Finding Common Ground:

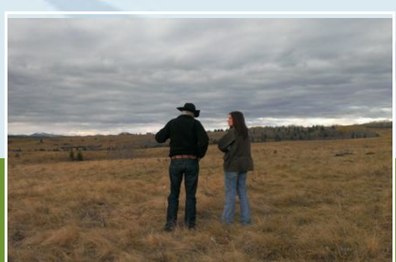
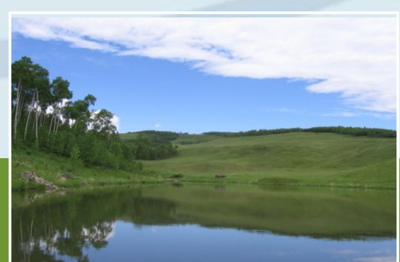
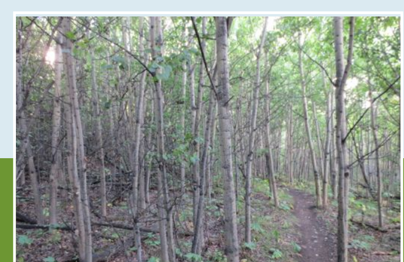
An Assessment of the Needs and Challenges in Integrating, Scoring and Web-Delivering ES Model Outputs

December 2013

Prepared by Rachelle Haddock and Guy Greenaway

MIISTAKIS INSTITUTE

APPENDICES

Prepared for:

The ABMI Ecosystem Services Assessment for Environmental Innovation and Competitiveness Project

Finding Common Ground:

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Appendices

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APPENDIX 1: PRELIMINARY USER NEEDS SCOPING QUESTIONS

1) How, in general, do you see the products of this project being used to support resource management decisions?

2) What do you hope the project's web portal would provide for users? Who do you think those users would be?

3) What would you see as the role of an ES score card for rangeland management? Who do you think would use it?

APPENDIX 2: ESA MODELLER NEEDS ASSESSMENT INTERVIEW QUESTIONS

QUESTIONS FOR MODELLERS

November 2013

Preamble

As you know, the Miistakis Institute has been working on three tasks related to the Ecosystem Services Assessment project; namely, an *ES Score Card* methodology, a *Web-based Portal* to facilitate serving the modelling outputs, and a *User Needs Assessment* to inform and assist the development of the score card and portal.

Though still at a conceptual level, the score card and the portal can be thought of as follows. The score card will be a mechanism for integrating outputs from the five models, providing a standardized structure to represent, weight, score and ultimately manipulate the various model outputs based on a user's need. The portal will provide a web-based system to 'animate' the score card, providing internet accessibility, user interactivity, and an unsupervised opportunity for users to explore scenarios.

As part of our *User Needs Assessment* work, Miistakis needs to connect with each of the project's modellers to get detailed information about the intended outputs and function of each ESA Project model.

We have divided the questions into the following categories:

- Integration with Other Models
- Data Inputs and Access
- Measurement and Valuation
- Interactivity
- Web Interface and Delivery
- Scale
- Scoring and Web Delivery Functionality
- Other Resources

Questions

<u>Model Overview</u>

- Provide an overview of the ecosystem service model.

APPENDIX 3: ESA MODELLER NEEDS ASSESSMENT INTERVIEW RESPONSES

Integration with Other Models

The following preamble was provided to each ESA Project modeller in advance of the "Integration with Other Models" questions, below:

> *"Preamble: Each ES model focuses on a specific ecosystem service. One characteristic which the User Needs Assessment's initial scoping identified as important was the ability for the models to provide an amalgamated representation of ecosystem services from a given landscape. Given that:"*

Q: Have you explored how your model could integrate with the other ESA project models?

Model	Response
Biodiversity Intactness	Integration with other ESA project models has not really been explored. The BIM explores the function of land cover more than anything else, and it responds to changes in land use or land management practices. BIM doesn't really lend itself to integration with the other ESA project models very well except when talking about different input land covers that are shared with the other models.
Biomass	Yes, but less so than we have explored integration for the water model. There are certain ways that it could be explored, such as in terms of the outputs tell a story for the ecosystem service, but I think there is potential to link the outputs for the biomass model that have more of a temporal component (e.g., forest management activities). For instance, we could look at what was harvested over the last number of years and how that output could be input into the water model. If there is a change in a land use we could explore how the spatial distribution of those changes affect water quality. The integration of the models offers an interesting dynamic: how could the output of one model be the input to another? What sequence might make sense to run the models and is there any back and forth between the models? There is a clear link between the biomass and the water models and the rangeland and water models. This link doesn't exist for the biomass and rangeland models as they are addressing different land bases (green vs. white zones).
Pollination	At present it has not been explored how the model could integrate with the other ESA project models. Pollination depends on land cover arrangements, and it responds to changes in land cover to create or reduce bee habitat. The change in land cover is the main driver in this model although there is a

	possibility that canola management may affect other ES (e.g., increased use of fertilizer could lead to decreased water quality). However, at present there is not a straight-forward way of integrating management for another ES with pollination. The rangeland production model is currently not integrated with the pollination model however there is overlap between the two (i.e., land good for producing forage is often good for producing pollinators). However, good forage habitat will only lead to improved pollination if crops (canola) are nearby. It's also possible for a parameter (say, grazing intensity) to impact both rangeland production and pollinator abundance, but we don't have the data to support the grazing-pollinator relationship. Basically, there are links between these two models but there is a lack of data to explore the integration.
Rangeland	Integrating the rangeland model with the other ESA project models has been explored including the idea of all projects using similar inputs. It was proposed that all of the models would use NetLogo for model delivery on-line, however the CENTURY model doesn't translate easily into this platform. Another place for integration lies in considering land use change across all of the models, although this hasn't been considered by all of the modellers. The models could also be linked spatially.

Q: Do certain of the other models lend themselves to integration with your model better than others? If yes, please explain.

Model	Response
Biodiversity Intactness	First, the models should be able to run on the same platform using the same input data (like using the same land cover layers), so multiple models can be run simultaneously in the same interface. This is definitely a goal and should be achievable as all of the modellers have been using the same input data. However, the main constraint will be computing power issues to run a few complicated models at once. The second form of integration would be how changes/management practices are coded into one model (e.g., water model) would impact other models. Another similar way this could happen is if we created a land use change model (so that a management action could consist of turning a patch of cropland into a patch of grassland), which would have impacts on any model using land cover type as an input. This type of integration is a bit less clear and might be a "next step" after the models are completed and in working order.
Biomass	The integration is better between the water and biomass models. There is

	less integration with the rangeland model and pollination model as they are focused on agricultural land. However we could explore how forest management affects pollination services if key forest areas provide pollination services- this may link into the pollination model.
Pollination	See previous question.
Rangeland	The biodiversity intactness and water models lend themselves to integration with the rangeland model. The biodiversity intactness and water purification models are spatially linked to the rangeland model. There may be integration potential with the pollination model.
Water Purification	The rangeland model lends itself to integration as certain land management practices (e.g., fencing cattle out of streams/riparian areas) are linked to water purification. However, the water purification model is not capable of modelling implications of changes in land/cattle management. Various management practices might be driving change that could be relevant to the water model. The water purification model might also have relevant inputs to the rangeland model.

Q: How do you see the outputs of your model integrating with outputs from the other models? Please provide both what you anticipate, and what you would desire.

Model	Response
Biodiversity Intactness	Biodiversity is another indicator of what is happening on the landscape, and it is not an ecosystem service. We are not applying any value to biodiversity intactness other than its intrinsic value (i.e., there is no dollar value implied). Other ecosystem services would drive decision-making from an economic perspective. Biodiversity is measured on a different axis than the ecosystem services, so what we'll really be showing is how/whether ecosystem services and biodiversity are correlated, or where trade-offs are occurring (e.g., you can have a lot of forage production and pollination value but that might lead to lower biodiversity and water quality).
Biomass	In terms of anticipated integration, there are lots of opportunities to work at the output level and link outputs from all models into a score card to tell a broader story about what is happening on the landscape. Hard integration (or interactivity between the models) is a complex analytical undertaking. With regard to what is desirable, exploring the extent that outputs could become inputs to other models would be a good first step. This applies to both the biomass and water model. They are all designed to answer different questions and it is hard to merge them all together. However, we can ask what components of each model are relevant to the other models. Generic integration (something feeding into each model in terms of inputs and outputs) is desirable.

Pollination	Uncultivated land in agricultural areas provides habitat for pollinators. The output value from the pollination model is the dollar value of the increased canola yield owing to the pollinators. The uncultivated land that provides bee nesting habitat will contribute to other ES such as carbon sequestration and water purification. So the "integration" of outputs is more about accounting for the multiple services (and their values) generated by a parcel of land.
Rangeland	For any given land base you can give a value on rangelands for carbon storage, forage production, biodiversity and water purification, so you can ask questions about how ecosystem service provision changes across the province. The rangeland model is comprised of two models (forage production and carbon storage). These two models are easily integrated as there will be trade-offs between carbon storage and forage production. It is not obvious how the pollination model outputs would integrate with the rangeland model, but they could link together because they both focus on a similar landscape. However, it is not certain how varied forage production or varied carbon storage would link to pollination. The actual land use could be the link between the rangeland and pollination models.
Water Purification	It all depends on how all of these models come together. If we are focusing on outputs, the water model produces an outputs map of supply where pollutants come from and where they travel. It is uncertain how to integrate this with outputs from the other models. The outputs from the water model could be input into other models such as the rangeland or biomass models. Further, different water quality scenarios could be linked (e.g., using outputs of biomass model as inputs for the water model). From a score card or web portal perspective, the integration of the models (each presenting outputs from a mapping perspective on ES) could collectively tell a story. I am not certain whether they need to be integrated into one common output.

Data Inputs and Access

Preamble: Much of the potential user interactivity and potential scope of ES scoring is determined up front by characteristics of the input data, including data access and confidence measures. Given that:

Q: Which are the primary data sets required as inputs to your model?

Model	**Response**
Biodiversity Intactness	There are two data sets: the ABMI vegetation layer and the wall-to-wall human footprint layer. The publicly available ABMI vegetation layer (on the

	ABMI website) is also supplemented with some additional information from forestry companies (AVI data) and a few other sources.
Biomass	The growth assumption in the model is based on forest yield curves and key data on forest stand age and strata. A lot of the data comes from ABMI's enhanced vegetation land cover layer. It has proprietary information owned by forest companies but ABMI has it and it is built into the model. The model also contains information on mills and forestry management. This information is freely available on-line through searching for data on mills, annual allowable cuts, Forest Management Agreement (FMA) holders' websites or forest management plans.
Pollination	There are three main spatial data sets: 1) the ABMI wall-to-wall vegetation map, 2) the ABMI wall-to-wall human footprint map and 3) the Agricultural Canada annual crop map. The crop map covers agricultural regions throughout Canada and includes crop types to a 56m resolution. By combining these data sets the model can find the small pockets of uncultivated land (using the ABMI human footprint layer) adjacent to and within canola fields. In addition to these data sets, statistical relationships (between land cover and bee abundance and bee abundance and crop yields) derived from the literature were used to create a preliminary model. A researcher from University of Alberta will look at more detailed pollinator analysis starting next summer. The outcomes of this research will add more detailed statistical relationships to the model. This research could look at managed bees and different canola management practices (organic, conventional, GM), as well as providing different relationships by region (northern, central, and southern AB).
Rangeland	AGRISID soil information and ClimateWNA are the inputs to the model. There are also parameters within the model that have been determined based on previous uses or the literature.
Water Purification	There are a number of data sets. All of the data is spatial data. Primary data sets include DEM information (ABMI land cover data layer, precipitation layer and human footprint layer). All of these data are spatially referenced and mapped. The model uses climate station data pulled in largely for calibrating the model. It is contained spatially through point-based data. Other key variables are manipulated by the user including information on sediment, P and N loading. The initial settings are supported by existing research, but it is structured to be manipulated. The relationships are related to land cover and are parameterized based on data from the literature. Those are the levers that can be pulled. Functioning in the model is dependent on statistical relationships regarding how water flows across the landscape.

Q: Where will the input data for your model reside?

- Are those data publicly available?
- How will users access those data?

Model	Response
Biodiversity Intactness	The input data reside on the web. The vegetation layer is enhanced compared to what is on website as it contains some proprietary information from the forestry sector. The enhanced layer is not publicly available at this time but we are hoping that it will be soon. The other data for BIM are statistical equations and ABMI's species monitoring data (raw species data are also publicly available on the web, but the equations are not).
Biomass	The biomass model will reside in a GIS database. It has raw data and the files are pulled from a specific directory of pre-processed data. Some of the data is publicly available and some is not. The forest growth yield curves are publicly available; however the stand age/strata (proprietary information) are built into ABMI's land cover layer. It is uncertain if the proprietary nature of the data is an issue if all we present to the public are model outputs that cannot be linked back to the proprietary data.
Pollination	The input data from both ABMI and Agriculture Canada are available publicly and users can access the data on-line.
Rangeland	The input data are publicly available data and they are available on-line. Both data sets require pre-processing.
Water Purification	The data is stored in two ways- spatially and in a GIS database. The information is processed into a form that the model can draw on. The processed information is stored in a file directory accessible to the model. Some of the data is publicly available and some of the data is not. The climate station data isn't publicly available but likely doesn't need to be accessed by the user. Statistical relationships (P and N loading rates) are not currently available but will be in the future- those will be levers that can be adjusted by the user.

Q: Is there capability for users to upload their own data sets, or identify other data sets to incorporate into the model?

Model	Response
Biodiversity Intactness	No.
Biomass	Assuming the user is an FMA holder, they could identify key loading points within the FMA which would drive adjustments to the model components that capture mill delivery costs. The model could relate to lowest cost route from identified points. In terms of uploading data, the portal could be

	structured to allow an individual mill or collection of mills to input updated information on their production and costs.
Pollination	At present, there is no capability for users to upload their own data sets, or identify other data sets to incorporate into the model. However, there is potential for the user to change pollinator management actions and observe the resulting changes in crop yields (e.g., look at trade-offs between decreased pesticide use and increased pollinator abundance on crop yields). Most of the users of the model are not GIS specialists however modellers could do some one-off testing with organizations such as municipalities and deliberately manipulate the model to explore different scenarios (e.g. ,by creating different input land cover maps).
Rangeland	This capability does not exist. However, it would be helpful for users to explore different land usage scenarios and how the outputs will be altered (e.g., low- vs. high intensity grazing). This could be done by providing outputs from the model exploring these scenarios and then users could specify the changes in land usage and get relevant outputs.
Water Purification	I think that there is. The model can input various data and the data need to be structured appropriately for the model to read. The functionality to allow the user to upload their data in a format to be read by the model depends on the resolution of their data. This functionality will require careful programming on the web development side in addition to key criteria for which a user maintains responsibility. There are opportunities to do processing behind the scenes by uploading a standard data set and carrying out pre-programmed processing. There is also an opportunity to have the user upload information and save it into a file on a directory that the model can access.

Q: How does your model recognize/represent variation in confidence based on quality of input data?

Model	Response
Biodiversity Intactness	This is one of ABMI's ongoing challenges: how to communicate uncertainty about the data. We are confident about land cover data but the species abundance versus human footprint equation is fraught with uncertainty. It is highly variable dependent on the species and the data sets aren't as robust was we would like, especially for less common species for which we have less monitoring data. This is an ongoing struggle.
Biomass	This is similar to the water model in that we recognize that there is uncertainty and variability in the input data (e.g., stand age and strata data) but there isn't much we can do about it, aside from acquiring updated or better spatial data layers. The key inputs (e.g., wood product prices,

	carbon prices, costs, inputs, mill production, etc.) can be adjusted by sliders or key inputs to explore or adjust confidence around data layers.
Pollination	The land cover data are of a consistent quality across Alberta; the variation would be due to uncertainty in the land cover-pollinator abundance and/or pollinator-yield equations. Currently, this uncertainty isn't included in the model. One way to convey the variation in confidence would be to run multiple analyses with minimum and maximum values to convey the upper and lower bounds of pollinator value. It is very challenging to clearly communicate uncertainty in maps as the visualization is difficult.
Rangeland	The model does not do this. There are potential sources of error in the AGRASID and the climate WNA data, and there are also many other sources of error in the case of misparameterization or processes not represented. These are limitations of models. That being said, CENTURY has been used hundreds of times and has been vetted in peer-reviewed literature. It would be helpful to do a validation exercise to see how the outputs compare to field measurements. However, it would be difficult to use the field measurements to link back to errors in the input data; at a certain point you can't encapsulate the complexity.
Water Purification	This varies depending on the data. Some of the information (e.g., precipitation, land cover) is taken at face value. We can look at variation in information and adjust the data layer. And, we can manipulate how that might vary over time. The loading rates for P, N and sediment are based on the relationships in the literature and they certainly possess some uncertainty. Sediment, P, and N are designed to be manipulated via sliders or levers and this allows users to change the assumptions about what is realistic or run scenarios to capture various levels of confidence or uncertainty associated with a particular assumption.

Measurement and Valuation

Preamble: At the heart of each of the ES models is a distinct philosophy and approach related to ES measurement and valuation. Each will consider the questions of supply vs. demand, non-monetization vs. monetization, monetization vs. commodification, total ES vs. change in ES, and contribution to human well-being in a distinct way. Methodologically, each model may use revealed-preference, stated-preference, and/or cost-based approaches. Given that:

Q: In a general sense, how does your model differentiate between modelling ecosystem function and modelling ecosystem service provision?

Model	Response
Biodiversity	None of the Measurement and Valuation questions apply to the BIM model.

Intactness	Biodiversity in and of itself is not an ecosystem service. It has intrinsic value and we will not be applying any economic value to it. It is more or less an indicator or "tag-along" statistic to go along with the other ecosystem services. BIM provides another index to measure and offers a comparative approach. It outputs a numeric measure that is quantitative however there is no dollar value or trading value attached to it. If a biodiversity offset system were created, the costs related to buying a piece of land or creating habitat could represent the dollar value associated with maintaining or producing a given amount of "biodiversity intactness units."
Biomass	This is similar to the water model in that the function is captured by the growth/yield curves and carbon yield curves for different carbon stocks (for above- & below-ground biomass, soil biomass all tied to stand age – have developed relationships to capture this). The ecosystem function that is captured is the forest growth and we are translating that into key ecosystem service provision. As the forest grows we have more volume and that is converted to timber production through harvesting activities, and the stock or sequestration of carbon based on changes in the forest condition.
Pollination	The ecosystem function modeled is pollinator presence/abundance and this is linked to where bees are produced and canola is grown. The model starts with canola fields and only looks at areas surrounding canola fields where bee habitat exists. The "function" would be pollinator presence/abundance, and the "service/value" would be pollination of cash crops. The model only generates pollinator abundance for canola fields, so it doesn't really capture any "ecosystem function" that is not also providing a service/value.
Rangeland	The rangeland model lies heavily in spectrum of ecosystem function. The CENTURY model was not built for ecosystem services. It is a process-based ecosystem model; dollar amounts will be attached to model outputs.
Water Purification	The function of the ecosystem is generating the supply or provision of the ES. Practically function is represented in the mechanics of the model. Water is flowing across the landscape and picking up/dropping off sediment, P and N. The collective nature of that function generates some relationships that we are equating to the provision of an ES. Water quality at a given location is a function captured by rules across the landscape. The rules capture emergent properties that we equate to ES provision. The provision (or supply) of ES is considered the total potential flow of ES, what actually translates into an ES depends on demand (i.e., is the potential being utilized by someone?).

Q: How does your model represent and juxtapose supply of ecosystem services and demand for ecosystem services?

- [Another way to consider this is, how does your model represent to whom ES value is delivered, and how does it represent who is augmenting/decreasing ES value?]

Model	Response
Biodiversity Intactness	N/A
Biomass	The supply is the direct result of the forest growth process and directly linked to timber production and carbon sequestration. In comparison to the water model, supply and demand are more integrated although this is not dynamically represented but it is captured by mills' production capacity and annual allowable cut. So, we are assuming that the demand for timber production is driven by that and then that drives harvesting activities and filling the mills. The demand for carbon is not currently captured in the mill but that moderates supply and that changes under the different forest conditions.
Pollination	The supply that is being modeled is source patches for pollinators in uncultivated areas adjacent to canola fields. The demand for this ES (pollination) is from canola producers. The model represents this by exploring the link between pollinators and increased canola yields.
Rangeland	Currently the model has no capacity for feedback for an increase in market value of carbon which may make land managers apply practices that would increase the carbon on their land. The only way supply and demand affects the model is that if the demand for carbon and forage production is high then our multiplier to create a dollar outcome will change. There is potential for changes in market value to affect land use but that will be better addressed/integrated in other models.
Water Purification	Currently the model is exclusively focused on supply. We do capture values but they are included in a general sense to document the value of ES potential. The model has been designed with this specific issue in mind and it is the focal point for the development of the model. We are focusing on making sure we can model supply in a way that we can explain and spatially link supply to demand. The model functions in a way that tracks movement across the landscape and delineate to a specific location. At any point on the landscape we can explore the amount of pollutant present and how it has been supplied by various parcels. With regard to next steps, we can look at who is at that end location and how are they benefiting from water purification (e.g., water treatment facility could explore how supply/cost affected by water quality changes upstream).

Q: In quantifying the ecosystem service, which of the approaches does your model use:

- Comparative
  - [*a numeric measure is produced allowing for quantitative comparison between model runs*]
- Monetization
  - [*a dollar value is assigned, but not one that is usable for commodifying and exchanging the ecosystem service*]
- Market or exchange value
  - [*a dollar value is assigned that is usable for the sale of the ecosystem service in a defined market*]
- Other

Model	Response
Biodiversity Intactness	N/A
Biomass	The model uses market and exchange values as approaches for both the timber production and carbon values. We are drawing on the voluntary and various carbon markets to estimate carbon price although we could also consider a social price on carbon (monetization).
Pollination	The model represents a combination of monetization and market or exchange value, depending on the landscape context/ownership situation. From a monetization perspective, the economic value of maintaining/creating pollinator habitat is the increased yield owing to native pollinators. Each piece of land gets a dollar value for what it contributes to improved yields. Often the uncultivated land and adjacent canola fields are owned by the same person/company, so there is no exchange; instead the land owner would be able to see how increasing pollinator habitat adjacent to/within a canola field (e.g., uncultivated patches, hedgerows) could increase overall profits. However, there is the possibility that a land owner with uncultivated land/bee habitat could benefit an adjacent canola field with a different owner. This could lead to direct payments to maintain pollinator habitat between one possible buyer and one possible seller (not a traditional market).
Rangeland	The model uses market or exchange value.
Water Purification	We are utilizing a comparative approach right now. We are more focused on biophysical variables and looking at how biophysical components change. There is also an evaluation component through monetization but the real driving force at this stage is a comparative approach with the anticipation that the demand side will really be market exchange and monetization. This is very specific and will have a bigger role in follow-up phases of work.

Q: If your model quantifies the ecosystem service using a monetization or market/exchange approach, which best describes your valuation method

- *(from Faber et al 2006):*
  - Replacement cost:
    - *The loss of a natural system service is evaluated in terms of what it would cost to replace that service (e.g., tertiary treatment values of wetlands if the cost of replacement is less than the value society places on tertiary treatment).*
  - Avoidance cost:
    - *A service is valued on the basis of costs avoided, or of the extent to which it allows the avoidance of costly averting behaviors, including mitigation (e.g., clean water reduces costly incidents of diarrhea).*
  - Travel cost:
    - *Valuations of site-based amenities are implied by the costs people incur to enjoy them (e.g., cleaner recreational lakes).*
  - Market methods:
    - *Valuations are directly obtained from what people must be willing to pay for the service or good (e.g., timber harvest).*
  - Hedonic methods:
    - *The value of a service is implied by what people will be willing to pay for the service through purchases in related markets, such as housing markets (e.g., open-space amenities).*
  - Production approaches:
    - *Service values are assigned from the impacts of those services on economic out- puts (e.g., increased shrimp yields from increased area of wetlands).*
  - Contingent valuation:
    - *People are directly asked their willingness to pay or accept compensation for some change in ecological service (e.g., willingness to pay for cleaner air).*
  - Conjoint analysis:
    - *People are asked to choose or rank different service scenarios or ecological conditions that differ in the mix of those conditions (e.g., choosing between wetlands scenarios with differing levels of flood protection and fishery yields).*

Model	**Response**
Biodiversity Intactness	N/A
Biomass	Market methods
Pollination	The model takes a production approach where pollinators are one input and this is tied to canola prices and the increased yield owing to wild pollinators. The modellers have not looked at replacement cost yet, but this could be

	used to explore a scenario involving the disappearance of wild bees, and what it would cost to use managed bees in their stead.
Rangeland	The model uses replacement cost for forage production, and market methods for carbon storage.
Water Purification	There are so many uses of water and it is challenging to start thinking about demand. Right now we are using avoidance cost. Moving forward we would need to utilize most of these approaches to properly capture all values of water purification. Practically, we will focus on avoidance and production function approaches to tie production costs of drinking water to the ecosystem service.

Interactivity

Preamble: The scoring and web delivery of the ES model outputs assumes that a given user will be able to exercise some unsupervised control (i.e., not requiring a modeller to operate the model) over the model, interactively setting up and running different arrangements of the model. Given that:

Q: Which are the key parameters of your model which a user can (should) manipulate?

Model	Response
Biodiversity Intactness	There are not a lot of key parameters which a user can manipulate. The user can look at the changes in biodiversity intactness owing to different land cover functions.
Biomass	Right now the user can manipulate input costs, wood product prices and carbon prices, so these are the key variables that can be adjusted. Some other things we could explore are adjustments in yield parameterization, but for right now the things that can be manipulated are related to the production side of things.
Pollination	The key parameter that a user can manipulate is canola price. The other parameter a user could change is landscape-bee abundance relationships. It is currently uncertain how to incorporate hedgerow creation into the model. Such a management action will also affect other models like water quality or carbon storage, and it is also uncertain how to incorporate these interactions into the model. Ultimately, the end goal is to show the interaction between two levers of pollinator-friendly management and changing canola prices. The model does not attempt to be prescriptive but explores the benefits/costs of pollinator-friendly management.
Rangeland	This is uncharted territory, however it could be led by what scenarios the

	modellers anticipate happening. It has been a challenge to incorporate changes in management into the model because very little is known about the effects of grazing which is the major management tool on native grassland. We can model those outputs but whether those actually reflect the whole contingency of responses that might occur is unknown. Secondly, this is a controversial area for range management/science. There are the two main scenarios that have been developed: changes in grazing intensity and changes in land use. There will definitely be outputs for changes in grazing intensity – something that people have wanted is comparison of tame pasture (non-native agronomic species for production) versus the ecosystem services provided by native grassland. Extensive consideration has been given to management and scenarios. We can compare that to a land use where there is no provision of ecosystem services such as a canola field (relevant to changes in land use). It is not known how relevant that will be for carbon storage (a canola field will store carbon). Perhaps it is possible to use some values from literature to estimate carbon storage in a crop setting and this could inform discussion about changes in broad land use categories. Specific changes in grazing management practices are tough to model as the knowledge does not exist yet and it is highly controversial.
Water Purification	The key parameters of loading rates of P, N and sediment are ones that can be manipulated for different purposes. The user could also run scenario analyses (e.g., land use is changing (remaining as agricultural land but changing tillage practice) and that may be a driver for adjusting those values.

Q: Does your model allow the user to articulate and test scenarios against a "Business As Usual" baseline? If yes, please explain.

Model	Response
Biodiversity Intactness	The user can test different land cover functions against a baseline to explore how it would affect biodiversity.
Biomass	Yes, again, based on those key assumptions in terms of input prices. There are some things we could look at such as changes in annual allowable cut for different users and exploring those kinds of scenarios.
Pollination	The model does not do this because the model does not incorporate all potential management practices (e.g., organic, GM, traditional canola crops). The local variation in canola is not mapped. The model presents a "Business as Usual" baseline but the levers can reflect local variation.

Rangeland	The model uses as "Business as Usual" baseline where users can change land use or grazing intensity.
Water Purification	Yes, we have a baseline condition of land cover types driven by land cover or management practices. When you make changes in land management practices this requires changing assumptions around loading rates from your BAU baseline. The user can conceive alternatives, adjust sliders or levers and run the model to explore how supply changes.

Q: Does your model allow the user to define and test trade-offs between scenarios in terms of ES degradation / augmentation? If yes, please explain.

Model	Response
Biodiversity Intactness	The model does not really do this without creating different landscape scenarios for input. Scenario modelling is one of the main goals for the final phase of the project when all of the models are completed and we can begin to deploy them to address specific questions. However, scenario modelling is likely too complicated for most users, at least via an interactive web portal. Users with GIS/modelling backgrounds (e.g., Government of Alberta, municipal governments) could download models to run their own scenarios, though.
Biomass	Yes, and this relates to previous question: it just depends how you structure that sort of a scenario. For the most part we are not focusing in on degradation specifically. We are focused more on changing production values and linking that to the carbon. There could be implications for carbon from over-harvesting.
Pollination	The model does not do this. The user can change the land cover arrangement and view the resulting change in crop yield. Users (such as municipal districts or other bodies) could work directly with the modellers to engage the model in testing different scenarios in terms of pollination or other ecosystem service degradation/augmentation however the average user will not be able to do so.
Rangeland	In a broad sense this is possible by looking at target levels of ES provision (outputs) and working backwards from there to discern what needs to be done to realize these outputs, but this is not possible in a quantitative sense.
Water Purification	Everything in the model is tied to land cover, so the user could create and test scenarios in terms of ES degradation/augmentation by changing land cover.

Q: Does your model allow the user to identify and monitor thresholds? If yes, please explain.

Model	Response
Biodiversity Intactness	This is not relevant because biodiversity intactness represents an average of different species responses. An individual species might have a sharp response at a threshold level of footprint, but because we are averaging across an assemblage of hundreds of species, sharp breaks get muted. The model could potentially pull out species of interest such as endangered species, keystone species or game species, but this has not been done yet.
Biomass	The model doesn't really do this right now but there are opportunities to explore thresholds.
Pollination	The model doesn't really do this. The bee abundance/canola yield statistical relationship is a saturating curve and there is a threshold were additional pollinators do not lead to increased crop yields. The model does help the user understand how much pollinator habitat they need. The model helps the user find the "sweet spot" where pollinator-friendly management practices lead to increased yields most effectively.
Rangeland	The model does not currently allow for this.
Water Purification	At this stage, thresholds haven't been the key driver. There are probably ways it could be used (e.g., think about extremes in different variables and how that drives changes to the outputs), but the model is not explicitly designed to identify or monitor thresholds. There is possibility that it could be a focus for future work.

Web Interface and Delivery

Preamble: Though each ES model has complex functionality, the web delivery of a given model usually represents a subset of that functionality. This is mostly due to limitations associated with users' modelling/software knowledge, transmitting large data sets, and simplified program interfaces. These limitations must be explicitly planned for in order for web applications to successfully draw information from the models.

Q: Are you aware of how your model interfaces with web delivery programs? If so, can you describe any pertinent challenges / opportunities?

Model	Response
Biodiversity Intactness	ABMI produced the biodiversity intactness metric in R which can be translated into NetLogo. NetLogo can be run in a web browser. The big challenge is the resolution of data (2m declines) and how we incorporate

	that into model.
Biomass	These challenges/opportunities are similar to the water model. Both are coded in NetLogo which has challenges and advantages. The data is a bit easier to process and collect and there is a lot of pre-processing that can be done.
Pollination	The model will be delivered on NetLogo platform which can be run in a web browser. All of the ABMI ES models were intended to run on a NetLogo platform however it is uncertain if this will be possible.
Rangeland	The rangeland model output can be represented in a map in ArcGIS. It is uncertain if the web delivery of the model would be structured around a NetLogo platform. There is a huge variety in terms of complexity and simplification of web data, and it is uncertain what others are thinking with regard to how to approach web delivery.
Water Purification	The model is hosted in NetLogo which is a Java-based program which lends itself to web delivery in a pretty straight-forward fashion. I am uncertain about the integration of the spatial data: does this have to happen on-the-fly based upon user input? This is an interesting challenge. Depending on where the web portal goes, the user could 1) upload data or 2) manipulate pre-processed information that sits on the web portal. The second option may be more realistic in the short-term. Also, there could be an opportunity to get more refined data (e.g., alternate precipitation data); this could also be a challenge.

Q: Are you aware of any challenges related to web programs drawing from the data sets which inform your model?

Model	Response
Biodiversity Intactness	No comments.
Biomass	I am not aware of any but that doesn't mean there aren't any.
Pollination	No comments.
Rangeland	No, the data sets wouldn't be uploaded on-line as the model will not be available on-line so this is not an issue. All of the input data are publicly available and the CENTURY model is open-source.
Water Purification	I am not aware of any but that doesn't mean there aren't any.

Q: Do you have a sense of any of the interactivity functions described above (scenario testing, trade-offs, and thresholds) not being translatable to a web-delivered format?

Model	Response
Biodiversity Intactness	Interactivity wouldn't work well in a web-delivery format although we could deliberately manipulate the model for specific scenarios. There is a possibility to include this in the future but it depends on the statistical relationships that ABMI has developed between human footprint and species abundances. You might be able to relate biodiversity intactness to grazing intensity or range condition, but we don't have a statistical model for that yet. If we did (or if we do in the future), it would integrate well with the management levers for the rangeland model; there is a possibility to develop this in the future.
Biomass	All of these functions should be feasible.
Pollination	No comments.
Rangeland	Given the computing power requirements of CENTURY the rangeland model can't be presented on-line. If the outputs of the model are shared on a NetLogo platform, one of the issues with NetLogo is that it only represents a small area of the province at once just for the outputs.
Water Purification	My sense is that it should all be easily converted given that NetLogo has sliders to use as key drivers. It is a matter of programming those sliders in a web –based format with model in the background.

Q: Have you undertaken / are you planning to undertake any pre-processing or tiling of model outputs that could speed web-based access/presentation of the model outputs?

- *(pre-set geographic sub-regions, pre-set scenario parameters, etc.)*

Model	Response
Biodiversity Intactness	ABMI is creating a "queriable" map (all data will be pre-run) that can report back pre-calculated metrics. This will be done through ABMI's website and not out of ES project's website. Other people are already working on this. For the actual model, the model outputs won't be tiled but some of input data would be; the fine-resolution data would be pre-summarized at quarter section scale.
Biomass	The outputs definitely need to be tiled to improve speed and this is being undertaken as we speak.
Pollination	There is a possibility that pre-processing or tiling of model outputs would happen. ABMI is currently creating a new website, and this web portal will be nested nestled within it. Although the pollination model will have its own page, some of the pre-processing/tiling might fall under the rest of ABMI website where information will be pre-processed by the quarter section, and the pollination model might piggy-back on the architecture of the new ABMI website. The "main" ABMI data portal would be different though; it's

	going to be a "queriable" map where users can zoom into and select a chunk of Alberta, and it would report back some statistics for each selected quarter-section (land cover types, human footprint %, biodiversity intactness, etc., and possibly also some ES stats). In contrast, the ES page would actually hold (and run) the models themselves.
Rangeland	The rangeland model has broken efforts down to planning regions. The rangeland model outputs will be tiled in terms of land-use regions.
Water Purification	This one is tricky for the water model because the data is intense and it would have to be pre-processed. There is tiling in a sense but we are looking at it from a watershed-based perspective. The tiling has to be tied to the watershed level and it takes 20 to 30 minutes to run. This goes back to question of challenges – in this case computing time and web context are a challenge.

Spatial and Temporal Scale

Preamble: The numerous data sets which inform the project's ES models vary greatly in their spatial coarseness/fineness as well as their temporal resolution. Regardless of the ability to mathematically upscale fine data sets and downscale coarse data sets, the resultant mix will likely be applicable in a resource management context only at certain spatial scales. Similarly, confidence in model outputs will decrease with increased use of older data sets, and will likely decline the further into the future they project. Given that:

Q: At which spatial scales can your model operate?

- Parcel-specific (up to quarter section, 160ac)
- Local (e.g., section, township, municipality)
- Regional (e.g., basin, natural region, LUF region)
- Provincial (Alberta)
- Other

Model	Response
Biodiversity Intactness	Each quarter section has own value and the user can look at as many quarter sections as they want. The use of the model makes most sense at a local or regional level but could be done for all of Alberta. Because of statistical error/uncertainty, we don't have a great deal of confidence in the intactness at any single point/quarter-section, but our confidence goes up the larger the region we're looking at.
Biomass	The model can operate at both local and regional scales. We can also operate it at the provincial scale although we lose specificity- things get a bit muddied but it could be run. The model does not operate at a parcel-specific scale because data demands are too high and we are trying to

	balance landscape level information (spatial distribution) and allocation of wood, distribution of mills, etc. which is best optimized at a regional level.
Pollination	The pollination model works at the parcel-specific, local, and regional/basin scale.
Rangeland	The model can operate at the ten square kilometers or 1000 ha average scale or larger.
Water Purification	The water model uses two pre-processed models that pull information at a quarter-section level (parcel-specific). It samples human footprint and land cover at a fine resolution and converts it to a higher resolution while maintaining key information. At a coarser scale the information is inputted into a watershed model and the model operates at a regional kind of level but it is based on parcel-specific upscaling information. It could operate at a lower level but you need the watershed scale to process data for a local scale. It is optimized for a regional scale, but feasible to be done from parcel-specific to regional. We did run the model at a provincial scale but it was too coarse a scale to get valid outputs.

Q: For which spatial scale is your model optimized?

- Parcel-specific (up to quarter section, 160ac)
- Local (e.g., township, municipality)
- Regional (e.g., basin, LUF region)
- Provincial (Alberta)
- Other

Model	Response
Biodiversity Intactness	The spatial scale of the model is optimized at the local or regional or provincial scale. The broader the lens the more confident we are in the results. Running the scale at a provincial level could present computational challenges.
Biomass	Regional
Pollination	Parcel-specific or Local
Rangeland	The data cannot be reduced to a smaller scale than the AGRASID polygon ($10km^2$). It can be up-scaled from the polygon to a provincial scale.
Water Purification	Regional

Q: How does your model account for the currency (or lack of currency) of the input data sets?

Model	Response

Biodiversity Intactness	The currency is good. The human footprint layer is updated approximately every two years.
Biomass	All of the data sets are current.
Pollination	All of the data are current. ABMI updates the maps every two years. The model uses the 2010 human footprint layer and vegetation layer (updated every one- to two years), and the 2010 Ag Canada map (updated annually).
Rangeland	The soils data for native grassland soils doesn't change, however the agricultural soils information for tame pasture is lacking and the model is not going to include assumptions or estimates for tame pasture. An accurate representation for land use is difficult because ABMI's data set and the Agri-Food Canada data set have errors, discrepancies, and different categories. This is a simulation model (what is potential ecosystem services in the province). It doesn't prescribe what is happening on each parcel of land.
Water Purification	The data is as recent as we can get. It is ABMI data spanning from 2010 and 2012.

Q: How does your model accommodate and represent the decreasing temporal resolution as model projects go further into the future?

Model	Response
Biodiversity Intactness	The model presents a static snapshot in time on a given landscape. The model is not predictive of how the landscape will change over time. The error and uncertainty is driven by potential future landscapes in which we may or may not have confidence.
Biomass	Right now the model simulates a 50 year temporal resolution. The model captures this through a discounting process on the valuation side (net present value). In a sense we are accommodating decreasing certainty by discounting future values, but that is the extent of our efforts.
Pollination	The model does not accommodate and represent decreasing temporal resolution. Time scale effects are challenging to the model.
Rangeland	We do not know how climate might affect the provision of ecosystem services in the future as we don't know what future climate will be realized. However ClimateWNA uses sophisticated climate projections and this data is as good as anyone else has. The soil data isn't an issue as it is constant. It is not a goal of the model to approximate how land use will change.
Water Purification	The water model doesn't capture temporal resolution. It is an annually based process that simulates for a given set of conditions. Time is captured in an abstract sense: it looks at water flows over the course of year over a weekly time step. The model doesn't forecast long into the future and this is

	not much of a concern. Through scenarios and trade-offs users can explore future conditions but there is no formal temporal resolution.

Scoring and Web Delivery Functionality

Preamble: Each modeller has known that the project would include score card and web-delivery applications, and likely has formed ideas around how that might look for their particular model. Given that:

Q: What aspects of your model do you feel lend themselves well to being scored in an ecosystem services score card?

Model	Response
Biodiversity Intactness	The BIM lends itself well to being scored in an ES score card as intactness represents the difference between what is currently on the landscape and a baseline of no human footprint (i.e., how many of each species "should" be there compared to what IS there). It would be great to have the overall intactness score and then be able to tweak which species we pull out for different audiences or different regions. This could be valuable to different audiences (e.g., hunters, land managers, government biologists).
Biomass	Similar to the water model, the outputs can map production values in the carbon stock and the timber production value (measured either from a merchantable volume or dollar values based on spatial location that dynamically captures transportation cost). Those two outputs would lend themselves to a score card. You also have the standing stock of carbon and how that is changing over time; this would also be an interesting thing to capture.
Pollination	The link between pollinator supply and pollinator value lends itself well to being scored in an ES score card. The ES score card could be used to explore current pollinator value and potential pollinator value by looking at different management/pollinator scenarios. The ES score card could be used to show room for improvement in terms of environmental management and the farmer's bottom line.
Rangeland	The rangeland model is fluid across its outputs, score card and web portal functions. The model outputs are outputs, the score card is a site specific version of those outputs, and the web delivery involves exploring a scenario based on outputs in a web environment.
Water Purification	In terms of the score card there are biophysical functions that we can manipulate, and there are some interesting opportunities to look at a rating scale in a biophysical sense and how these things change in light of various scenarios. As a caveat, we have to have scenarios outlined in

	order to capture how things change, and we need a score/rating for the baseline and alternative scenarios. We could include percent change, increase/decrease, range of values, ten point scale, etc.

Q: What characteristics of your model, or of the ecosystem service you are modelling, would you most like to see reflected in an ecosystem services score card?

During the interviewing, respondents indicated confusion about the distinction between this and the previous question (i.e., between model 'aspects' and 'characteristics'), and the authors recognize the distinction was unclear. Respondents tended to provide a single synthesized answer, and this summary reflects their approach.

Q: What aspects of your model do you feel lend themselves well to being represented in a web-delivered format?

Again, during the interviewing, respondents indicated confusion about the distinction between this and the following question (i.e., between model 'aspects' and 'characteristics'), and the authors recognize the distinction was unclear. Respondents tended to provide a single synthesized answer, and this summary reflects their approach.

Q: What characteristics of your model, or of the ecosystem service you are modelling, would you most like to see reflected in a web-delivered format?

Model	Response
Biodiversity Intactness	We could potentially hand-pick ten species to explore how land use change affects their abundance in a web-delivered format. Or even have a check-list of a bunch of species, and a user could select which one(s) they want the model to report on. Again, this might be a computational challenge.
Biomass	Similar response to above- the outputs are map values at an interesting resolution that can easily stack on top of the other outputs to produce score card-related information. The outputs are the main driver.
Pollination	Similar to the ES score card, but incorporating information about crop rotations would be interesting (if the model can support this kind of input). At its most basic level, if a canola field only actually grow canola once every 4 years, the potential annual pollinator value is reduced by 75% compared to looking at just a snapshot of one year. So being able to choose the rotation year/how long a rotation is being used would lend itself to being represented in a web-delivered format, but this would require some additional work on the model.

Rangeland	The rangeland model is fluid across its outputs, score card and web portal functions. The model outputs are outputs, the score card is a site specific version of those outputs, and the web delivery involves exploring a scenario based on outputs in a web environment.
Water Purification	Is the intention for the user to be running models as opposed to a web output of models and interesting assessments (e.g., a score card with relative values across landscape)? The latter is a little easier to tackle in the sense that the outputs of the model can quantify sources of sediment, N and P and how they are spatially allocated across the landscape. You could link that with other models and their outputs in creating some sort of overlay to create a score card which could look at how each parcel of land is providing different services. From that context those outputs would lend themselves well to a web-delivered format. I am struggling with what the ultimate vision of a web portal would be: is its function for users to manipulate models and do their own thing with it? How is it different from a web-delivered score card that delivers outputs as results? It is useful to have a value tied to the score card as it becomes the formal integration of all the model outputs into an overarching ES assessment of a parcel of land. Each model could have outputs that feed into the score card which is easy to deliver in a web-based format.

Other Resources

Preamble: We recognize that you may already have articulated concepts that relate to these questions through existing web resources, comparable models, user guides, model summaries, etc. Given that:

Q: Do you have any other resources that you would like us to consult as we develop the ES score card and web-delivery structure?

Model	**Response**
Biodiversity Intactness	No.
Biomass	We have documentation on the model that could be helpful.
Pollination	No.
Rangeland	There is a document providing an overview of the rangeland model. Also, there is a lot information on the CENTURY model, the AGRASID and climate WNA data on-line.
Water Purification	We have some draft documentation on the model that may be a helpful resource for you.

References

Farber, S., R. Costanza, D. L. Childers, J. Erickson, K. Gross, M. Grove, C. S. Hopkinson, J. Kahn, S. Pincetl, A. Troy, P. Warren, and M. Wilson. 2006 Linking Ecology and Economics for Ecosystem Management: A Services-Based Approach with Illustrations from LTER Sites. *BioScience* 56:117-129

Appendix 3: Conventional economic valuation handout

The following was provided to respondents in the ESA Modeller Needs Assessment to support answering the question on ecosystem service quantification to ensure answers followed the same format and would be comparable.

Revealed-preference approaches

- Travel cost: Valuations of site-based amenities are implied by the costs people incur to enjoy them (e.g., cleaner recreational lakes).
- Market methods: Valuations are directly obtained from what people must be willing to pay for the service or good (e.g., timber harvest).
- Hedonic methods: The value of a service is implied by what people will be willing to pay for the service through purchases in related markets, such as housing markets (e.g., open-space amenities).
- Production approaches: Service values are assigned from the impacts of those services on economic out- puts (e.g., increased shrimp yields from increased area of wetlands).

Stated-preference approaches

- Contingent valuation: People are directly asked their willingness to pay or accept compensation for some change in ecological service (e.g., willingness to pay for cleaner air).
- Conjoint analysis: People are asked to choose or rank different service scenarios or ecological conditions that differ in the mix of those conditions (e.g., choosing between wetlands scenarios with differing levels of flood protection and fishery yields).

Cost-based approaches

- Replacement cost: The loss of a natural system service is evaluated in terms of what it would cost to replace that service (e.g., tertiary treatment values of wetlands if the cost of replacement is less than the value society places on tertiary treatment).
- Avoidance cost: A service is valued on the basis of costs avoided, or of the extent to which it allows the avoidance of costly averting behaviors, including mitigation (e.g., clean water reduces costly incidents of diarrhea).

From: Farber, S., R. Costanza, D. L. Childers, J. Erickson, K. Gross, M. Grove, C. S. Hopkinson, J. Kahn, S. Pincetl, A. Troy, P. Warren, and M. Wilson. 2006 Linking Ecology and Economics for Ecosystem Management: A Services-Based Approach with Illustrations from LTER Sites. *BioScience* 56:117-129 (Page 120)