Producing health knowledge by calculating accessibility of ecosystem disservices

Mikko Kesälä
Geography Research Unit, University of Oulu. e-mail: kesalamj@gmail.com

Abstract: Conservation of environment is important not only for maintaining biodiversity and moderating global warming, but also for increasing public well-being. Studies on ecosystem services show that nature's features have both positive and negative effects on human wellbeing. These effects can occur at individual and population level. Nature can decrease mental or physical wellbeing among humans for example by causing fear or by negatively affecting the already weakened physical condition of an individual. The elements of nature that have negative impacts are called ecosystem disservices and are the focus of this study.
For producing health knowledge, it is meaningful to know a providing unit of ecosystem disservices and how the unit is situated in relation to human habitation and living environments. This ecosystem-human spatial relationship can be analyzed with a spatial link between these two locations. By knowing the providing unit of ecosystem disservices and the spatial link between people and ecosystem disservices, we have more tools for environmental planning and can provide better information of the disadvantages of nature to society. A providing unit of ecosystem disservices can be modelled by using GIS-based analysis or statistical methods depending on the nature of the ecosystem disservices. The spatial link can be modelled by accessibility calculations. Accessibility modelling gives information about the shortest distance between ecosystem disservices and population. With accessibility models it is thus possible to determine ecosystem disservice areas within a specific distance from a population location, and this way to determine how high the risk of encountering the disservices is.

Keywords: Accessibility, Ecosystem disservices, Health geography

Introduction

There are several contextual features that affect human health. Generally, the features are divided into services that occur in the social environment (*e.g. income level, education, employment and other social and cultural factors*) or in the physical environment (*e.g. environmental planning, clean air and water*) [Millennium Ecosystem Assessment (MA) 2005; Kinding 2007]. These ecosystem services can provide economic benefits (e.g. *forestry, berries, mushrooms*) or provide environments for recreational activities (*urban parks, forest of neighborhood and nature parks*). There are also several ecosystem services, which maintain other ecosystem services and thus sustain the Earth's conditions suitable for living (MA 2005).

Usually, the studies on ecosystem services focus on those services, which have a positive effect on human health. However, there are nature features, which can impact also negatively on human health. They are

called *ecosystem disservices*. Features causing fear (e.g. *darkness, beasts, lightings*), phenomena that lead to economical disadvantages (*floods, storms, earthquakes*) and physical health disadvantages (*diseases caused by animals or plants*) are examples of these disservices (Dunn 2010; Lyytimäki 2014). By analyzing disservices along with ecosystem services, it is possible to contribute to conservation and land management planning and also to provide geographical health knowledge (Dunn 2010). For example, by knowing the spatial distribution of a certain disservice, it is possible to locate conservation and recreation areas to places where the risk of encountering with the disservice is small. This provides opportunities for improving public health (Maes *et al.* 2012; Lyytimäki 2015; Ala-Hulkko *et al.* 2016).

Accessibility calculations provide several possibilities for producing information of the spatial link between two locations (Syrbe & Walz 2013; Ala-Hulkko *et al.* 2016). Accessibility analysis answers to question how easily people access a place they want or need to reach (Morris 1978; Chen et al 2007). Larue & Nielsen (2008), Brabyn & Sutton (2013) and Ala-Hulkko *et al.* (2016) have used accessibility calculations in determining the benefits or disadvantages of an ecosystem. Least cost path analysis determines the shortest distance from the nearest ecosystem disservices to a population unit (Ala-Hulkko *et al.* 2016). However, the least cost path analysis produces only one spatial link. It is not presumable that people encounter ecosystem disservices always at the nearest location, even though the closeness of human habitation increases the probability of disservice encounter. Therefore, there is need for more detailed knowledge about the ecosystem-human relation.

Providing knowledge about ecosystem disservices for accessibility calculations

Ecosystem (dis)services are defined as services which have direct or indirect effects on human wellbeing or welfare (MA 2005; Dunn 2010). Disservices are those features of nature which cause harm to economy or decrease the wellbeing of individuals or populations (Fisher et al 2009; Dunn 2010; Lyytimäki 2014). According to Lyytimäki (2015), people may perceive nature as an injurious, inconvenient or unwanted, and these nature features can be considered ecosystem disservices. If the disservices are viewed from the general ecosystem services perspective (Maes *et al.* 2012), based on Escopedo's et al (2011) conceptual framework of the disservices, the influences of the disservices are financial, social or environmental.

Figure 1 illustrates the rather complex framework of ecosystem disservices with a tick as an example. First, there needs to be some kind of attraction (*e.g. nature trail*) in the environment of ecosystem disservices that acts as the providing unit of the disservice (Syrbe & Walz 2012). People do not usually go to forest (*tick environment*) without some attraction element. Hence, ticks do not cause disadvantages in locations where human presence is non-existent. In encounter situations, ticks have a strong direct impact on human wellbeing as they

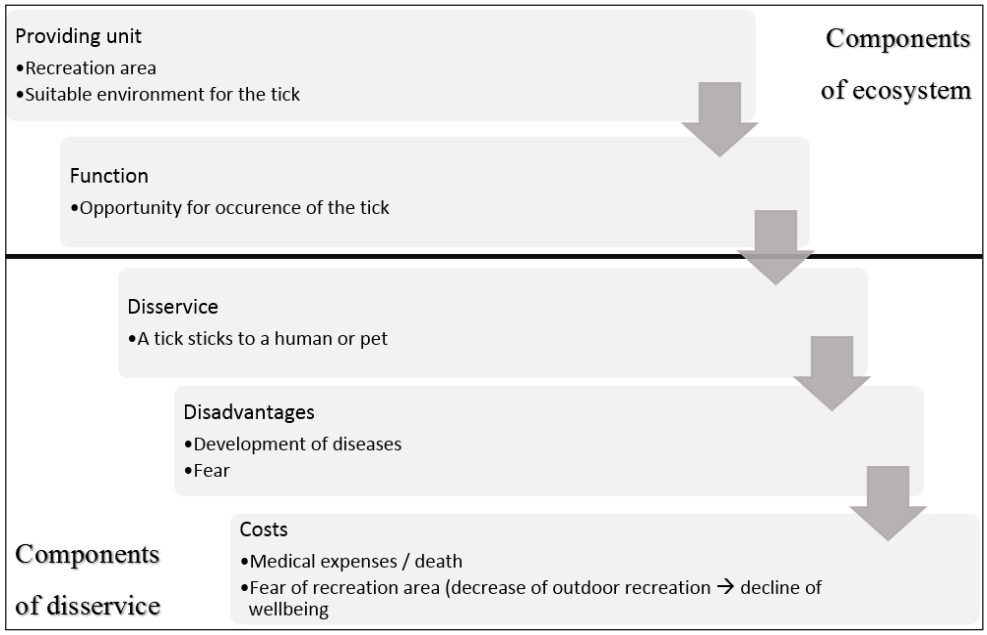

Figure 1. A framework of ecosystem disservice with tick as an example.

spread certain diseases. In addition, they affect indirectly on human wellbeing by causing fear that can lead to decrease in outdoor recreation activity.

For producing geographical knowledge about ecosystem (dis)services, either statistical or GIS (*geographical information system*) tools are utilized. The analysed phenomenon determines the choice of the appropriate method (Kopperoinen *et al.* 2014; Ala-Hulkko *et al.* 2016). Nature is a complex system, and producing geographical knowledge about the disservices is highly contextual. It is also necessary to outline the ecosystem (dis) service areas, where ecosystem disservices can actually cause disadvantages (Dunn 2010; Escobedo *et al.* 2011; Lyytimäki 2015). These areas are called the providing units of ecosystem disservices (Table 1).

Table 1. Examples of ecosystem disservices, providing units and their costs [based on Escobedo *et al.* (2011: 2081) table].

Costs	**Ecosystem disservices**	**Environment of providing unit**
Financial (Land, labor and capital)	Factors that weaken forestry, e.g. pest diseases	Area reserved for forestry
	Vegetation damage to urban infrastructure	Urban environment and city parks
	Foregone land use opportunities	Environment of financial opportunities
	Blocked sunlight – increased energy use	Built areas
	Green waste – debris, falling tree, branches, litter	Urban, power lines in forest, recreation areas
	Human injuries due to illness, wildlife/insect bites, allergies	Urban, city parks, recreation areas, residential environment
Social nuisances	Allergenic pollen and urushiol	Urban, city parks, recreation areas, residential environment
	Refugia for vector-spread diseases (eg. lyme disease)	Urban, city parks, recreation areas, residential environment
	Damages of wild animals (eg. bites and attacks on pets)	Urban, city parks, recreation areas, residential environment
	Decreased aesthetics, fear of crime and safety hazards from tree fall	Urban, city parks, recreation areas, residential environment
Environmental	Functions that weaken water quantity and quality	Urban and industrial near ecosystem services production area*
	Functions that alter soil nutrient natural cycles	Urban and industrial near ecosystem services production area*
	Air pollution emissions from maintenance activities	Urban and industrial near ecosystem services production area*
	Increased energy consumption	Urban and industrial near ecosystem services production area*
	Displacement of native species and introduction of invasive species	The natural environment**

* The functions that strongly alter natural cycles are ecosystem disservices. The strong altering of natural cycles can ruin the benefit of ecosystem services or result in stronger ecosystem disservices. The functions of environmental costs are basically human activity (eg. industrial activity). However there are some natural phenomena that can be the functions of environmental costs (eg. volcano eruption).

**Displacement of native species and invasive species have a strong effect on ecosystem by changing environment relatively rapidly

Accessibility analysis of ecosystem disservices

Morris (1978) and Chen *et al.* (2007) define accessibility as the ease of people to access an activity using some mode of transportation. Geurs & Ritseman van Eck (2001) say accessibility is the measurement of the amount that a transport system enables either individuals or goods to reach their desired destinations. Hence, accessibility calculations have been seen useful also in determining benefits of the ecosystem services. Common calculation methods of accessibility in this context are geographical accessibility and potential accessibility in addition to least cost path calculation (Rodrigue *et al.* 2006). All the methods are illustrated in figure 2.

While the least cost path analysis takes into account only one spatial link, geographical accessibility considers every single possible distance between the population unit and disservices providing unit in a specific cutoff, and determines means for these distances. The potential accessibility method is a more detailed accessibility calculation method that provides knowledge about *how many people are potentially using the services*. Potential accessibility considers how distances affect people's willingness to go to services by distance decay function (Kotavaara 2012: 26): the longer the distance, the less likely people will travel to services. An applied version of potential accessibility considers also how the distances between similar services affect the attractiveness of each service. Obviously, demographic characteristic (*e.g. age, gender*) and the location of peoples' workplaces also influence the potential number of people who might use a specific nature service (Salze *et al.* 2011).

The potential accessibility method in its basic form is not applicable in all occasions. If a disservice is located in the same unit with population, it more likely gets the potential population amount already from that unit, as people often use the surrounding environments of their living place for outdoor activities (Sievänen & Neuvonen 2011). Hence, if there is no attraction or other reasons why people would go to the disservice unit from other locations, the accessibility analysis can be realized without distance calculations. In this specific occasion, the index of ecosystem disservice must be between 0 and 1.

Ecosystem disservices are not, in general, considered as attractions, but nature features like hunting opportunities or beautiful landscapes can be located in the same area with a disservice (Lyytimäki 2015). Thus, accessibility methods should be applied only on those ecosystem disservices that have a negative effect on human health at the disservice location. Though distance is one of the most powerful factors in estimating people's willingness to go to some service, it is important to understand that the level of attractiveness of the different disservices providing units may vary.

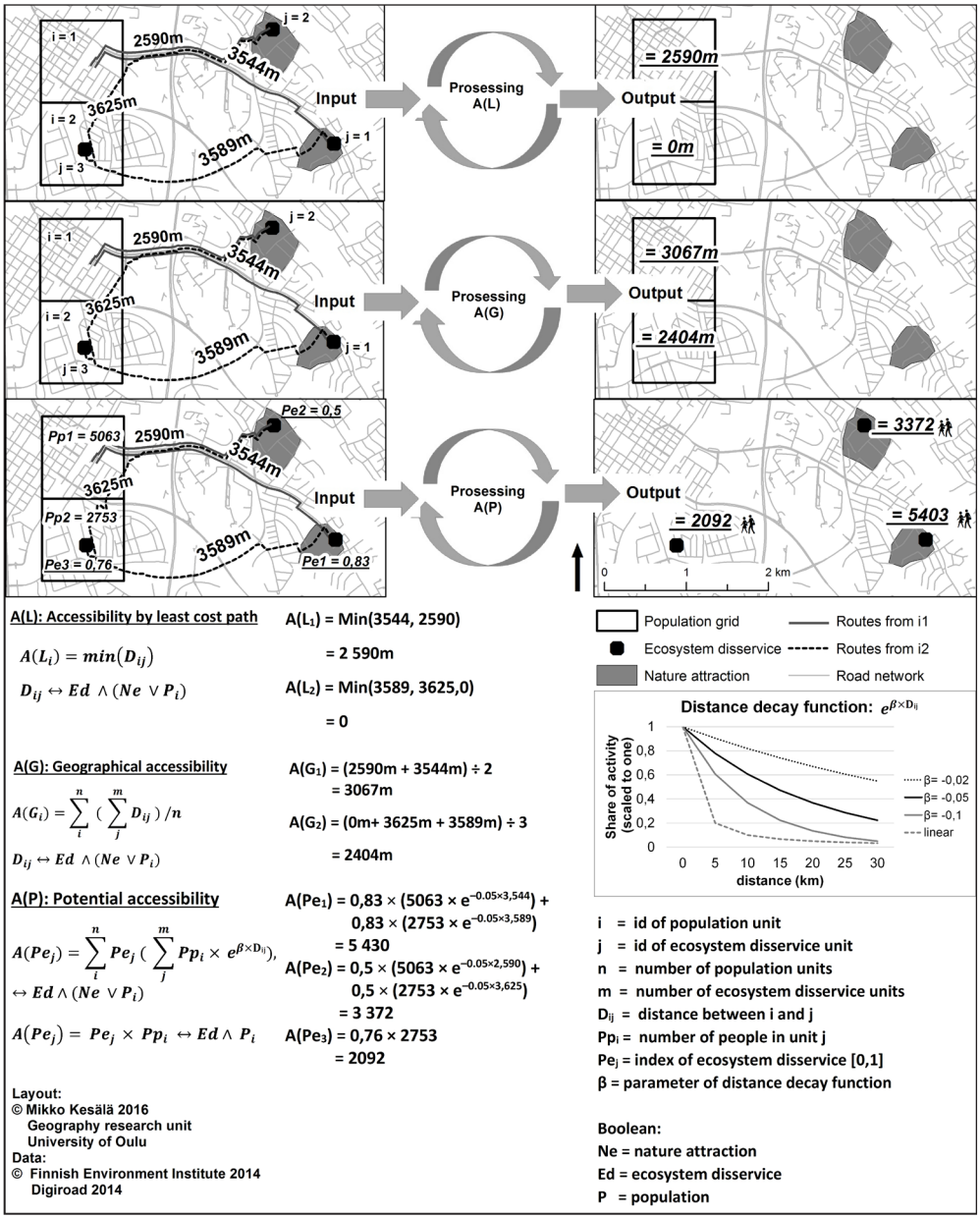

Figure 2. Accessibility calculation methods that can be used in ecosystem (dis)services studies. Ecosystem disservice in the population or nature recreation unit are the providing units of ecosystem disservices in this example.

Conclusion

For estimating disadvantages of ecosystem disservices spatially, we need to gather GIS-data about specific disservices. Because ecosystem disservices are diverse, different methods to gather data are needed. For example, distribution of harmful species can be modelled by statistical methods from species observation data, and nature safety hazards from observation data. Moreover, we need to study peoples' nature recreational habits: How the vicinity of several similar nature recreation areas affects their usage level? How distances to different kinds of nature recreation areas (*e.g. cottage place, water activity, parks*) affect their usage? By knowing these variables, we can estimate disadvantages of ecosystem disservices more accurately and thereby provide better nature experiences to people.

References

Ala-Hulkko, T., Kotavaara, O., Alahuhta, J., Helle, P. & J. Hjort (2016). Introducing accessibility analysis in mapping cultural ecosystem services. *Ecological Indicators* 66: 416–427.

Brabyn, L. & S. Sutton (2013). A population based assessment of the geographical accessibility of outdoor recreation opportunities in New Zealand. *Applied Geography* 41: 124–131

Chen, A., Yang, C., Kongsomsaksakul, S. & M. Lee (2007). Network-based accessibility measures for vulnerability analysis of degradable transportation networks. *Networks and Spatial Economics* 7: 241–256.

Dunn, R. R. (2010). Global mapping of ecosystem disservices: the unspoken reality that nature sometimes kills us. *Biotropica* 42: 5, 555–557.

Escobedo, J. F., Kroeger, T. & J.E. Wagner (2011). Urban forests and pollution mitigation: Analyzing ecosystem services and disservices. *Environmental Pollution* 159, 2078–2087

Fisher, B., Turner, K.R. & P. Morling (2009) Defining and classifying ecosystem services for decision making. *Ecological Economics* 68: 3, 643–653

Geurs, K. & J. Ritsema van Eck (2001). Accessibility measures: review and applications. Evaluation of accessibility impacts of land-use transport scenarios, and related social and economic impacts. RIVM report 408505 006. 265 p. 20.8.2016. <*http://www.rivm.nl/bibliotheek/rapporten/408505006.pdf*>

Kinding, D. A. (2007). Understanding population health terminology. *The Milbank Quarterly*, 85: 1, 139–161.

Kopperoinen, L., Itkonen, P. & J. Niemelä (2014). Using expert knowledge in combing green infrastructure and ecosystem services in land use planning: an insight into a new place-based methodology. *Landscape Ecology* 29: 1361–1375

Kotavaara, O. (2012). Accessibility, population change and scale dependency. Exploring geospatial patterns in Finland, 1880–2009. *Nordia Geographical Publications* 41: 4.

LaRue, M. A. & C. K. Nielsen(2008). Modelling potential dispersal corridors for cougars in midwestern North America using least-cost path methods. *Ecological Modelling* 212: 372–381.

Lyytimäki, J. (2014). Bad nature: newspaper representations of ecosystem disservices. *Urban Forestry & Urban Greening* 13: 3, 418–424.

Lyytimäki, J.(2015). Ecosystem disservices: Embrace the catchword. *Ecosystem Services* 12: 136

Millennium Ecosystem Assessment (MA) 2005. Millennium ecosystem assessment: Ecosystems and human well-being. 245 p. Island Press, Washington D. C.

Maes, J., Egoh, B., Willemen, L., Liquete, C., Vihervaara, P., Schägner, J. P., Grizzetti, B., Drakou, E. G., La Notte, A., Zulian, G., Bouraoui, F., Paracchini, M. L., Braat, L. & G. Bidoglio (2012). Mapping ecosystem services for policy support and decision making in the European Union. *Ecosystem Services* 1, 31–39.

Morris, J. M., Dumble, P.L. & M. R. Wigan (1978). Accessibility indicators for transport planning. *Transportation Research* 13A: 91–109s.

Rodrigue, J-P., Comtois, C. & B. Slack (2006). *The geography of transport systems*. 297p. Routledge, New York.

Salze, P., Banos, A., Oppert, J. M., Charreire, H., Casey, R., Simon, C., Chaix, B., Badariotti, D. & C. Weber (2011). Estimating spatial accessibility to facilities on the regional scale: an extended commuting-based interaction potential model. *International Journal of Health Geographics* 10: 2.

Sievänen, T. & M. Neuvonen (2011). Luonnon virkistyskäyttö. Metlan työraportteja 212. 190 p. 21.8.2016. <*http://www.metla.fi/julkaisut/workingpapers/2011/mwp212.htm*>

Syrbe,R. U. & U. Walz (2012). Spatial indicators for the assessment of ecosystem services: Providing, benefiting and connecting areas and landscape metrics. *Ecological Indicators* 21: 80–88.