4.

Spatial Implications of New Road Infrastructure for the Use of Land and Resources in Suriname: Land Use Scanner

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Introduction

Plans to develop road infrastructure to connect Suriname with Brazil have been on Suriname's policy agenda for several decades. These plans have been designed as a vital component of the country's strategy to diversify domestic energy supply by means of hydro-energy. The diversion of the waterflow of the Tapanahoni River and Jai Kreek, the so-called TapaJai Project, would contribute to the hydro-energy potentials of the Brokopondo storage lake in the north of the country and create the opportunity for the construction of additional small hydro-power stations in the forests south of the Brokopondo storage lake. To facilitate the construction of dams, canals, power plants and high voltage lines, roads are required to reach these construction sites from the north. In addition, the ambition to develop the port of Paramaribo as a transit port for northern Brazil has resulted in the plan to construct a connection between Paramaribo and

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the Brazilian border in the vicinity of Vier Gebroeders. It is Suriname's intention to realize a road corridor between Paramaribo and Manaus, a major industrial centre in the heart of Amazonia at the Amazon River.

So far the southern part of Suriname's interior has been inaccessible over land. The only types of transportation in the interior are small boats and small planes. Construction of a new road would open up the country's forest areas, increase accessibility of natural resources such as timber and mining products, and would seriously impact upon the livelihood of indigenous peoples, particularly those living along the Tapanahoni River in the very south of the country nearby the border with Brazil. The plans referred to above have not yet resulted in formal decisions regarding the construction of road infrastructure. Consequently, no strategic environmental assessment (SEA) has been made concerning potential impacts of such infrastructure works on the socio-economic and environmental conditions in the potential impact area.

This chapter investigates potential spatial implications of infrastructural development plans on land use in Suriname. The study is based on earlier investigations undertaken as contributions to a research project on the impacts of interventions in the south east of Suriname. See Molendijk et al. 2013; Jolly. et al. 2012 and Van Dijck 2013. Geographical information combined with advanced land use models play a crucial role in assessing potential spatial changes in land use and resource use resulting from these infrastructural plans. The implications of such interventions for people and the environment in the potential impact areas can be demonstrated by presenting potential impacts in maps. These maps have to be accessible to the local population in the impact areas and to others. Visualization of the outcomes of modelling exercises can support awareness of impacts which may subsequently contribute to optimisation of routing and choice of transport mode, and the development of policies in relation to these infrastructure proposals and plans.

In the context of this investigation the following issues are addressed: selection and construction of geographical data required for the assessment of spatial implications on land and resources; investigation into the potentials of land use modelling to assess spatial impacts; options to make the information available to a wider audience.

The chapter is organized as follows. The next section presents some reflections on land use modelling. The third section focuses on road construction and its impact on land use, as studied by using the Land Use Scanner and applying a scenario approach. Section four analyses current land use in Suriname on the basis of available data. The next section presents modelling outcomes regarding the location of the impact area. Section six deals with techniques to make the findings accessible to the public. Some final reflections are presented in the last section of this chapter.

Simulating the future

To model future developments, a set of maps has been constructed that displays information on population, biodiversity, qualities of the soils, current land use, physical infrastructure and other dimensions that are of significance to understand potential impacts of road construction in forested areas. These maps are essentially spatial databases that can be linked and combined by means of Geographical Information Systems (GIS) information. The collection of maps and the description of the relationships between these maps may be considered as a 'system' that can be used for simulating changes in map elements and relationships between these elements within the set of map layers. Scenarios may be developed and their impacts on 'the system' may be investigated.

Impact assessment studies of new road infrastructure commonly include geographical analyses and model applications following the classic example of Chomitz and Gray (1996). Different scenarios for impacts of a new road can be fed into the geographical system, and by running the model, we may calculate and assess possible consequences of different routings of the corridor.

Nearly all SEAs apply ex ante boundaries of the impact areas, in most cases related to the location of mountain ranges, wide rivers and national borders. This study, however, does not apply such ex ante boundaries and includes the surface of the whole country in the assessment of the potential spatial impact of a road. Indeed, potential transboundary impacts may be the object of a follow up research project.

Land use models are tools to support the analysis of the complex and dynamic relationship between causes and consequences of land use change (Verburg et al. 2004). Several types of such models exist, all with their own characteristics: static versus dynamic models, transformation versus allocation models, deterministic versus probabilistic models, sector specific versus integrated approaches and so on (Koomen and Stillwell 2007).

Land use models are based on a number of theories and methods. Koomen and Stillwell (2007) describe eight theoretical principles underpinning these models: economic theory, spatial interaction theory, cellular automata, statistical analysis, optimization techniques, rule base simulation, multi agent theory and micro simulation. Economic theory and rule based simulation are particularly significant in the study presented here.

Several elements from economic theory are particularly important for land use models: bid rent theory, discrete choice theory and the concepts of centripetal (agglomeration) and centrifugal (dispersion) forces that play a crucial role in the new economic geography put forward by, amongst others, Krugman (1998). The bid rent is the price competing land users are willing to pay for land, depending on accessibility of that area of land in terms of relative distance (Alonso 1964). The fundamental idea behind the discrete choice theory (Mc Fadden 1978) is the choice consumers have between two or more discrete mutually exclusive alternatives. It establishes the probability that a consumer or land user will choose one type of land use from a range of alternatives. It does not allow for multiple land-use changes at the same location. Agglomeration forces have been formalized in, amongst others, the cluster theory developed by Porter (1990 and 1998) which focuses on spatial aspects of allocation decisions: firms settle in the same area because of external economic advantages such as investment in infrastructure. Translated to land-use modelling as in our case study: the suitability for certain types of land use is strongly related to their current spatial distribution, because of these agglomeration forces. In rule-based simulation, known processes are imitated by feeding strict location-based rules into a model (Koomen and Stillwell 2007). This approach is particularly useful to represent physical processes that follow straightforward, deterministic cause effect chains and is, for example, used to link impact assessments to land use change models (Sheridan et al. 2007).

Road construction and impact on land use

Land Use Scanner

The Land Use Scanner is a model for analysing the effects of different scenarios on land use change. It has been applied extensively in policy-related studies including strategic environmental assessments (Koomen and Borsboom-van Beurden 2011; Koomen et al. 2011). Infrastructure development can be an important aspect of a scenario study and so are demographic growth and spatial policy options. The model is less suitable for predicting the exact location of a new road, but is very useful to project the effects of nearby new infrastructure for developments in built-up areas, agriculture, deforestation and maybe mining. The projection may take other relevant developments modelled in the scenarios also into account.

The Land Use Scanner has been developed to allocate future land use. The model is capable to (1) determine whether all future spatial demands can be satisfied simultaneously; (2) allocate and map spatial distributions with maximum suitability of land use types; and (3) help to evaluate the impact of resulting spatial distribution, for example by means of the accessibility indicator, explained below. Clearly, the model does not predict demographic growth or commodity prices.

In the model, possible land uses compete with one another as the outcome of a certain scenario, resulting in a map that indicates for each location on the map its most suitable type of land use. Agglomeration forces influence the spatial allocation decisions since: e.g. large-scale agriculture is likely to concentrate in areas that are already in use for agricultural purposes. Thus urban space or mining locations will not likely convert to agricultural land use. An example of a rule-based simulation in the model could for instance be the establishment of a high threshold value for the probability that the land use in official nature reserves will convert in the future into large scale agricultural land use.

The Land Use Scanner is developed in The Netherlands where land use is mainly influenced by spatial planning due to the high pressure on land, but the model has recently also been applied in other countries in Europe (Te Linde et al. 2011; Hoymann 2010). The software framework and allocation algorithms applied in the model are also used in the land-use model that is currently being applied by the European Commission in policy preparation studies (Lavalle et al. 2011). Investment decisions usually have a time horizon of several years in terms of project realisations and payback time. Therefore, the model usually calculates in a dynamic way plausible changes in land use in several time steps of 10 or 15 years. In our case study, the impacts of the construction of a new road have been calculated iteratively with time steps of one year or smaller. The suitability factors are classified as dynamic as they depend on the allocated land use in the previous period, or other factors that change over the projection period. This dynamic approach enables a stepwise presentation of changes in the course of time, not only the final outcome, which gives a detailed insight into the process of land use change.

Scenario approach

On the basis of our understanding of the relations between the map elements and map layers – the geographical 'system' – and our designed scenarios, future effects may be calculated. As neither the functioning of the current land use system nor the factors affecting future land use are completely known, modelling future land use always involves uncertainties. A popular approach to deal with uncertainties is using scenarios. Thus, the effects of a range of alternatives regarding future land use can be assessed, based on a logical and consistent set of assumptions. These scenarios usually generate outcomes in a range of possible plausible changes in land use. In a scenario approach, the focus is not so much on making the best possible forecast but on developing a consistent set of alternatives, used to communicate a specific message to stakeholders. For that reason rather extreme scenarios may be used that convey the message clearly.

Scenarios may be conceptual or more operational. Well-known conceptual scenarios like the 'liberal market approach' and 'government-dominated approach' may result in different demands for types of land use and in many parameters for suitability maps. In a 'liberal market' scenario, point of departure will be a certain percentage of economic growth, leading to a more unrestrained expansion of space needed for housing and work. In such a scenario, we may expect a higher degree of urban sprawl in the resulting calculations. In operational scenarios, as used in the case study presented in this chapter, only few parameters differ between the scenarios.

Road infrastructure

Road construction may have substantial and widely spread impacts on adjacent territories: it induces new claims on space for economic activities and housing, not only in the short term as a result of the construction works, but particularly because of increased accessibility of the newly opened areas (Scholten et al. 2001). Kaimowitz et al. (2002 p. 43) refer to an overwhelming amount of literature showing that forests are more likely to be cleared with a road nearby, measured in terms of distance or travelling time. Nepstad et al. (Rudel 2005 p. 62) investigate road paving in the Brazilian arch of deforestation and find that 'whereas farmers cleared 0 per cent to 9 per cent of their land within 50 km of unpaved roads, they cleared 29 per cent to 58 per cent of the land within 50 km of paved roads.' A road opens up previously less accessible areas of land, which stimulates various forms of economic exploitation: timber logging, mining, small-scale and large-scale agriculture and cattle breeding. Previously peripheral villages get better connections with the centre at lower costs. Consequently, land speculation is likely to flourish, and interests in concessions for timber or mining extraction will increase.

All these impacts have an important spatial dimension. Ultimately, the selected trajectory of the road will be the key factor for the allocation of spatial developments. Geographical or spatial information is needed to understand what areas will probably be affected substantially by the construction of new infrastructure. Consequently, collecting spatial data on current land uses and on plausible future trajectories of infrastructure developments was a major component of the study presented in the next sections.

Land use in Suriname

Suriname is a sparsely populated country. Its total population of about 500,000 inhabitants is mainly located in the coastal zone particularly in the city of Paramaribo and to a lesser extent in urban areas like Nieuw Nickerie and Moengo. More to the south, population density decreases, land is forested and less accessible. Traditional subsistence agricultural is predominant among the Maroon and indigenous populations in the area. Large parts of the territory are concession areas for mining and timber production or so-called domain land; gold digging is widespread, particularly in the eastern and south-eastern part of the country.

In December 2010 a memorandum of understanding (MoU) was signed between the Suriname government and the Chinese company China Harbour to construct a road and a railroad between Paramaribo and the border with Brazil nearby the village of Vier Gebroeders. The MoU refers as well to the construction of a deep-sea port. These intentions indicate at a focus on the transportation of bulk goods such as mining products and timber from Suriname's interior and possibly Brazil to the north of the country. The status of these proposals and plans is not entirely clear. Political conditions tend to fluctuate and impact upon the positioning of persons and institutions regarding these proposals and plans.

Current land use

Starting point of a spatial impact analysis is an accurate understanding of current land use. When using simulation results of spatial impacts of a new road for planning and investment purposes and to raise awareness among a broader audience, small inaccuracies in the current land use map may generate inaccurate projections and, moreover, may contribute to confusion.

A land use map of Suriname covering each relevant land use type for the case study was not available. Paper-based maps were digitized, rasterized (as the selected Land Use Model operates with spatial raster data) and reclassified to the identified relevant land use classes. Each raster cell in the map represents an area of 250 by 250 meter. At the country level, this resolution fits our research purpose best: it represents sufficient detail, and at the same time allows for fast calculations based on millions of raster cells in the model.

The following land use types were distinguished: shifting cultivation; small-scale agriculture; large-scale agriculture; irrigated agriculture (wetlands for cultivation of rice); human settlements; forest; swamp/savannah; open area; and water. Several sources of data for the new maps were used. Paper-based maps on vegetation and agriculture were provided by the Centre for Agricultural Research

(CELOS) provided important inputs for the final land use maps. A map of areas that were deforested due to mining activities was provided by WWF Guyanas. This map was used to update the CELOS vegetation map by reclassifying CELOS 'forest areas' as 'open areas' in the final current land use map. For water bodies and rivers, a base map of the former Centre for Aerial Cartography (Centraal Bureau Luchtkartering, CBL) was used in which rivers and water bodies were digitized as lines without surface. By overlapping the CELOS vegetation map with the map of water bodies, some overlapping areas were identified, and the land use type of these areas were subsequently reclassified as 'water'. Data taken from the UN Food and Agriculture Organization (FAO) were used for altitude and slope maps. FAO data were also used to establish the national boundaries of Suriname, adjusted with hand digitised demarcation of the national territory in contested border areas with Guyana and French Guyana. The cells outside the national boundaries are classified as sea or as abroad. Country totals with the number of hectares land use per type were mainly derived from data from the General Bureau of Statistics of Suriname (ABS).

As it should not be excluded on forehand that plans developed with China Harbour may have some relationship with the potentials to exploit reserves of natural resources such as iron ore, bauxite, and copper, a dataset with the locations of such resources was added to the map collection. This data set is extracted from the map of Lutchman et *al.* 2003. See also Conradi 2003 and Kranenburg 2007. Geological information was taken from the Planatlas Suriname 1988, based on Dahlberg 1975. According to Planatlas, it is not possible to extract natural resources at present in a profitable way.

The paper maps were georeferenced and digitized. No recent geological research has been published since Dahlberg 1975 (Kroonenberg 2009). In 2011 the 'One Geology Project' was started by the Surinamese Ministry of Natural Resources (NH), together with the Suriname Environmental and Mining Foundation (SEMIF) and the ADEK University of Suriname. This project focuses on the geological survey of the south of Suriname, in collaboration with the Brazilian government, and investigates potentials for exploitation of mineral resources. Resulting project data have not been published yet.

Data on concessions were derived from the Foundation for Forest Management and Production Control (SBB) and the Geological Mining Service (GMD) of the Ministry of Natural Resources.

Data on human settlements were based on Open Street Map (OSM). The premise here is that the density of road networks in OSM is directly related to human settlements: the higher the density of the road network in an area, the more probable it becomes that this area is a human settlement. The density of roads in a cell is calculated by counting points that are positioned at a regular pattern on each road. If this number exceeds a certain threshold, the cell is classified as a settlement cell. The threshold value is based on expert knowledge and validated with Google Earth satellite data. For most cells, this procedure has resulted in accurate output. However, this procedure fails for cells in larger settlements that do not exceed the threshold (e.g. a park in a city); and for cells outside settlements that do exceed the threshold (e.g. a cross road).To include the first type of cells and exclude the last type of cells, a spatial neighbourhood operation has been added. By doing so, the score of each cell is dependent on the score of neighbouring cells: the more neighbouring cells are classified as 'human settlement', the more likely a cell should be classified as 'human settlement' too.

Since the new road will cross the forested interior, where indigenous people live without OSM coverage, another paper-based map of small villages was added to the generated OSM settlement map. This paper-based map was also provided by CELOS and verified with data on villages of the interior provided by the ABS. With this revision of OSM data, supplemented by the small-village map to cover settlements in the interior, a realistic pattern of settlement cells has been produced.

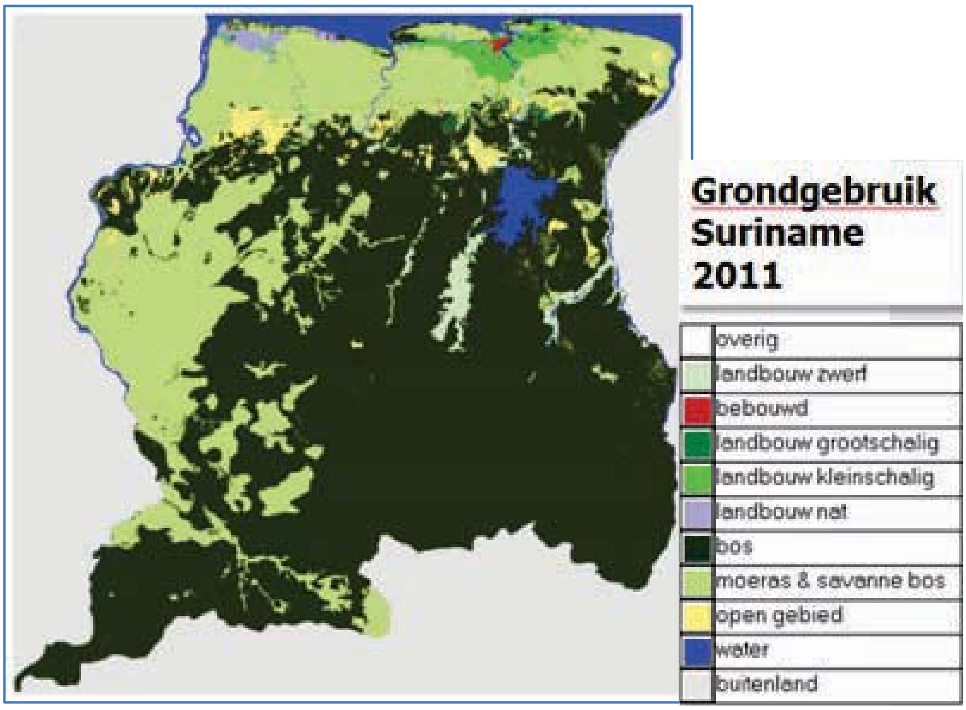
The collection of spatial data was a cumbersome process, since geo-information is considered a valuable asset for organizations owning geographical data. Moreover, data were often available in paper format requiring quite some technical expertise to transform paper maps into an accurate land use map.

The current land use map was constructed by combining all data mentioned above. Remaining raster cells – that is: cells with no land use type or value – were assigned to a certain type of land use based on the most frequently occurring types of land use in the immediate neighbourhood. The result is the land use map, presented as Map 4.1.

Infrastructure

Road infrastructure in Suriname is concentrated in the most populated areas in the coastal zone. In the last decades, the interior has been opened up gradually, particularly because of the spread of small-scale mining activities, as well as the upgrading of unpaved roads. Data on road infrastructure were derived from OSM and CELOS maps. Projected roads and new dams and water bodies were based on the plan by Boksteen (2009). To design a plausible route for the proposed road to Brazil use has been made of altitude and slope maps of FAO, in combination with the current land use map. In the design of the projected trajectory, steep inclinations of the road were avoided to the extent possible. Clearly, this projection is merely an

Map 4.1 Current land use map, 2009, Suriname



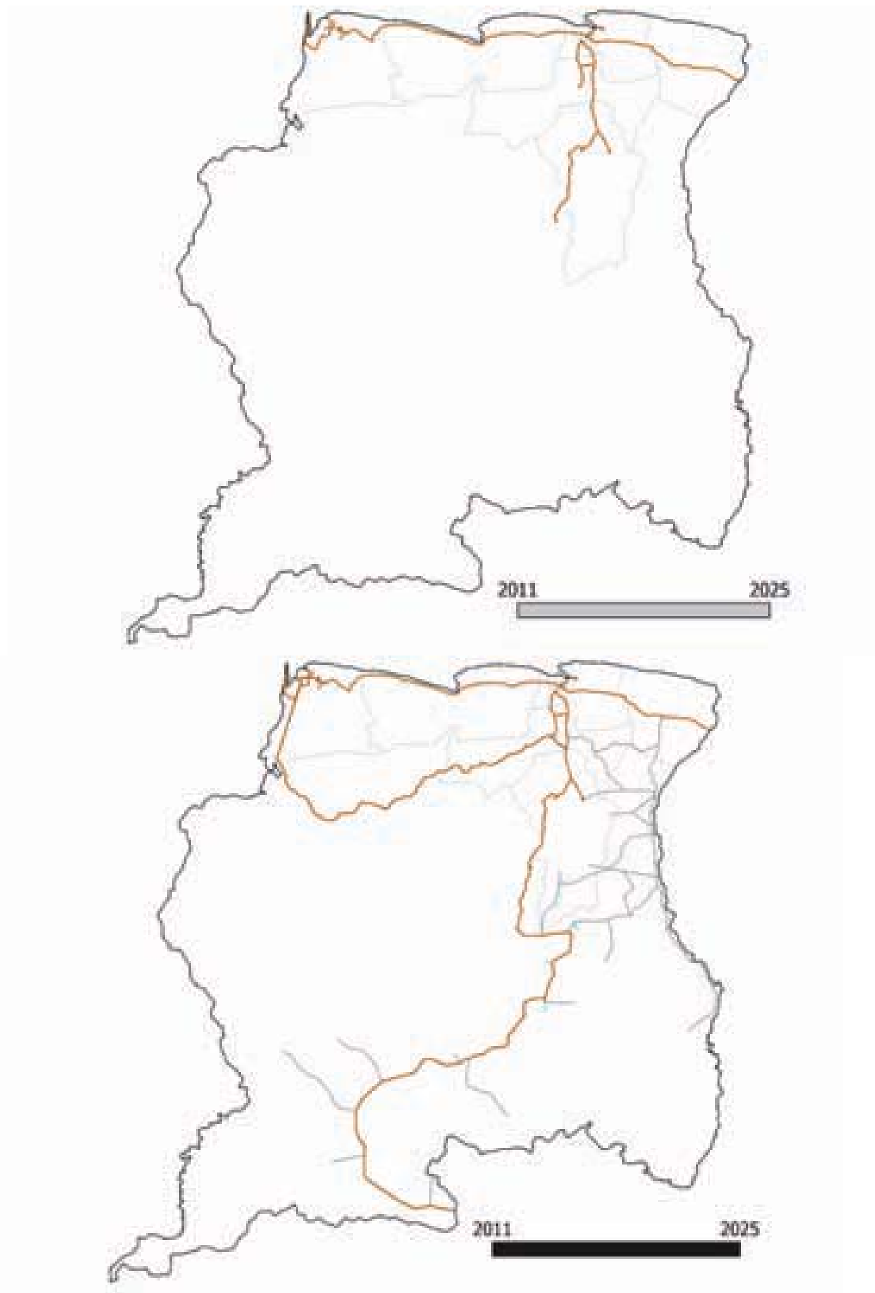
approximation of the possible future trajectory. Based on the expectation that such a road may be useful to exploit natural resources in the area such as timber and minerals, secondary roads to link the main road with locations of mineral resources were added. Combining the plan by Boksteen (2009) with the trajectory of the proposed road to Brazil results in Map 4.2 of road infrastructure developments.

Modelling the impact area

The next step is to use the Land Use Scanner in order to measure in a dynamic way the impact of the new road on adjacent territories. As the construction of a new road develops over time, the model calculates for each defined time interval the effects of the road on land use. These effects are input data for the calculation of the effects of the next time interval.

The Land Use Scanner is a GIS based model that generates spatial projections for alternative scenarios, depending on a series of variables related to land suitability, physical factors, infrastructure, markets, population concentrations and government policies. The raster cells compete with one another for the most suitable land use, based on the bid rent theory. The model is rule-based as well: based on the cluster principle, the selection of optimal land use type in a

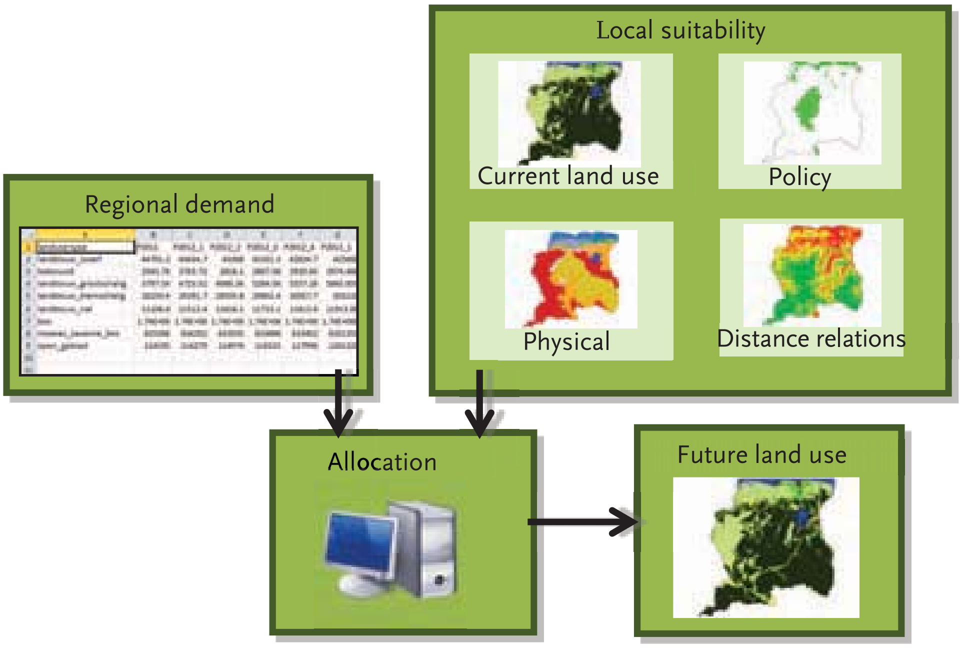
Map 4.2. Suriname, development of road infrastructure, 2011-2025



cell is influenced by the land use type in neighbouring cells. In line with other rules the calculation of distance maps is not only based on absolute distance but also on relative distance: the time it takes to get from one location in the map to another location is determined by absolute distance, as well by the terrain conditions, such as variations in altitudes, locations of swamp areas and other variables.

So the basic assumption is that multiple land use types such as built area, agriculture, forest, nature, water, and others, compete for the same limited amount of land. Figure 4.1 illustrates the components

Figure 4.1 Conceptual scheme of the Land Use Scanner Suriname



of the Land Use Scanner and their mutual relations. 'Regional demand' and 'local suitability per land use type' determine the price a land user is 'willing to pay' for a specific land unit.

Regional demands are projections of the total amount of hectares necessary per type of land use for a region, or even the whole country in the future. These projections vary per type of land use. Sources for these projections can be sector or demographic models. To illustrate the point: predicted demographic growth usually results in a higher demand for built up areas and agricultural land.

In the case study, a high population scenario is used to define the demands for human settlements and agricultural land use. The demand for extra open area in the future is based on the number of kilometres the new road will cover. We expect the model to locate extra open land alongside the newly constructed road. Forest is used as a rest category, so the total number of forest cells will decrease with the increase in number of cells for human settlements, agriculture and open area.

In our case study regional demand is de facto national demand. This implies that in the annual calculations for each type of land use, only one aggregate value for the whole country is used. If more regional data would be available, the case study could be improved by regionalization of demand.

Local suitability is modelled for each type of land use at the grid cell level. It indicates how suitable a cel is for the modelled type of land use. Per individual cell the model may incorporate a large number of suitability factors referring to various aspects such as:

(1) current land use. The suitability of a type of land use for a unit of land is often higher if that type of land use already occurs in the land unit in the previous period. Especially when transition of land use involves high transition costs this factor may be a significant factor. Moreover, the presence of the same type of land use in adjacent territory also tends to increase suitability for similar used of land. A case in point is the use of land as a housing area when services are available in support of such land use in adjacent housing areas;

(2) physical properties, such as altitude, slope and type of soil. Horizontal land units at low altitudes are often relatively more suitable for built-up area, infrastructure and intensive agriculture, as construction and maintenance costs are relatively low;

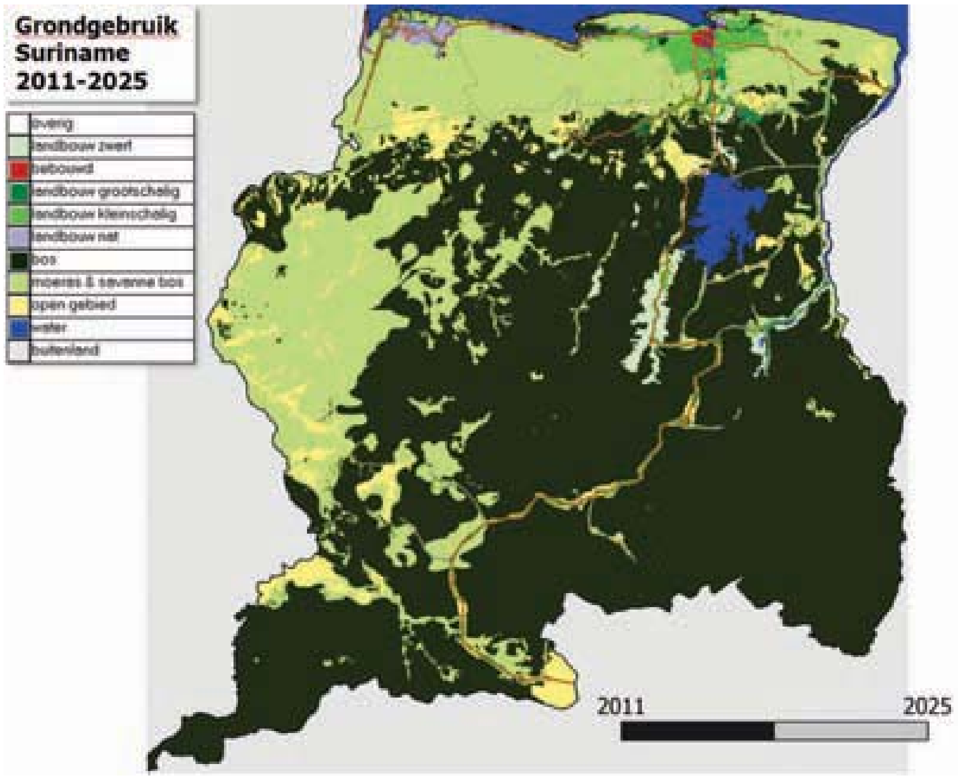
(3) planning policies, such as protected areas or concession policies and known areas where raw materials (such as gold, platinum, bauxite) are found determine to a large extent how suitable a cell is for economic exploitation and development. For example: for the suitability of human settlements and open area concessions have a positive effect; for the suitability of agriculture land use types the effect is negative.

(4) distance to towns, harbours, roads or rivers. Distance impacts upon the suitability of a cell for a particular type of land use, especially when transport costs play a significant role.

The suitability of land units is affected by nearby improvements of roads. In the Suriname case study, new roads will reduce travel time between the interior areas in the south and Paramaribo from for example 24 hours to less than 8 hours. Clearly, such road improvement may impact differently on the various types of land use, implying that some types of land use will pay higher prices per unit of land in case of improvement of accessibility. In the allocation module, these higher prices will result in the allocation of built-up area and agriculture in territories adjacent to the improved or new road, all other factors remaining the same.

The allocation module allocates the types of land use according to their local suitability, taking regional claims as preconditions that need to be fulfilled. If the claims cannot be fulfilled, status information on why no feasible solution can be found is presented. The allocation model uses a discrete allocation function, resulting in one type of land use for each unit of land. For more information on this function see http://wiki.objectvision.nl/index.php/Discrete_Allocation. GeoDMS software has been used to calculate these results. GeoDMS is a modelling framework that supports a controlled and efficient calculation process and is particularly useful for large spatial datasets. In the Surinamese case study allocation results are calculated for more than 4 million grid cells and dozens of suitability factor maps within one minute.

Map 4.3 Projected land use Suriname 2018

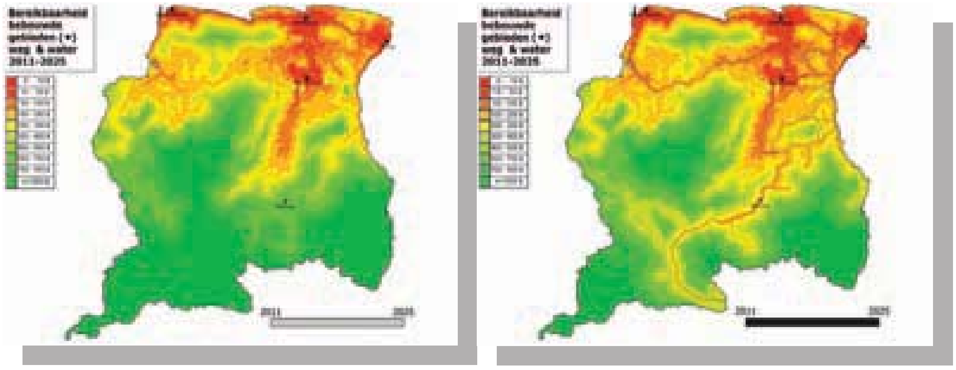


The result of the Land Use Scanner is a projection of future land use. This future situation is the result of a land use change process over multiple years. The results are generated for multiple time steps of one year or smaller, which leads to a deeper understanding of the process of land use change. Animation techniques can be used to visualize developments, using the future land use of the time steps as input. An example is Map 4.3.

The impact of the road on land use varies from low impact areas within a buffer zone of 500 meter to high impact areas with a buffer zone of four km. Differences in impact result from suitability of areas for developing settlements and agriculture, deforestation and mining.

The accessibility of large parts of the interior is strongly affected by new infrastructure and resulting land use changes. Map 4.4 shows the change in accessibility between 2011 and 2025. The green areas, nature, are less accessible. The costs involved to travel to these areas are relatively high. In 2025 large parts of the initially green areas have become yellow or orange, indicating that travel costs to reach these areas from the coastal zone will diminish substantially as a consequence of the new road.

Map 4.4 Suriname, increased accessibility of the interior towards major settlements 2011-2025



Accessibility is only one indicator to evaluate future land use. Other indicators can be added to broaden the analysis. Cases in point are assessment of impacts on carbon sequestration or biodiversity.

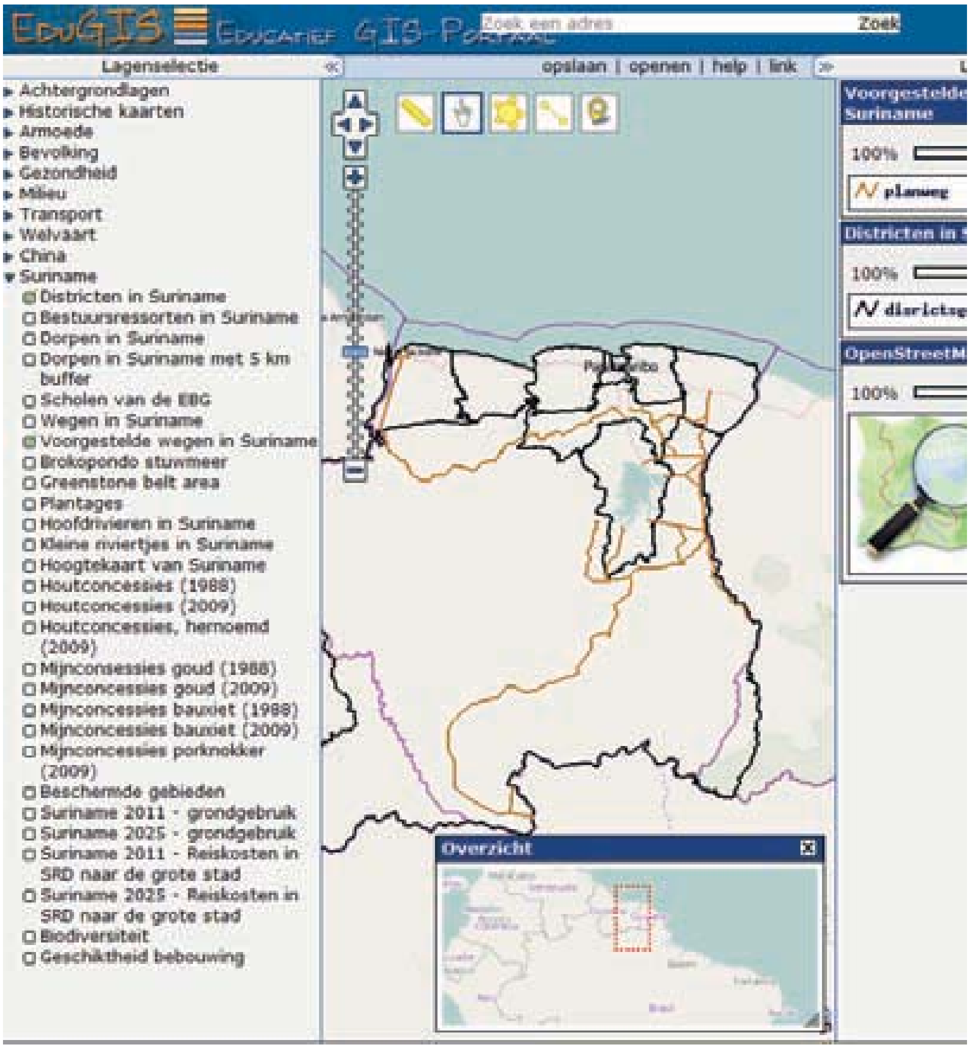
Making information accessible

Among the main objectives of using the Land Use Scanner in this case study is stimulation of public debate by identifying desired and undesired effects of a new road and related policies. This information is useful to technical experts involved in optimal land use planning, policy makers, locals living in the potential impact areas of roads, and other stakeholders such as investors, entrepreneurs, environmentalists and researchers. Descriptive information of the project and the resulting animations are available at: http://www.objectvision.nl/projects/suriname-new-infrastructure.

See also Van Dijck 2013 Chapter 8. The Land Use Scanner, including the configuration of the scenario developed with stakeholders in Suriname in 2013, is available at: http://www.objectvision.nl/demos/land use-scanner-training-edition-suriname. This internet page is particularly of interest to technical users who like to experiment with the tool.

For a broader audience, mainly interested in the basic land use map, the infrastructure plans and the results of the Land Use Scanner projections, information is presented on the EduGIS website. EduGIS is a web-based GIS platform, developed for educational purposes. The information can be found at: http://www.edugis.nl/lesmodules/Suriname. By using this public website, everyone with an internet connection is able to consult spatial data sets, zoom in to the relevant areas, combine map layers in order to perform basic

Map 4.5 EduGIS website, Suriname section



visual analyses. This allows users to find out about the distance between proposed or planned infrastructural works and the location of villages, concessions for timber logging and (gold) mining, or areas with high levels of biodiversity. Map 4.5 distinguishes the maps collected at the left-hand side of the menu under '*lagenselectie*' (layer selection). Each map can be displayed in the screen, and different map layers can be combined, depending on the interest of the user. To explore the datasets or maps, an educational module has been developed, shown at the right-hand side of the menu.

Reflections

In the Suriname case study relevant geo-information on land use and infrastructure could be collected to generate a base map of the current land use that was considered appropriate for analysing impacts of new infrastructure. With the Land Use Scanner the effects of the infrastructure plans were modelled based on an operational scenario. The local suitability of land units were modelled with multiple maps on the current land use, physical properties, planning policies and distance relations. We experimented as well with different rules in the model, attaching different weights to the suitability factors. One scenario was established in a stakeholder training session, resulting in a higher quality of the model results, and, more importantly, contributing to a higher awareness of suitability factors that may influence land use in the future.

All information – ranging from animations of changes in land use, to maps, data and software – has been made accessible to all on the internet. Additional research may expand our understanding of the impact of new physical infrastructure by investigating impacts in neighbouring countries, since impacts of newly planned infrastructure do not end at the border. Moreover, the impact areas could be analysed in more detail by including regional demands at the district level. Plans and accompanying assumptions at the district level of Suriname could be incorporated into the model, leading to a more comprehensive investigation of impacts on the spatial environment. Finally, as soon as information becomes available on the exact location or trajectory of new physical infrastructure, the model should rerun automatically all procedures including this new information.

The method can be applied at a smaller scale as well, for instance to assess the spatial impacts of infrastructural plans in the Amazon region. To evaluate the resulting future land use maps, several indicators can be adopted: accessibility, as has been discussed in the fifth section, and also carbon sequestration and biodiversity.

In general, these data, tools and scenarios enable the construction of meaningful images of future impacts of road construction on the use of land and resources.

Stakeholder participation plays a vital role in the preparatory process of defining the relevant parameters for the model. Results of modelling may subsequently be used to discuss desired and non-desired outcomes with a larger group of stakeholders. Counteracting measures may be discussed with stakeholders, and new rules can be fed into the land use model to calculate whether these improved countermeasures sort the desired effect on future land use. In this way land use models can support the optimisation of routing of new road and the development of participatory policies regarding infrastructural proposals and plans.

References

Alonso, W.A., *Location and Land Use: Toward a General Theory of Land Rent*, Harvard University Press, Cambridge, 1964.

Boksteen, L.W, Strategische Analyse en Participatief Actieplan voor Zuid-Ooost Suriname. Deelstudie Impact Vergroting Beschikbare Hoeveelheid Water in het Bestaande Brokopondo Stuwmeer, 2009. [Online] Accessible at: http://www.cedla.uva.nl/20_research/pdf/vDijck/suriname_project/Deelstudie.pdf. Accessed 24 01 2014].

Chomitz, K., and Gray, D.A., Roads, 'Land Use and Deforestation: A Spatial Model Applied to Belize', *The World Bank Economic Review*, Volume 10, 1996, pp. 165-174.

Conradi P., 'De Nieuwe Kaart van Suriname', *Geologie* (KNAW) 01.01.03, 2003. [Online]. Available at: http://www.knag.nl/index.php?id=640&tx_ttnews%5Bswords%5D=gis&tx_ttnews%5Bpointer%5D=89&tx_ttnews%5Btt_news%5D=256&tx_ttnews%5BbackPid%5D=502&cHash=4b9be18c7e. Accessed on January 28, 2014.

Dekkers, J., P. Retveld, 'The Adoptation of Geo-ICT in Economics: Increasing Opportunities for Spatial Research in Economics', in H.J. Scholten, R. van de Velde, and N. van Manen (eds), *Geospatial Technology and the Role of Location in Science,* The GeoJournal Library 96, Springer, York, 2009.

Dijck, P.van, *The Impact of the IIRSA Road Infrastructure Programme on Amazonia*, Routledge, London and New York, 2013.

Hoyan, J., 'Spatial Allocation of Future Residential Land Use in the Elbe River Basin'. *Environment and Planning B' Planning and Design,* Volume 37, Number 5, pp 911-928, 2010.

Joly, C. and T. Kuyper, *GIS Kaarten voor Impactanalyse*, Project Strategische Analyse en Participatief Actieplan voor Zuidoost Suriname, FALW – VU, Amsterdam, 2010.

Kaiowiz, D., P. Mendez, Atie Puntodewo, and J. Vanclay , 'Spatial Regression Analysis of Deforestation in Santa Criz, Bolivia' in: Wood, C.H. and R. Porro (eds), *Deforestation and Land Use in the Amazone*, University Press of Florida, Gainesville, 2002.

Kloterman, R.E. and C.J. Pettit, 'Guest Editorial: An Update on Planning Support Systems'*, Environment and Planning B*, Volume 32, pp 477-484, 2005.

Kooen, E. and Stillwell, J. 'Modelling Land-Use Change; Theories and Methods' Chapter 1, in: Koomen, E., J. Stillwell., A. Bakema and H.J. Scholten (eds.), *Modelling Land-Use Change; Progress and Applications,* Springer, Dordrecht, pp. 1-21, 2007.

Komen, E. and J. Borsboom-van Beurden, J. (eds.) 'Land-Use Modeling in Planning Practice', *Geojournal Library*, Volume 101, Heidelberg, Springer, 2011.

Kooen, E., A. Koekoek. and E. Dijk, 'Simulating Land-Use Change in a Regional Planning Context', *Applied Spatial Analysis and Policy* , Volume 4, Number 4, 2011, pp. 223-247.

Kraneburg, R. and H. Lutchman: 'Een Nieuwe Kaart voor Een Land Waar Ruimtelijke Planning Niet Bestaat', *Geologie* (KNAW) 01.10.07, 2007.[Online] Available at: http://www.knag.nl/..fileadmin/geografie/index.php?id=640&tx_ttnews%5Bswords%5D=landbouw&tx_ttnews%5Bpointer%5D=9&tx_ttnews%5Btt_news%5D=885&tx_ttnews%5BbackPid%5D=502&cHash=86f4121570. Accessed on January 28, 2014.

Krooneberg, S., 'Ik Denk Dat Het met Die Klimaatverandering Wel Meevalt', interview, November 17, 2009. [Online] Available at: http://www.salomonkroonenberg.nl/doc/Een-menselijk-sleutelgat-van-dertig-jaar.html. Accessed on January 28, 2014.

Kruman, P., 'What's New About The New Economic Geography?' *Oxford Review of Economic Policy ,* Volume14 , Number 2,1998, pp. 7-17.

Lavale, C., Baranzelli, C., Batista e Silva, F., Mubareka, S., Rocha Gomes, C., Koomen, E. and Hilferink, M., 'A High Resolution Land Use/Cover Modelling Framework for Europe: Introducing the EU-ClueScanner100 Model in: B. Murgante, O. Gervasi, A. Iglesias, D. Taniar and B.O. Apduhan, (eds.), Computational Science and Its Applications – ICCSA 2011, Part I, Lecture Notes in Computer Science Volume 6782. Springer-Verlag, Berlin, 2011, pp. 60-75.

Lutchman, H. and A. Karssen, Kaart van Suriname, Stichting Leermiddelen en Leerprojecten, Amsterdam, 2003.

Mc Fadden, D.L., Modelling the choice of residencial location, in: A. Karlsqvist, L. Lundqvist, F. Snickars and J. W. Weibull (eds) Spatial Interaction Theory and Planning Models, Amsterdam, 1978, p. 75 – 96.

Molendijk, M., M. van der Beek and R. Lassche, 'Spatial Implications for Land and Resources of New Road Infrastructure in Suriname: Land Use Scanner'; 'Opbouw Kaart Huidig Grondgebruik voor Land Use Scanner Suriname'; 'Geologie van Suriname, Een Voorstudie voor Land Use Scanner Applicatie' in: P. van Dijck and M. Wallis, *Handleiding bij Seminars en Trainingen over Planning en Beleid voor Optimal Landgebruik in het Kader van Grootschalige Infrastructurele Werken in Suriname,* CEDLA and WWF, Paramaribo,2013.

One Geology Project, On Mapping a New Geological Map for Suriname, 2011. [Online] Available at: http://www.gov.sr/sr/ministerie-van-nh/actueel/geological-mapping-on-the-border-suriname-brazil.aspx. Accessed on 28 January, 2014.

OSM, n.s., Open Street Map. Available at: Open Street Map data [Online]. Available at: http://www.openstreetmap.org. Accessed 24 January 2014.

Planatlas Suriname, Stichting Planbureau Suriname, Afdeling Regionale Planning en Ruimtelijke Ordening, Organization of American States, Map 5B of Mineral Resources, 1988, based on the 'Metallogenic Map' of E.H. Dahlberg 1975.

Porter, M.E., *The Competitive Advantage of Nations,* Free Press, New York, 1990.

Porter, M.E., 'Clusters and the New Economics of Competition', *Harvard Business Review*, Volume 76, Number 6, pp. 77-90, 1988.

Rudel, T.K., *Tropical Forests. Regional Paths of Destruction and Regeneration in the Late Twentieth Century,* Colombia University Press, New York, 2005.

Sheridan, P., J.O. Schroers and E. Rommelfanger,' GISBased Modelling of Land-Use Systems; EU Common Agricultural Policy Reform and Its Impact on Agricultural Land Use and Plant Species Richness', Chapter 2 in: Koomen, E., J. Stillwell, A. Bakema and H.J. Scholten. (eds.), *Modelling Land-Use Change; Progress and Applications,* Springer, Dordrecht, pp. 375-389, 2007.

Te Linde, A.H., P. Bubeck, J.E.C.Dekker, H. De Moel and J.C.J.H. Aerts,' Future Flood Risk Estimates Along The River Rhine', *Natural Hazards and Earth System Sciences,* Volume 11, Number 2, 2011, pp. 459-473.

Verburg, P.H., P.P. Schot, M.J. Dijst and A. Veldkamp, 'Editorial: Predicting Land-Use Change', *Agriculture, Ecosystems and Environments,* Volume 85, 2004, pp. 1-6.