establish a relationship of trust and to allow the researcher to become properly embedded in the stakeholder community. In addition, while researchers led the process, the physical results of workshop activities (ideas written on post-it-notes and wall charts, completed activity sheets) always came directly from the participants themselves. At the writing up stage, the extensive video material recorded during the workshops helped to reduce bias caused by researchers’ unintentional interpretation of the primary data—where possible we actually transcribed verbatim the dialogue recorded on video before interpretation.

The participatory modeling process was developed through a chain of iterating participatory/non-participatory activities in which 9 separate steps were identified (Table 3).

4 Results

Results of the participatory modeling process developed through the three stakeholder workshops are summarized as follows. For more detailed description of all the workshop activities and the results obtained see Hewitt et al. (2012, 2014), Escobar et al. (2015) and Hewitt et al. (2016). Full descriptions of the Workshops can also be found on the project webpage.¹

Table 3 details the key modeling stages and the input received at each stage from the participatory process and the corresponding non-participatory (analytical-technical) activity subsequently undertaken by the research team.

4.1 Workshop 1—22nd February 2012

The aim of the first workshop, at which 14 stakeholders were present, was to inform participants about the DUSPANAC project and the proposed modeling activities, and to collect information from them directly in order to parameterize the model. In the first activity (discussion and reclassification of land use categories in groups) the most relevant land use categories for explaining the dynamics of change in Doñana

¹<http://www.geogra.uah.es/duspanac/taller.html>.

Table 3 Step-by-step model procedure, together with the relevant participatory and analytical-technical tasks

Modeling step#	Modeling step	Sub-step	Participatory method	Analytical-technical method
1	Decisions on setting up an application	Delineation of modelled region	<u>Workshop 1:</u> stakeholder assessment of most suitable study area to reflect dynamics	Researchers' decision based on dynamics observed and own understanding
		Selection of land use classes for modeling	<u>Workshop 1:</u> stakeholders select and reclassify land use categories based on their understanding of land use in the natural area	Selection of land use classes according to land change dynamics observed in cross-tab analysis, process understanding and expected model use
		Assign land use classes to behaviour types: dynamic vs. static	<u>Workshop 1:</u> stakeholder evaluation of dynamics (drivers of LUC) stakeholder responses help to understand which classes are most important for dynamic modeling	Assignment of land use classes to types according to land change dynamics observed in cross-tab analysis
		Choose spatial resolution	No consultation	Chosen by researchers on the basis of own knowledge and available datasets
2	Analysis of dynamics of land use change in the territory to be modelled	<u>Workshop 1:</u> stakeholder evaluation of dynamics (drivers of LUC, category losses and gains, assessment of map quality)	Cross-tabulation analysis of LUC, neighbourhood analysis and landscape pattern analysis	
3	Data preparation and setting up the model for the calibration period	Input land use maps Prepare accessibility, suitability and zoning layers	No consultation until parameters need to be defined (stage 4, below)	Data preparation and incorporation of above defined parameters into modeling environment

(continued)

Table 3 (continued)

Modeling step#	Modeling step	Sub-step	Participatory method	Analytical-technical method
4	Calibration	Set neighbourhood rules Set random parameter Set accessibility parameters, Set suitability parameters	Parameters defined by stakeholders from information gathered in <u>Workshop 1</u>	Model manipulation and data handling, statistical testing (kappa sim, clumpiness, visual inspection)
5	Analytical testing/evaluation of calibration	<u>Workshop 2</u> : participatory visual inspection of cell-by-cell accuracy & spatial patterning	Statistical testing of model goodness of fit (cell-by-cell accuracy & spatial patterning)	
6	Fine-tune calibration	Adjust parameter set in step 4	Apply results of participatory model evaluation to reconfigure model	Re-configure model with new datasets or parameters
7	Scenario development	<u>Workshop 2</u> : participatory estimation of demand for land uses	Input stakeholder demand and run scenarios	
8	Evaluation	<u>Workshop 3</u> : Explore model in workshop session, evaluate model and modeling process		
9	Indicator development	<u>Workshop 3</u> : Brainstorming of indicators	Development of prioritised indicators in GIS	

were defined. Prior to the workshop, the research team had undertaken a preliminary reclassification of the Andalusian Regional Government land use and vegetation cover database (Moreira 2007), reducing 107 land use categories to 48. This was still too many for a workable land use model, but further aggregation clearly required local knowledge. To undertake this task, participants were divided into 3

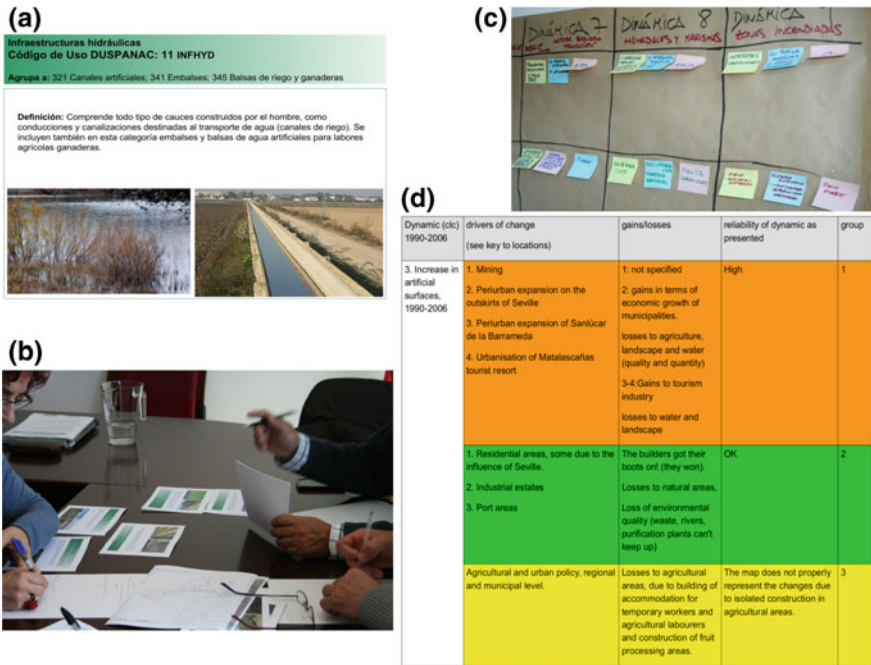


Fig. 3 Workshop 1 activities; **a** example of land use cards used in activity 1; **b** stakeholders debating the land use classification in groups; **c** Stakeholder analysis of land use dynamics on post-it notes; **d** Results of stakeholder analysis of land use dynamics in digital form

groups of 4/5 and each group was tasked with building a new, simpler land use categorisation to represent synthetically and as realistically as possible key land use dynamics from the 48 initial categories. A set of cards illustrating and describing the 48 initial categories was handed out to each group to support the group discussion. Each group chose a spokesperson who presented their categorisation to all participants. Finally, a common and representative “consensus” classification was obtained through general discussion with all participants (Fig. 3). The tangible result of this first activity was the definition of the final 23 land use categories to be introduced into the model.

In the next activity, stakeholders were asked to analyse land use changes that have been observed in Doñana on the basis of previous studies. As in the previous activity, participants worked in groups and later shared their conclusions with the whole group. This activity gave the research team a much better understanding of the land use dynamics of the study area, and enabled us to set the model transition rules (neighbourhood, zoning and suitability) (Table 1), allowing model calibration to begin. In the final activity, participants evaluated the influence of particular suitability factors (rainfall, slope, temperature etc.), on each land use class in the study area through a simple qualitative scoring system—strong (mucho), weak (poco), or no influence at all (nada). On the basis of this information, an agreement

or confidence index (C) was calculated by allocating a value of 0 where all three groups disagreed, a value of 1 where two groups disagreed with the third group, and 2 where all groups agreed. These values were then added together to create a total agreement index for each suitability factor. The categorical responses (strong, weak and no influence) given by the stakeholders for each land use regarding the influence of a given factor were translated into a simple scoring system of 2 (strong), 1 (little) and 0 (no influence) to create what we called the influence index (I). Finally, the confidence index (C) was multiplied by the influence index (I) to give a total overall score by land use for each suitability factor. Thus, for example, in assessing the PLASTIC (intensive crops grown under plastic) land use, all three groups felt slope to be important and responded strong, a score of 2 for each group, giving $(2 + 2 + 2) = 6$. Since all groups agreed about the importance of slope for this land use, the highest confidence score (2) was allocated. Thus the total score for the slope factor for the PLASTIC land use category was 12 (6×2), indicating that the stakeholders felt, with a high degree of confidence, that slope was influential in determining the location of crops under plastic, for which flat and slightly-sloping land was preferred. Suitability parameter settings inside the model were estimated on the basis of this information. For example, in the case of the Industrial (IND), Rice (RICE), Intensive crops under plastic (PLASTIC) and Intensive woody crops (INTWOOD) categories, high suitability parameter values were given to areas with slopes of less than 5%. These values were subsequently modified using an iterative trial-and-error approach which involved experimenting with various different suitability values for different slope categories in relation to these land use classes until some improvement could be seen in the location and spatial pattern according to the analytical assessment methods used.

4.2 Workshop 2—11th December 2012

The second participatory workshop was held on December 11, 2012. Its main objective was to assist in model calibration through three main participatory activities; (1) visual assessment of the quality of model simulations at different phases of calibration; (2) estimation of land use demand for 4 model scenarios adapted from the Doñana Eco-Futures (Palomo et al. 2011), and; (3) estimation of new land use location through a participatory cartography exercise. For the first activity, after a brief explanation and introduction, participants were tasked with evaluating model goodness-of-fit (Fig. 4a, b). To do this, participants were divided into 3 groups and given four simulations representing different stages of the calibration process (Table 1), though only 2 simulations (11 and 35) were successfully evaluated by all participants in the time available. Simulations were provided both on screen and as paper printouts. Participants explored the simulations and then debated the merits of each one in groups (Fig. 4a). Subsequently they rated the similarity of location and degree of clustering of simulated land use categories compared to real land use categories on a pro-forma worksheet. This activity aimed,

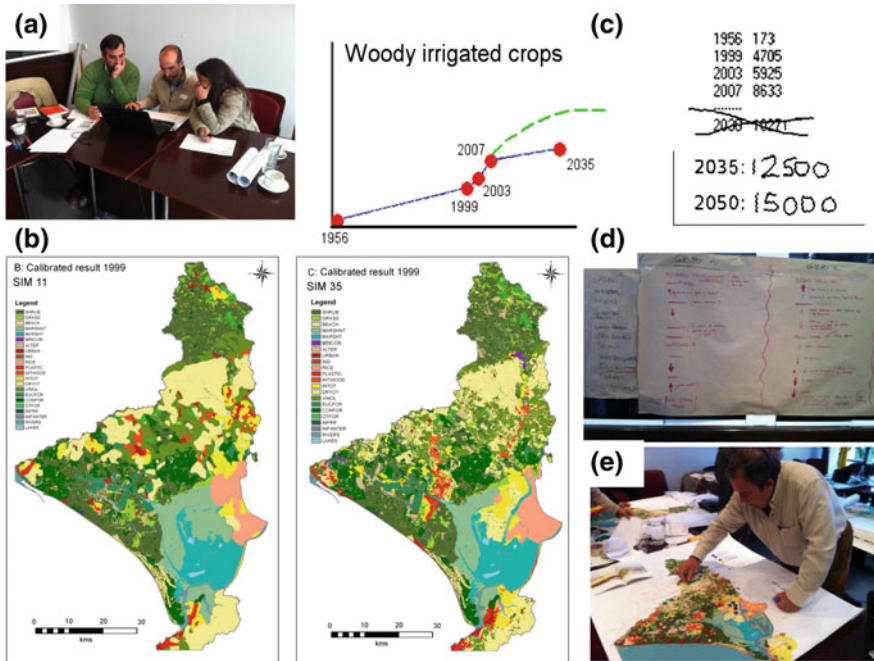


Fig. 4 Workshop 2 activities; **a** Stakeholders evaluating simulation goodness-of-fit on the computer; **b** Simulations 11 and 35 which were evaluated by stakeholders; **c** Land use demand with example of modified tendency curve and demand estimated by stakeholders; **d** Paper wall chart with land change tendencies from open discussion of land use demand; **e** Stakeholder using counters to locate land use demand on a paper map

first of all, to better acquaint the stakeholders with the detailed process of creating land use simulations and to remove a little of the mystery surrounding the operation of the model. It also sought to enhance the validity of the process of visual inspection of calibrations, a job researchers normally do themselves. Clearly, while evaluation of goodness-of-fit with the human eye is highly subjective, subjectivity decreases when simulations are evaluated by many people. Taken together, stakeholder goodness-of-fit evaluation broadly agrees with the results of the statistical tests (Fig. 5).

The second activity of the workshop was intended to link the CA land use model with the Doñana Eco-Future scenarios. The Doñana Eco-Futures were developed prior to our research team’s work by stakeholders working with a group of researchers in socio-ecosystems. Full details about the scenario development process can be found in Palomo et al. (2011). Though the research team was very fortunate in being able to work with existing scenarios, these were not suitable, in their existing form, for direct inclusion in the model, since the land use categories selected by stakeholders in Workshop 1, and later used to build the model, were not explicitly present in the scenario narratives. To address this, stakeholders first

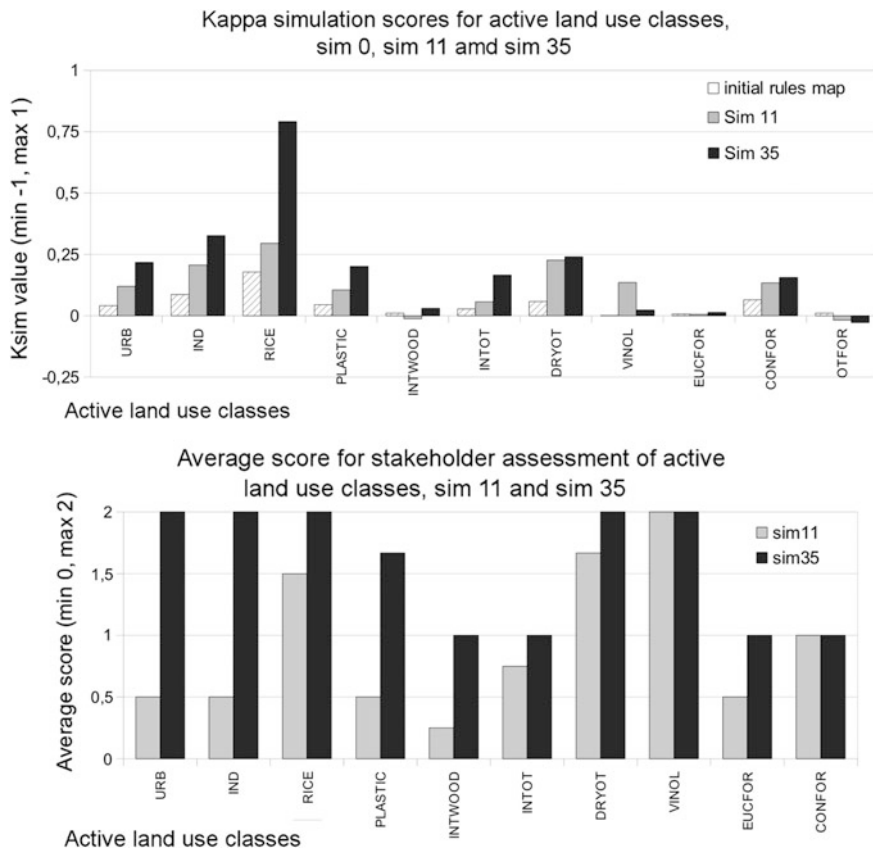


Fig. 5 Results of statistical tests (*top*) and stakeholder evaluation (*bottom*) for two calibration phase simulations, 11 and 35

analysed the scenario narratives looking for references to land use change which they then related to a category. On the basis of this qualitative information for each of the 4 Eco-Future scenarios (1. Doñana globalized knowledge; 2. Trademark Doñana; 3. Arid Doñana; 4. Adaptive Doñana: wet and wild), stakeholders were able to estimate land use demand for the model for each category under each scenario (Fig. 4c, d). In the final activity of the workshop, participatory mapping, stakeholders located the land use demand they had previously estimated using coloured buttons representing different quantities of land (e.g. large button, 50 ha, small button 10 ha) on a A0 paper plot of the 2007 land use map (Fig. 4e). Results were recorded photographically.

4.3 Workshop 3—25th September 2013

The final workshop was dedicated to evaluation of the model and the participatory process and participatory indicator development from the land use simulations. In the first activity, participants explored the future land use simulations that had been generated for each of the 5 scenarios (Business as Usual, a linear extrapolation of past land use tendencies, plus the four Eco-Future scenarios discussed previously). Their comments were recorded and discussed with the whole group. The second activity in this workshop involved developing the indicators that stakeholders considered necessary to support land use planning and environmental management of the area. This activity was carried out in two phases: (a) definition of a set of indicators to be extracted from the model simulation results, and (b) prioritizing these indicators in order of importance according to the stakeholders' preference. Identification of indicators was carried out in groups, and a final list of prioritized indicators was then agreed through a process of open discussion. The final activity in this workshop was dedicated to evaluating the participatory process through three linked activities. In the first, stakeholders responded to two questions; (1) Has your knowledge about change in the Doñana natural area increased through participation in the workshops? (2) Have you had any new reflections about the future of the Doñana natural area as a result of your participation in the workshops? In the case of affirmative responses, participants wrote their new knowledge/new reflections on post-it notes and added them to the wall chart (Table 4). In the second and third parts of the evaluation activity, participants were asked to rate the individual activities of the participatory process through the dartboard technique (see, e.g. WAC 2003; O'Brien and Moules 2007; Herás Lopez 2015), by identifying which activities produced most new ideas (Dartboard 1) and which were found to be most difficult (Dartboard 2). The dartboard was divided into 6 wedges, with each wedge

Table 4 Stakeholders' own evaluation (verbatim transcript in translation) of new knowledge and new reflections acquired as a result of the process

Utility of new knowledge acquired from the process	New reflections arising as a result of the process
To apply the data to reports and studies which were not previously available	Land change drivers
Training/learning	Importance of prioritizing sustainable use of water in general
Awareness of the complexity of the factors that influence the predictability of the new scenarios	Coastal erosion will endanger urban developments
To improve my everyday work activities	Rice and intensive crops would be reduced under climate change
To prevent situations of environmental degradation	Consequences arising from soil sealing
	I feel that I participate in the future but I do not think that others feel the same way
	The trends in most cases indicate a difficult future for the natural area

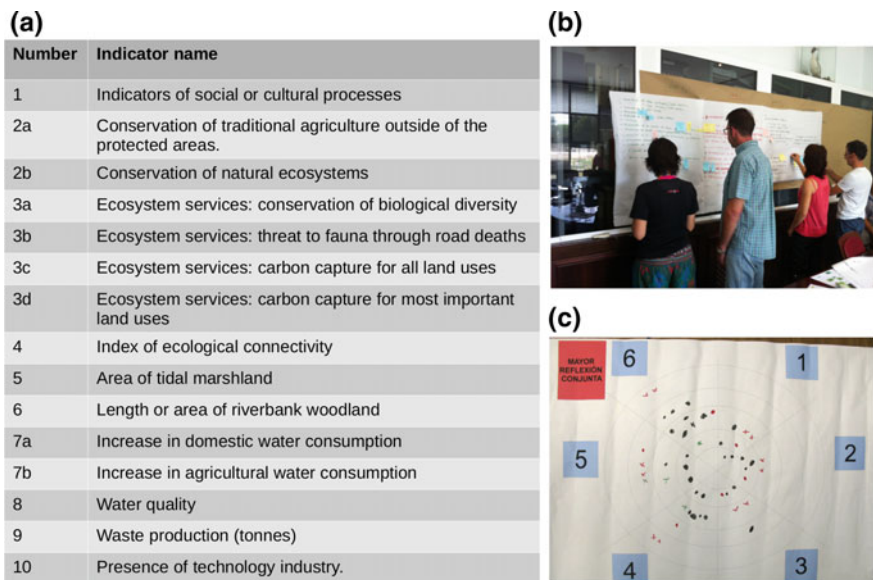


Fig. 6 Workshop 3 activities; **a** Participatory indicators to be developed for model scenarios; **b** Stakeholders evaluating new knowledge and reflections on the wall chart; **c** results of the dartboard evaluation activity for “best group reflection”

corresponding to an activity to be evaluated (Fig. 6c). This exercise was carried out individually, with each participant scoring the activities on the dartboards on the basis of their personal opinion. The land use classification exercise (Ws 1, Activity 1) and the participatory analysis of land use dynamics (Ws 1, Activity 2) were highly rated by participants for group reflection and discussion in the dartboard exercise (Fig. 6c). Stakeholders regarded the participatory evaluation of model goodness-of-fit (Ws 2, Activity 1) as the most difficult of the activities undertaken.

Finally, working in groups once again, participants located the participatory modeling process on the “participation stairway” (Fig. 7). Groups 1 and 2 located the process on the third stair from the top, while Group 3 located the process a step below, since they felt that they had not had sufficient time to fully learn how to use the model outputs.

5 Discussion

5.1 Benefits of the Participatory Modeling Process

In light of the fact that participatory processes have become so fashionable, in the work presented in this chapter a conscious effort has been made to move beyond what we see as a worrying tendency to dress up simple dissemination activities or

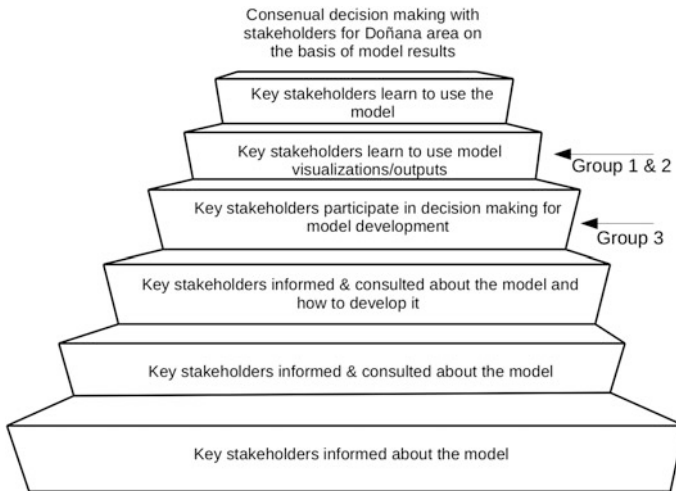


Fig. 7 Results of the “participation stairway” exercise

informative workshops as “participatory processes”. Our approach is different for the following reasons:

Real information elicitation takes place. Specific information is provided to researchers by other stakeholders for a specific purpose. Researchers return this information to stakeholders in its processed form, and invite discussion and criticism, which is then used to improve the model. Knowledge is thus co-generated by all stakeholders.

The participatory activities have given rise to genuine changes in the way the work was carried out. Had researchers simply developed the model unaided and presented the results to stakeholders, the model would have been completely different, with different land use categories, different drivers, different scenarios and different indicators.

The participatory process and its most visible output, the land use model, have been subjected to a rigorous process of evaluation using a range of methods. All stakeholders have been given the opportunity both to contribute information and to criticise the process and its outcomes. Not all of this information is presented here, for reasons of space, but it is provided in full on the website (<http://www.geogra.uah.es/duspanac/taller.html>).

The participatory modeling approach presented here has a number of important benefits with respect to non-participatory modeling approaches, particularly where, as in this case, the aim is to influence decisions about the management of natural resources. Firstly, the participatory process is likely to lead to a better model. Researchers obtained a large quantity of useful information that was used directly for model development, for example, advice about the most important land use changes to represent in the model, group assessment of model calibration goodness-of-fit, and the most useful indicators that the model should try to produce.

Secondly, workshop participants clearly felt the process to be an enriching and worthwhile experience, as can be seen from their responses to the evaluation activities. The land use categorisation and land use dynamics activities were highly rated by participants, who said that they had learned a great deal, especially about the concept of drivers of land use change.

The participatory evaluation of model simulations was found to be very useful as a goodness-of-fit testing procedure. Though visual inspection is clearly a subjective process, incorporating multiple opinions increases the degree of confidence in the results, and in any case, the model also performs adequately with respect to comparable studies (e.g. Van Vliet 2013) for two widely accepted metrics, K_{sim} and *clumpiness*, for both calibration and validation periods.

The participatory indicator development exercise, discussed in detail in a separate paper (Hewitt et al. 2016), was highly successful since it focussed stakeholders' attention on model outputs and possible future utility of the model. We recommend that there should be at least one output-focussed model activity in order to establish a link between the development process and the model's potential use.

There were two activities (Ws 2, Activity 2, and Ws 3, Activity 1) in which participants worked directly with model simulations on the computer. Though these activities were perceived to be the most difficult, they were very useful to communicate the way the model actually worked, much more useful in fact than lecturing stakeholders on model design and operation. In general, the very visual nature of the model makes it attractive for hands-on learning and information sharing.

One of the most interesting reflections emerged during the scenario-based activities in Workshop 2. These activities generated some revealing discussions, predominantly centred around the level of realism that should be represented in the scenarios. Two clear positions emerged, one, which we might call "fantasising about paradise is not the solution", was highly critical of the strongly environmental scenario 4—adaptive Doñana: wet and wild—which this group saw as unhelpfully idealistic. The opposing position, which we might call "dare to dream", strongly emphasised the need for "outside the box" thinking that transcended currently accepted possibilities in order to look for new, sustainable, alternatives. It is possible that the strongest proponents of these positions, in the first case, a regional government employee, and in the second case, a researcher, may be broadly representative of the attitude of their peer groups in society. However, this is not simply a clash between idealism and realism, since actively searching for new, creative options is probably a more realistic approach to finding solutions to the alarming degradation of the natural area than continuing with business as usual. It may be that the regional government representative was not prepared to consider that the extensive environmental measures taken by their organisation could be insufficient or unsuccessful. This is understandable, since these measures, compared with many other areas, are exemplary. Unfortunately, they are unlikely to be successful in the long term, unless an effective alternative to the reigning ideology of "growth without limits" can be found. The incoherence of this position is starkly illustrated by the recent decision of the regional government to push for the

reopening of the Aznalcóllar mine, upstream from the Doñana wetlands, in which a disastrous industrial accident occurred in 1998.² As a consequence of this decision, during the preparation of this chapter, Doñana was added to the World Wildlife Fund's list of UNESCO world heritage properties threatened by industrial development (El País 2016). Unless we blindly accept that "all development is good development", this decision is hard to understand. In the words of one workshop participant (Table 4, new reflections) "The trends in most cases indicate a difficult future for the natural area".

5.2 *The Role of Participation in Land Use Models*

Even a participatory process like the one described above, with various in-depth workshops, does not really allow time for the detailed workings of the model to be completely assimilated. It is therefore important to find out to what extent the stakeholders had come to understand the model by the end of the participatory process. Unfortunately, this is difficult to measure without a specific test, and developing such a test was not felt to be a priority in this research given the pressures of time and the fact that quite extensive participatory evaluation procedures had been carried out anyway. However, despite the numerous activities aimed at improving participants understanding, it seems highly likely that most stakeholders probably had an incomplete picture of the model and its capabilities. This is important, because some sources caution that poorly understood models are useless and can even be dangerous, in the sense that they may lead to significant misunderstandings about important issues (see, for example, <http://www.fund-model.org/>). However, the extent to which this is a significant problem depends very much on the individual case, and the experiences that have been shared in this chapter lead us to think otherwise, for the following reasons:

- The model does not actually make decisions itself, and can instead be used to support policies over the long term. In the short and medium term, the modeling and embedded participatory process is used to inform discussion and share knowledge about a particular issue. Clearly, while a poorly understood decision-making robot might be dangerous, a poorly understood discussion support tool is simply less useful than a well understood one. For our purposes, an incomplete understanding of the model is a significant improvement on no knowledge at all.

²On April 25, 1998, the collapse of part of a tailings dam flooded the Agrío and Guadiamar Rivers with high pyrite content mine tailings and acid water containing dissolved heavy metals. The spill affected a branch of the Guadiamar river basin measuring 62 km long with a width of between 500 and 1000 m between the village of Aznalcóllar and the border of the Doñana National Park, with catastrophic effects on flora and fauna (Hernández et al. 2004).

- Though misunderstandings of the model are frequent, they rarely have serious consequences. The commonest misconception among stakeholders was a tendency to attribute to the model capabilities it does not have. This is, in itself, a constructive process, since it can lead participants to come up with interesting and useful hypotheses. For example, in the Business as Usual (BAU) scenario one group of participants noted the disappearance of areas of crops under plastic in the municipality of Lucena, even though the BAU scenario shows an overall increase of this crop type. This was interpreted as an attempt to change the strong economic dependence of the municipalities in this area on these crops, by searching for substitute crops with less environmental impact or refocussing the economy towards other services. However, this explanation does not explain the behaviour of the model, which did not include these factors (in fact, other model areas are simply more attractive, so this crop type moves location). Nonetheless, the interaction of the participants with the model simulation has allowed an interesting real world dynamic to emerge that could be used to inform future policy in this area. This is a nice example of what Cartledge et al. (2009) call “constructive ambiguity”, very useful for developing new policies or expanding the “option spaces” in which policy actions can take place (Oxley et al. 2002). In practical terms, this is also useful for improving the modeling tools and approaches themselves, e.g. the software, since stakeholders will typically have preconceptions about what a model can or cannot do which will differ substantively from the modeller’s or software developer’s vision of the way the model should work.
- Involving stakeholders in building and using the model may indeed lead to misconceptions, but it also reduces them, as well as informing more widely about what models are and what they do. We argue that the “danger” lies in the uncritical acceptance of scientific data, whether from models or from other sources, and that our aim as researchers is to reduce this danger by encouraging participation in, and critical reflection on, the scientific process.
- Human societies are already in serious danger from an economic model that makes the planet’s life support systems subservient to the accumulation of monetary capital and consumer goods. Given the urgent need to secure sustainable future for threatened ecosystems like Doñana, risks that may arise from misunderstanding a land use model are outweighed by the benefits that the participatory model development process brings, e.g. uniting stakeholders with different or opposing views to discuss the future of shared territory, transparent dissemination of the inner workings of a scientific process, building confidence in cross sector collaboration on environmental issues etc.
- Ideas about models being “dangerous” in the “wrong hands” carry with them some questionable assumptions that risk reinforcing the persistent myth of scientists as objectively separate from society as a whole. In fact, scientists are an inseparable part of the society in which they operate and bring to their work many conscious and unconscious biases that mean they are unlikely to be more

objective than any other stakeholder (see, for example, Marshall 2015). In addition, while scientists can provide many tools and approaches, they are likely to lack specific local knowledge. The assumption that scientists are somehow omniscient is rarely intentional or conscious, but it is important to challenge it, nonetheless. Much information, especially relating to land and natural resources, is informal and unwritten, and is not easily accessible to outsiders without formal knowledge sharing procedures of the kind discussed in this chapter.

6 Conclusions and Outlook

6.1 *Limitations of the Study and Future Work*

As with any such study, some limitations can be identified, leading to questions for future research.

Although the scenarios were constructed by stakeholders as part of a prior participatory process (Palomo et al. 2011), not all of the participants from this earlier process attended the participatory modeling workshops. In future, it would be interesting to try to seamlessly integrate the whole scenario modeling chain, from narrative construction to scenario building through to land allocation for the scenarios as they appeared in the model, ending with participatory scenario evaluation.

Stakeholders (Table 2) represented a wide variety of sectors and professional skills, but did not specifically include local people, park visitors or religious tourists (an important group due to Doñana's importance as the site of a famous local pilgrimage). There is no doubt that the inclusion of these other stakeholders would have brought to light new and different perspectives that did not emerge here. Additionally, although the organizers aimed to strike a balance in terms of the stakeholders contacted, when it came to the stakeholders that actually attended, policy makers were over-represented. This was almost certainly because of the choice of venue for the workshops (national park offices). In future, choosing a more neutral venue might help to even out the balance.

Finally, it is clear that the participatory process could be enriched to include a role-playing game, with stakeholders encouraged to play roles that have nothing to do with their professional responsibilities (e.g. farmer as policy maker, scientist as religious tourist etc.).

6.2 *Who Knows Best?*

This paper presents a land use model for the Doñana natural area which was co-developed through a series of participatory workshops held with key

stakeholders from a variety of sectors. Fundamental decisions about model set up and calibration were made consensually by the whole group. The participatory modeling process was extremely useful to the research team, but also clearly beneficial to all stakeholders, as evidenced from the results of the stakeholders' own evaluation.

The answer to the question “Who knows best?” posed in the title of this chapter, is probably “it depends”, i.e. it depends on the context of the modeling exercise to be undertaken. Clearly there are many situations in which a researcher with the relevant training and experience is the best person to undertake a scientific task. But for the insights obtained from a scientific approach, such as a land use change modeling process, to be properly integrated into decision-making, it is insufficient for scientists to carry out the task alone, and then baldly state that “the results are likely to be of interest to land use planners and resources managers”. Even stakeholders with similar perspectives, such as environmental researchers and protected area managers, are often unable to communicate effectively through standard information sharing channels. When, as is normally the case, the stakeholder community is much more diverse than this, these problems are compounded. For example, while the agricultural sector has the potential to be well-informed about relevant scientific developments e.g. through trade periodicals, we are not aware of any standard procedures that ensure that knowledge flows the other way—e.g. that farmers' own knowledge is routinely available to scientists. This is no doubt because of the implicit presumption that farmers are not generators of “useful” knowledge. If these preconceptions are not challenged, it is likely that misunderstandings between stakeholder communities will persist and environmental problems will continue to resist long-term solutions.

A participatory modeling process is a very useful way to bridge the significant differences between these different stakeholder communities and spark a genuine process of social learning, in which the importance of stakeholders' knowledge depends on its relevance to the question, rather than on conventional social structures or traditional knowledge hierarchies.

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