Paper 115. Using a Water, Energy and Land research model to bridge the gap between research and teaching

Bojana Bajzelj[1], Richard A. Fenner[1], Elizabeth Curmi[1] and Keith S. Richards[2]

[1]Department of Engineering, University of Cambridge, CB2 1PZ.

bb415@cam.ac.uk

[2]Department of Geography, University of Cambridge, CB2 3EN.

Abstract

As the discussion on sustainable development moves forward, increasingly complex themes arise – such as that of the Water, Energy and Land Nexus. This deals not only with the finite nature of resources, but also with their interconnectivity. These complex concepts about system feedbacks can be difficult to communicate to students in a standard teaching context, which often rely on linear narratives.

Here we report how we explored these connections amongst water, energy and land resources, initially as part of a first-year undergraduate Geography course, and subsequently to postgraduate Engineering students. To achieve this we used a model, called Foreseer, currently being developed by an interdisciplinary research team in the University. This model represents physical flows of the three resources (water, land and energy) from their sources, through transformations, to the services they deliver. The main feature of the model is that resources are interconnected. For example, agricultural activity is an integral part of the land system, and is also linked to corresponding demands for irrigation water and energy for mechanisation and fertilizer production in water and energy systems. The model provides a visual interface that dynamically communicates this system analysis.

Students were given short instructions about how to use the tool to create four scenarios. They were invited to register to use the online version of the tool. About half of students participated in the exercise, which was voluntary. Their understanding of the resource connections and their ability to extract information from the model were checked with an online questionnaire. This exercise presented a valuable exchange of knowledge between researchers and students. For students, it was an interactive and engaging way to learn about these complex concepts in sustainable development. For researchers, it provided feedback on how understandable the model is, and how to develop its user interface further; it also provided novel research ideas. The exercise proved to be a helpful way to connect the two main dimensions of higher education, research and teaching, to the benefit of both.

1 Introduction

The discourse in sustainable development covers increasingly complex themes. The most prominent example in recent years is the increased awareness of the importance of the interconnections amongst major resource systems, all of which are complex in their own right. The Water, Energy and Food nexus (also called the Water, Energy and Land (WEL) Nexus, or simply the Nexus) represents a way of thinking about these connections and their feed-back loops.

Sir John Beddington, former British Government Chief Scientific Advisor, called the interconnections between the three resources, and the associated aggravated consequences which they are expected to create by 2030, “The Perfect Storm” (Beddington, 2009). Energy and water inputs are needed for food production, land is converted for both energy and water infrastructure, and providing water at the right time and place requires energy. All three resources are connected, and more often than not, changes in one will have knock-on effects on the other two. The World Economic Forum’s (2011) Global Risks 2011 report echoes Beddington's warnings: “Any strategy that focuses on one part of the water-food-energy nexus without considering its interconnections risks serious unintended consequences.”

Considering all three resources together is difficult, both for the research community and in terms of communication to students. This partly is because of early discipline specialisation and specific focus on priorities within each sector, as well as the departmental structures and boundaries common in most universities (and beyond). Tightly coupled feedback loops create circular knock-on effects that happen simultaneously, which is difficult to capture within the standard teaching context and its linear narratives. In the research community the use of computer models is seen as an effective way to include all of the connections in decision-support tools.

An interdisciplinary team based in the Department of Engineering in Cambridge is developing such a decision-support computer WEL nexus model called Foreseer. The focus on visualisation of interconnections and user interactions distinguishes it from other models. The primary driver for this focus was an aspiration for improved communication to policy makers, and to provide improved understanding and transparency of the model. As such, the model also has the potential to be used as a teaching tool.

There are not many other models that deal with the WEL nexus explicitly. The CLEW model is one example, composed of three soft-linked pre-existing single resource models (WEAP for water, LEAP for energy and AEZ for land), where the results of one model can be manually entered as inputs into the other models (Hermann et al., 2012). This requires expert involvement in the process and is opaque. On the other hand, public understanding and participation tools have been developed on the topic of climate change and energy. The so-called ‘Stabilization Wedges’ concept, developed at Princeton University (Pacala & Socolow, 2004), is a well-known example that seeks to educate about the options necessary to achieve emissions reduction is the USA. Although this concept has been criticized for over-simplification and for failure to include interactions amongst the reduction options, it was very successful as a teaching tool about climate change in the USA, becoming regularly used in upper-level high school curricula (Climate Mitigation Institute, 2013). Another example of a public engagement tool with teaching potential is the Department of Energy and Climate Change (DECC) Carbon Calculator (DECC, 2012). Foreseer is operating conceptually between these three tools: it combines the complexity of a Nexus model with a problem-solving approach of the Stabilization Wedges and the dynamic visualisations and user interactions characteristic of the DECC Carbon Calculator.

A decision was made to test the Foreseer research model as a way of explaining the nexus ideas to students. It was therefore first used within a Land and Water module taken by first-year Geography undergraduates, and in an identical form, was then exposed to graduate students taking the MPhil in Engineering for Sustainable Development. Since visualising interdependencies is such an important part of Foreseer, a secondary objective was to provide feedback from the students using the Foreseer tool, to provide suggestions of potential improvements for the model development team to consider.

In this paper we briefly describe the Foreseer model, explain how we have used it in classes and conducted a user study. We show the results of the exercise and discuss how it brought teaching and research activities closer, benefiting both dimensions.

2 Background to the Foreseer model

Foreseer models the connections between water, energy and land systems, including their impacts on greenhouse gas emissions. For example, agricultural activity is an integral part of the land system, and is also linked to corresponding demands for irrigation water and energy for mechanisation and fertilizer production in the water and energy systems. These connections are treated in the whole resource context – for example, Foreseer is not only concerned with the water footprint of a particular technology, but also with the role of this footprint in the whole water system. This includes the source of water, the stages it goes through before reaching its use, and the alternative uses and trade-offs. To represent whole systems, Foreseer traces physical flows of the three resources from their sources, through transformations, to the services they deliver.

A second important property of the model is that it creates dynamic scenarios for future resource flows, and at the moment, this is fully implemented in a case study based on the US state of California until 2050. Economic relationships and consequences are not yet included – all system interactions are based on physical relationships.

The visual representation offered by the Foreseer model is a third major focus. The tool uses coupled dynamic Sankey diagrams in an effort to represent the scale of resource flows, and the relationships between them, intuitively. The model is interactive – users can set and run their own scenarios by changing input parameters, and hence explore the impacts of policy decisions and policy alternatives. User friendliness is therefore very important.

The model can be viewed by registering at www.foreseer.group.cam.ac.uk.

3 Methodology

In order to be used in teaching, the Foreseer user interface was set at a level of complexity that was deemed appropriate for student interaction over a limited time period. Four scenarios were designed to be run by students in their own time and at their own pace. The setup instructions for each scenario were described on a one-page handout that was given to students (see Appendix1). Students were required to register in order to be able to use the online version of the Foreseer tool.

The four scenarios were designed to explore the problem of unsustainable groundwater use in California, the factors contributing to this, and the opportunities for mitigation. This theme emerged as critical through our implementation of Foreseer to California. At the same time, similar conclusions about groundwater depletion emerged from other studies, using very different methods. Specifically, the four scenarios explored the impacts of: (1) population increase and therefore intensification of agricultural production, (2) food trade, (3) the production of biofuels, and (4) mitigation options through different water policies. Along with the main task of observing water sources and uses, students were also asked to observe land use changes, energy use for water services, water used in energy production, and embedded resources in imported and exported goods, associated with these scenarios.

First year geography students were given a short introduction to the model, along with a discussion on links between water and land issues. MPhil Engineering students used this exercise more independently, having had no demonstration of the model. Both groups were asked to conduct the exercise individually in their own time, on a voluntary basis. Their success with using the tool and understanding of underlying principles was measured with an on-line questionnaire set up using SurveyMonkey; the hand-out and questionnaire are provided in Appendix 1. The core of the online questionnaire asked participants to extract specific values and results from the models, and to explain the background dynamics and linkages. At the end, students were encouraged to give their own assessment of the tool by identifying any sensitivities, commenting on its usefulness and suggesting further development ideas. At the same time they were asked about their user experience related to technical questions, providing a user test of the model.

4 Results

Student performance (success rate) was assessed by analysing the questionnaire responses in relation to our own knowledge of the expected answers when specific requirements were set in the scenarios. While this is interesting for several reasons discussed here, the real results of this exercise were the learning outcomes for both the students and the researchers. These can only partially be measured by the success rate. Our assessment of learning outcomes is rather based on anecdotal evidence from both groups.

4.1 Exercise results

90 first year Geography students and 47 Masters Engineering students were invited to use the tool, complete the exercise and the online questionnaire. Since the participation was voluntary, not all of them became involved, as we anticipated. 52 and 23 students from their respective groups filled in the questionnaire. Students reported spending between 45 minutes to two hours on the exercise in total. The response rate in the first group might have been higher, but this initial exercise revealed a technical problem with the on-line tool which prevented some potential participants from completing the exercise. This related to the use of a particular version of Microsoft Silverlight which prevented the tool from opening in Apple computers. Of course, discovery of this problem was itself a very beneficial outcome from the first exercise, and led to software modification that resolved the issue for the second survey.

While the students were not being assessed on the correctness of their answers to the quantitative questions, it is nonetheless interesting to compare how well each group did. For the developers of the model and the study, it was interesting to observe which questions posed problems to the students. Table 1 compares the success rates for each of the questions for both groups.

Generally the differences between the two groups in terms of correct responses were statistically insignificant. For example, by defining the proportion of correct answers for each student, then comparing the distributions of these proportions between the two groups, a t-test statistic of $t=0.80$ was obtained. Compared to the critical value of $t=1.994$ at the 95% confidence interval for these sample sizes, this is not significant. However, an alternative analysis is to examine each question in turn and compare the proportions of correct responses in the two groups. In a test of the significance of the difference between two independent proportions, with these sample sizes a difference of greater than 20% tends to be statistically significant at $p=0.05$ in a two-tailed test. In Table 1, these cases are shown in bold type; the first year students did slightly better than the Masters students, with a majority of better performances, but the previous analysis showed this not to be significant. The first year Geography students were given a brief (c. 5 minutes) introduction to the model during the course of a 50-minute lecture on water resources, whereas the MPhil Engineering students received no prior explanation. When analysing the open-ended answers, those provided by MPhil students were more elaborate and also provided a more critical analysis. The questions resulting in greater discrepancies between the two groups were the more complex, comparative ones later in the exercise.

Table 1. Proportions of correct quantitative answers obtained from the Foreseer model by the two groups of students (First year geography and MPhil engineering for sustainable development). Bold entries indicate proportions that differ significantly at p = 0.05.

Scenario	Q	Question summary	1A Geography	MPhil Engineering
1	1	Level of groundwater stocks	79%	78%
1	2	Quantifying virtual water	92%	96%
1	3	Quantifying water use in energy	71%	52%
1	4	Quantifying land shortages	81%	91%
1	5	Food imports	81%	78%
1	6	Energy use in water supply	90%	87%
2	7	Level of Groundwater stocks in S2	87%	87%
2	8	Quantifying virtual water	94%	87%
2	9	Comparing virtual water to S1	85%	74%
2	10	Quantifying water use in energy	79%	70%
2	11	Quantifying land shortages	90%	87%
2	12	Comparing land shortage to S1	81%	83%
2	13	Explaining changes in land	83%	83%
2	**14**	**Food imports**	**73%**	**91%**
2	15	Energy use in water supply	90%	83%
3	16	Level of Groundwater stocks in S3	81%	83%
3	17	Comparing groundwater stocks to S1& S2	88%	87%
3	**18**	**Explaining changes in groundwater**	**92%**	**74%**
3	19	Virtual water	83%	83%
3	**20**	**Water for energy**	**50%**	**26%**
3	21	Land shortage	85%	87%
3	22	Explaining changes in land	90%	83%
3	**23**	**Biofuels produced**	**85%**	**61%**
3	24	Food imports	79%	83%
3	25	Biofuels energy	94%	83%
3	26	Biofuels share	71%	57%
3	27	Significance of biofuels	90%	87%
3	28	Resources for biofuels	92%	91%
3	**29**	**Energy for water**	**94%**	**74%**
4	30	Mitigation options: recycling	85%	87%
4	31	Mitigation options: desalination	83%	87%
4	32	Mitigation options: all together	83%	78%
		Average	**84%**	**79%**

4.2 Learning outcomes for students

The following concepts were covered in the exercise, through the scenario building and the targeted questions:

- The causes of groundwater depletion in California
- The state of groundwater stocks in the next 40 years in a business-as-usual scenario
- Increasing pressures on land and water resulting from dietary changes
- Virtual water and its relationship to food trade
- Food trade implications for land resources
- Food trade implications for energy use (for example, energy use for water pumping decreases with increased food imports)

- Increased pressures on land and water resulting from biofuel production
- The role of imports and exports in general in all three resource systems
- Effectiveness of different policies to reduce groundwater depletion
- Tight coupling of land and water management in California.

Students learned about these concepts through an interactive use of the tool. It is difficult to assess what students have learned compared to their previous knowledge, but we can gain some insight based on their comments in the online questionnaire:

> "[I've learned that] changes in land use change the way water and energy are used. California is a fertile region and so land use is particularly important regarding the production of biofuels and agriculture, changes in land use have a significant impact on groundwater."
>
> "I was surprised how strong these links, dependencies and interactions between the three resources are, and adjustments made to one of them will have implications and ramification on the others."
>
> "I learned a lot about water usage and the water cycle. I have had very little exposure to this in the past so did not know about how it was used and where; this was particularly useful."

Only one student (from the Masters group) stated that he/she had not gained any new insights beyond what was already known. However, this was clearly an unusual response, and reflects the fact that the Masters students are a relatively heterogeneous and international group (compared to the predominantly UK undergraduates), and may have included one individual who by chance had had significant prior exposure to water resource issues in California.

The last question in the survey asked respondents about their two main take-home messages from the exercise. These answers are also helpful in trying to determine what the students learned. The selection of the two take-home messages was completely open-ended, with no suggestions given to the students. Nonetheless some messages appeared many times, as shown in Figure 1. The open-ended nature of the question made these answers especially interesting in revealing how the main messages for a "casual" user of the tool may differ from those we, as researchers, thought the model would communicate, based on our own knowledge and interpretation. While "the interconnectivity of resources" was an expected main message (indeed it was mentioned most frequently), we were more surprised by the number of respondents who were particularly struck by the resource intensiveness of biofuel production and by the significance of imports in California.

In the design of the exercise and the questionnaire we tried to avoid influencing the students' opinions by suggesting any conclusions to them. As a result, different interpretations of scenarios were possible. For example, as one of take-home messages, 11 students mentioned they were struck by how little difference alternative water supply policies made, whereas four have specifically mentioned the opposite view, that the policies were effective. Similarly, when asked whether they thought biofuels played an important role in one of the scenarios, most students answered that was not the case, while many have argued that they were indeed significant. Both groups gave compelling and valid explanations for these seemingly mutually exclusive interpretations.

Based on the comments made by the students and their general success in finding the right answers, we can conclude that the majority of students gained a better understanding of the interconnectivity of resources and the importance of considering them jointly in resource planning from this exercise

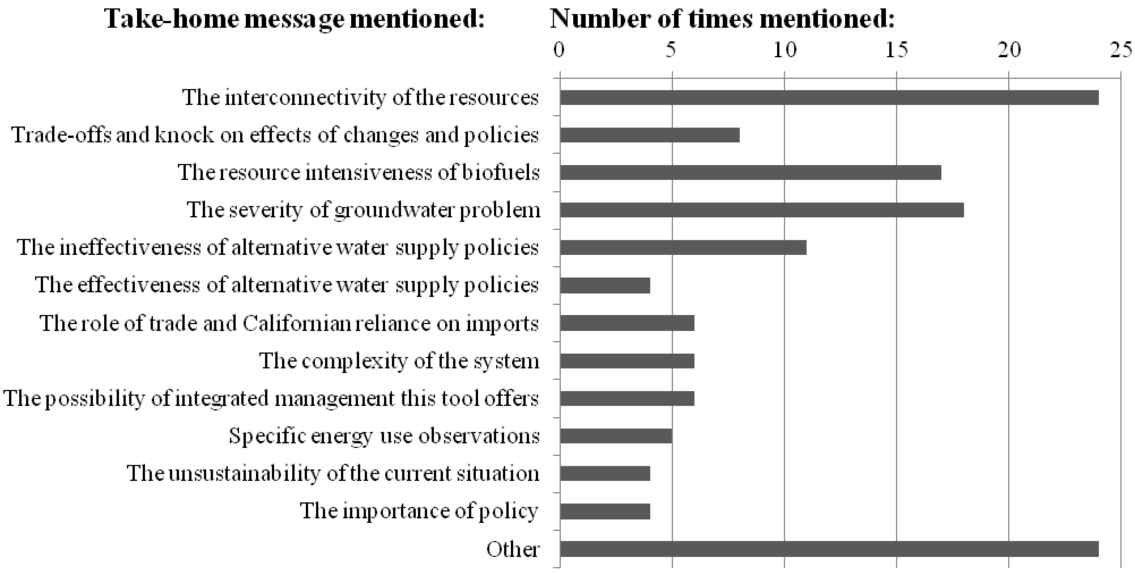

Figure 1: Frequency with which particular take-home messages were mentioned

4.3 Learning outcomes for researchers

We, as researchers, have also learned from the feedback we have received. As noted above, there were some technical problems for certain browsers and operating systems, and it was extremely useful that the exercises revealed these so that they could be rectified. As Table 1 shows, question no. 20 stood out in terms of the number of wrong answers. After some consideration we realised this must have been due to an awkward positioning of the label. Similarly the relatively weaker answers to questions about water use in energy were rooted in the flows being so small that the lines in the diagram were very thin and difficult to identify. Some possible misunderstandings were discovered, for example that it is possible to misinterpret the time axis for the y-axis of the diagram. Many students expressed a wish for more interactive onscreen instructions, and more background information, encouraging us to develop these aspects further.

Students were asked to suggest possible scenarios of their own to be implemented in the Foreseer tool. Most of these suggestions have been already considered by the research team, showing a good understanding by the students of the topic and the model's capabilities. For example, students suggested a scenario that investigates the role of behaviour change; more detailed climate change scenarios; and a version of Foreseer that would be set in an urban environment. Some of their ideas were really interesting and have translated into a further research agenda for the modelling team.

In another question students were asked to name any reservations and sensitivities surrounding the model. Here we were equally happy to see many of them correctly noting that any predictive model such as Foreseer is inheritably surrounded by uncertainty. Several students observed that such a tool can never include all possible drivers of future change, for example game-changing technologies and possible societal changes. We see this ‘criticism’ as a sign of success, for two reasons. Firstly we believe it is our responsibility as the developers of models such as Foreseer not to overstate the capabilities and the scope of the model or give a false appearance of certainty. It is encouraging to see that the model is not perceived in this way, although the communication of uncertainty could be further improved. Secondly, it is equally important to see that students approach information with caution and a critical mind. Several students mentioned that they would like to know more about the underlying data, and correctly identified that the data references were not satisfactory (the referencing system of Foreseer was a work in progress at that stage). This showed their keen awareness of the importance of the reliability of information sources.

While the model was not initially designed to be used in teaching, it is clearly at some level a learning tool, and can therefore be translated to a pedagogic purpose with minimal adjustments. The model is complex, but step-by-step instructions and the building of successively more complex scenarios from simple ones ensured that most students felt confident about using it after some initial reservations. Many of their comments were along the lines of:

"[The model was] initially confusing, but improved as I got used to it"

This suggests that while the level of model complexity presented to students was ultimately satisfactory, more could be done to prevent an initial unfavourable reaction that may lead many to drop out from using it an early stage.

Most students responded enthusiastically, praising the visual and dynamic aspects of the tool, stating that they prefer this medium to 'plain text'. Many seemed to have particularly liked the use of animations and bright colours, and there were no problems with the user parameter-input interface. Such positive responses, in conjunction with constructive suggestions and problem identification, has been an encouragement to us, the researchers, to improve and develop the Foreseer tool.

5 Bridging the gap between research and teaching

This exercise presented a valuable opportunity to exchange knowledge between researchers and students. For students, it appears that it was an interactive and engaging way to learn about these complex concepts in sustainable development. It introduced them to research activity in the university and they were able to see that they can contribute actively to this. For researchers, it provided feedback on how understandable the model is, and how to develop its user interface further.

It may not always be possible to integrate research and teaching activities in a university. It is advantageous for researchers to contribute to the teaching syllabus when this benefits their research. In this example there was a clear gain in the form of a 'user study', and since the visual and understanding aspects of the model are very important, the opinion of the students was very helpful. On the other hand, research brought into teaching must be at the right level of complexity. Perhaps because the nature of the Foreseer model is so interdisciplinary, it is more suitable for introduction to students than much other academic research, which is highly specialised and narrow in focus. In the end, this exercise proved to be a very helpful way to connect the two main dimensions of higher education, research and teaching; and to the benefit of both.

References

Beddington, J. (2009). Food, Energy, Water and the Climate: A Perfect Storm of Global Events? London. http://www.bis.gov.uk/assets/goscience/docs/p/perfect-storm-paper.pdf

Climate Mitigation Institute: Stabilization Wedges Game Website, accessed 15/04/2013; http://cmi.princeton.edu/wedges/game.php

Department of Energy and Climate Change: Carbon Calculator website, accessed 15/04/2013; http://2050-calculator-tool.decc.gov.uk/

Hermann, S., Welsch, M., Segerstrom, R. E., Howells, M. I., Young, C., Alfstad, T., Rogner, H., et al. (2012). Climate , land , energy and water (CLEW) interlinkages in Burkina Faso : An analy intensification and bioenergy production. *Natural Resources Forum*, **36**, 245–262.

Pacala, S., & Socolow, R. (2004). Stabilization wedges: solving the climate problem for the next 50 years with current technologies. *Science*, **305** (5686), 968–72. doi:10.1126/science.1100103

World Economic Forum (2011). Global risks 2011 report. http://reports.weforum.org/global-risks-2011/

Appendix: Foreseer Hand-out and Questionnaire

FORESEER - AN ANALYSIS OF INTEGRATED RESOURCE FUTURES (THE LAND-WATER-ENERGY NEXUS)

In this exercise, we would like you to compare some future resource-use scenarios for California

To access the Foreseer tool, first register by going to www.foreseer.cam.ac.uk, clicking on the 'Foreseer Model' tab, and follow the registration from there. Your registration will be confirmed by email, and you can than access the model from the same webpage.

Once you've logged in, you will see that the main window of the Foreseer tool displays a Sankey diagram showing the annual flows of land, water or energy. You can swap between the three resources by using the tabs at the top of the diagram. The three diagrams are generated simultaneously from the same model – when you run a scenario, all three Sankey diagrams are updated.

To the right of the main diagram is a parameter input panel, with the inputs divided into groups (for example, try clicking on "Future Energy Mix Inputs" to access that section). Here, you can change the parameter values that you would like to test. Once you have set the parameters for a particular scenario, you need to click on "update model" to run the model and see the results. Once the model has finished calculating, the play/pause button in the lower left corner and time line next to it will allow you to view the results of the scenario as an animation. As you animate the results with the 'play' button, you will see changes in the Sankey diagrams as a result of your parameter inputs. Some year-to-year variations, particularly in the water diagram, illustrate the effects of natural variability of properties such as precipitation, from dry to normal to wet years.

The Sankey diagrams show annual flows, but you may also be interested in cumulative values of some important parameters such as cumulative groundwater use over the time-period studied (which can be accessed by clicking on the "stock levels" tab). When you click on the elements of the yearly flow diagrams or the stock level diagrams, related information is displayed in two panes below the main diagram, including a graph which shows the change in quantity over time for the current scenario (in dark blue) and the previous scenario (in light blue). This feature allows you to compare the results of two different scenarios.

On the following pages there are some scenarios for you to evaluate, and a form you can use to note your findings and conclusions. When you have completed this, you can go to the following SurveyMonkey webpage and enter your results: https://www.surveymonkey.com/s/?????????

Scenario 1

In scenario 1, assume the population in California in 2050 reaches 50 million people (from today's 35 million, as estimated from population growth statistics), and assume that the increase in food demand of this increased population is entirely met by attempting to grow more food in California (Food demand increase met by imports in the "Shortfall reduction inputs" is set to 0). This is the Baseline Scenario.

Water.

1. What is the cumulative use of groundwater stocks by 2050?
2. What is the use of external virtual water (avoided water)?
3. How much water is used in energy production?

Land.

4. What is the implied shortage of land by 2050 as a result of the increase in food?
5. What are the food imports calculated in carbon amounts?

Energy.

6. What is the total amount of energy used for treating and distributing water under this scenario ?

Scenario 2

This is the same as scenario 1, but this time, the extra food needed for the increased population is assumed to come from food imports. This scenario is more realistic, as environmental legislation is quite strict in California, and forest and shrub land is not likely to be changed into cropland or pasture. This scenario also implies that California may need to shift from export-based agriculture to agriculture that provides more of its own food requirements.

Water.

7. What is the cumulative use of groundwater stocks by 2050 in this scenario?
8. What is the annual virtual water demand in 2050?
9. How does it compare to that in the Baseline Scenario?
10. How much water is used in energy production?

Land.

11. What is the implied land shortage for this scenario?
12. Has it increased or decreased relative to the Baseline Scenario?
13. Why do you think it has changed?
14. What are the food imports calculated in carbon amounts?

Energy.

15. What is the energy required for water services in this scenario?

Scenario 3

In this scenario, we assume that 10% of liquid fuel demand in California is met through biofuel production within California itself, and that 50% of this is grown on cropland (Miscanthus, second generation biofuels- irrigation needed) and 50% is grown on marginal land (Agave, also a second generation biofuels- no irrigation needed). The extra increase in food needed by the higher population in 2050 is once again met through imports as in 2.

Water.

16. What is the cumulative use of groundwater stocks by 2050 under this scenario?
17. How does this compare with the previous two scenarios?
18. Explain briefly the reasons for the difference
19. How much virtual water is required to produce the food imports?
20. How much water is used in energy production?

Land.

21. What is the implied land shortage in this scenario?
22. Why does this shortage arise?
23. What is the final service for fuel production, measured in carbon?
24. What the food import amounts, measured as carbon?

Energy.

25. What is the energy production from crop biomass?
26. How does it compare with the demand for oil?
27. Do biofuels represent an important part of the energy mix?
28. What are the effects of growing biofuels on water and land use?
29. How much energy is involved in providing water services in this scenario?

Scenario 4

This scenario is the same as scenario 3, but introduces water policy mechanisms. There are currently four water policy scenarios available: increasing the % of urban water recycled; increasing the % of recycled water used to recharge aquifers; increasing the % of desalinised water; and increasing the amount of water storage capacity.

30. What is the effect of increasing urban water recycling from the current 8% to 50% on the cumulative use of groundwater stocks?
31. What is the effect of increasing the use of desalinated water by 400 times on cumulative use of groundwater stocks? (Leave recycling water at 50%)
32. What is the effect of implementing all of the policies, as far as permitted, on the cumulative use of groundwater stocks by 2050 (compared to scenario 3)?

General questions

34. Why do you think it is important to examine water, land and energy resources together? Which connections between the resources seem particularly important for California?
35. Why is it important to look at not only the annual net change to groundwater stocks but also to the cumulative use of groundwater stocks over time?
36. Do you find the animated Sankey diagrams understandable, and effective in conveying messages about changes in resource flows?
37. Did you find Foreseer easy to use? Note any stages where you got stuck and were not sure how to continue. Can you think of any improvements to the tool and the web interface?
38. Can you think of any weaknesses and uncertainties in the analysis given by the Foreseer tool?
39. Can you think of any other scenarios that would be interesting to explore using the Foreseer tool? If so, what other user inputs would be needed to investigate these scenarios?
40. What are two things you've learned by using Foreseer? How far has this exercise helped you to understand the consequences of resource use?
41. You may have noticed there is a 4th diagram showing greenhouse gas emissions we haven't mentioned yet. What value do you think it adds to the assessment?