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Methods for land use impact assessment: A review

Tatiana Perminova [a,b], Natalia Sirina [a,*], Bertrand Laratte [a], Natalia Baranovskaya [b], Leonid Rikhvanov [b]

[a] Research Centre for Environmental Studies and Sustainability, University of Technology of Troyes, CNRS UMR 6281, 12 Rue Marie Curie CS 42060, F-10004 Troyes Cedex, France
[b] Department of Geoecology and Geochemistry, Institute of Natural Resources, National Research Tomsk Polytechnic University, 30 Lenin Avenue, 634050 Tomsk, Russia

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ABSTRACT

Many types of methods to assess land use impact have been developed. Nevertheless a systematic synthesis of all these approaches is necessary to highlight the most commonly used and most effective methods. Given the growing interest in this area of research, a review of the different methods of assessing land use impact (LUI) was performed using bibliometric analysis. One hundred eighty seven articles of agricultural and biological science, and environmental sciences were examined. According to our results, the most frequently used land use assessment methods are Life-Cycle Assessment, Material Flow Analysis/Input–Output Analysis, Environmental Impact Assessment and Ecological Footprint. Comparison of the methods allowed their specific features to be identified and to arrive at the conclusion that a combination of several methods is the best basis for a comprehensive analysis of land use impact assessment.

Contents

1. Introduction

The current stage of development of the world economy is characterized by the increasing level of land use and the environmental impact associated with it (Foley et al., 2005; Lambin and Meyfroid, 2011). The complexity and intensity of the interactions, both natural and man-made lead to a degradation of the land quality, biodiversity reduction,

* Corresponding author.
E-mail addresses: tatiana.perminova@utt.fr (T. Perminova), natalia.sirina@utt.fr (N. Sirina), bertrand.laratte@utt.fr (B. Laratte), natalya.baranovs@mail.ru (N. Baranovskaya), rikhvanov@tpu.ru (L. Rikhvanov).

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food security concerns and lack of environmental sustainability (Reid et al., 2000) at different scales. Since land is one of the most essential resources needed for humans, not only as a living or economic activity space, but also for the ecosystems, it is vitally important to preserve it and prevent possible irreversible effects associated with human activities.

Talking about environmental impacts on land use, two basic land use activities should be considered: land use change and land occupation (Koellner and Scholz, 2007). Land use change (transformation) is a man-made change of the land use from one type to another (e.g. from forests to agricultural crop). On the one hand, such changes could be dramatic and lead to environmental damage (biodiversity decreases, etc.); on the other hand, they can have a positive influence, for example, transformation of built-up areas to gardens or secondary forests. Land occupation is continuous use of some area for a certain period of time for specified land use type. The environmental impact from land occupation could be different (negative or positive). Thus, all human impacts on soil, water, plant and animal life, etc. caused by the land use activities are referred to land use impact (Doka et al., 2002). Such impact not has only ecological consequences, but in so far as land use is part of a worldwide research agenda, sustainable land management is also a political, economic and social issue (Meshesha et al., 2014). Therefore land use impact assessment could be understood in this broad sense. But we should note that in our study we use the term "land use impact assessment" specifically in the context of environmental impact assessment.

Nowadays there are many types of methods, tools and methodologies to assess the environmental impact of land use. Each of them has their own particularities, depending on the specific research purposes. To identify the existing methods used, their scope and scale of application, understand which ones are the most commonly used, for what purposes, and finally highlight the most promising ones for supporting different levels of decision-making, we performed a bibliometric analysis of the state of the art in land use impact assessment. A comparison of the methods is presented in two tables, which offer a view of the essential elements of the issues studied depending on the objectives of each case study.

Since there are no generally accepted definitions of "method", "tool" and "methodology" (see section on *Limits*), we used the following definitions for our research. *Methodology* is a way to solve a research problem that includes collection of rules, practices and procedures and explains why we use specific methods and tools (McGregor and Murname, 2010). *Method* is a technique including a systematic and planned procedure for performing research (McGregor and Murname, 2010). *Tool* is a specific instrument or device that can be used within different methods to carry out a particular task (for example, SimaPro or GaBi in LCA).

Several criteria summarized in Table 1 were chosen to compare the methods and to understand their importance within different contexts of land use.

Table 1
List of criteria chosen to compare the methods with several examples provided in brackets.

"First" group	"Second" group
Criteria (*example*)	
Method type (*analytical or procedure oriented*)	Driving forces (*incentives or regulation*)
Method strategy (*bottom up or top down*)	Application areas (e.g. *territory, product*)
Necessity of use (*voluntary or compulsory*)	Target audiences (e.g. *policy makers*)
Main principle (e.g. *mass balance*)	Indicator levels (e.g. *impact*)
	Input data type (*primary or secondary*)
	Scale (e.g. *global*)
	Combination(s) of methods (e.g. *MFA and LCA*)
	Land use type (e.g. *agricultural*)
	GIS and RS application (e.g. *GIS*)
	Subject division (e.g. *production*)

Our so-called "first" group of criteria was based on the general assumptions typical of each method that were explicit in the definition and generic existing description.

The "second" group of criteria took into account the use of non-evident characteristics of the methods, and this is the basis of our analysis, bringing out the state of the art and usefulness of the methods. These criteria were chosen for different reasons. For instance, knowing that compulsory procedures enforced by policy regulation and markets, could be driving forces favoring the use of some methods more than others, we decided to include the mechanisms promoting their use in our analysis. The application of the methods, and the target audience for whom the study is made, could influence the choice of method depending on the goal of the assessment, hence it was important for it to be included in the study. The next important criteria seemed to be an indicator level showing a qualitative or quantitative measure of the land use impact. Quite often the quality of the outcome depends on the way the data is collected (e.g. sampling) or the accessibility challenge if it is necessary to use external databases. Even though we could assume the data type used in each method, it was very interesting to see how it was developed, knowing that, for example, LCA is very often criticized for using mainly secondary data thus generating considerable uncertainty in results. So, the input data type was another chosen criterion. The geographical scale of the assessment is also of importance, as it shows how the information is represented and generalized spatially and temporally. It was included as a criterion. A comparison of methods could show potential interrelations and possibilities of combining them to obtain a more explicit assessment, so this criterion was also included. Most studied land use type shows the priority of such types in the current state of the knowledge, so appeared to be important. Since land use has spatial and temporal aspects, geographical information system (GIS) and remote sensing (RS) are quite important to be applied to land use assessment studies. Thus, the use of these two tools within the methods was chosen as a criterion. The subject division allows the identification of the fields where land use is most studied.

Comparison according these criteria summarized in two comparative tables (Tables 2 and 3) shows the current state of the art in this area and opens the discussion of their use.

2. Methodology

To achieve the main goal of our study we carried out a bibliometric analysis (BA). We examined several articles discussing different approaches to perform a bibliometric analysis (Coroama and Hilty, 2014; Loiseau et al., 2012; Russell et al., 2011) and decided to use a strategy represented by Russell et al. (2011). Basing on this approach that included two steps: the first is the choice of journals based on scientific journal ranking (SJR) (SCmago Journal & Country Ran) and the second is the choice of key words within those chosen journals we run our study. Among the four possible options for key word search, Publish or Perish software seemed more user-friendly and thus was chosen despite some disadvantages, for example, inaccuracy of results using search by author (Baneyx, 2008). This drawback was avoided by using the key-word search.

Choosing scientific journals that could be relevant to the ecological issue, among the various subject categories proposed by the SJR platform (SCmago Journal & Country Ran), only two categories were retained as being of interest: "*Agricultural and biological sciences*" and "*Environmental Science*". Since the ranking of journals is more or less consistent over time, we chose a default year of 2013 for our study. To take into account the journals of all possible countries in these categories, we did not exclude a journal based on country of origin. Furthermore, we selected the top 100 journals in each category and verified their listing to exclude duplication. In our case the studied categories included several numbers of the same journals. We finally retained just 187.

Table 2
Comparative characteristic of methods.

№	Method criteria	LCA	MFA/IOA	EIA	EF
1	Type	Analytical	Analytical	Procedure-oriented	Analytical
2	Strategy	Bottom up	Top down	Top down	Top down Bottom up
3	Utilization	Voluntary	Voluntary	Compulsory	Voluntary
4	Main principle	Life cycle	Mass balance	Defined geographical boundaries	Agent environmental impact

Our next step was to identify the key words that could help us to carry out our study. We chose *obligatory* and *optional words* to make our research more reliable. The obligatory words meant that all of them should be found in the article. *Optional* ones are not obligatory but we decided to include them as they could give us more robust results. The *obligatory words* we chose were "land use", "environmental impact", "indicator", "data", "scale". *Optional words* were "assessment", "evaluation", "estimation", "method", "tool", "approach", "analyze".

After these two steps, we had the information necessary for our analysis: 187 journals to be analyzed as well as obligatory and optional words to be used in the software program *Publish or Perish* to perform our research. There are numerous fields to be completed to use this program, depending on the strategy used and way sources are selected, the results can be quite different.

All the journals examined covered the period 1975–2013. Ninety eight of the 187 journals did not give any results with our search words, as they did not have a direct connection with land use, even if this phrase occurred in the articles. Thus our research was based on the remaining 87 journals. The number of articles in each journal varied significantly, some journals contained only 1 article, others more than 30.

Finally, 177 different articles were chosen, and our first results are based on them. It should be noted that only h-index articles were taken into account. This index shows that the content of the article presents scientific interest and significance that was important to our study.

In addition, every single article had been carefully studied and in depth research had been done choosing particular criteria that could make the results more accurate and reliable. Many of the articles selected by using our methodology did not meet the necessary requirements for our study (in some articles keywords were just mentioned, but the article itself did not focus on the subject of our research; in some articles we could not find essential information within the criteria chosen, etc.). Thus, depending on the article content and degree of details of information represented, 117 articles were subsequently excluded from the study. The remaining results are based on 60 articles. Fig. 1 summarizes the steps of our research methodology.

3. Explanation of the results

3.1. First screening: review of 177 articles

We analyzed the state of development (and integration) of methods for land use impact assessment within the chosen period. Our first screening, based on 177 articles showed increasing interest in the issue (Fig. 2) in recent years. Fig. 2 shows that studies started in 1992, before that we found only one study in 1975. However, real growth in this area started in 1996. We assume that the 1992 Rio Conference drove research in this area forward by given special attention to critical resources (water and land), as well as land use changes, and also by promoting sustainable land-use planning and management (UNCED,

Table 3
Comparative characteristic of methods derived from BA analysis.

№	Method criteria	LCA	MFA/IOA	EF	EIA
5	Driving forces	Incentives (ISO standards 14001)	Incentives	Incentives (ISO 14001 EMAS)	Regulation (e.g. EIA Directive 2014/52/EU)
6	Application area	Product Process Service Product system	Territory Material Process	Land capacity Territory	Project planning Territory
7	Target audience	Industries Policy makers Organizations (companies, business…)	Industries Policy makers	Policy makers Organizations (companies, business…)	Industries Policy-makers
8	Indicators level	Impact	Pressure	Impact	Impact
9	Data type	Primary Secondary	Secondary	Primary Secondary	Secondary
10	Scale	Regional Global	National Regional	Local Regional National	Project
11	Combination of methods	MFA/IOA, EF, EIA	LCA, EF	LCA, MFA/IOA	LCA
12	Land use type	Agricultural land Forests Artificial surfaces	Agricultural land	Agricultural land Forests Artificial surface	Agricultural land Forests Wetland
13	GIS and RS application	GIS, RS	GIS, RS	GIS, RS	GIS
14	Subject division	Consumption and production Energy, including bioenergy and biofuels Biodiversity and ecosystem services Emissions and wastes Agriculture			
15	References[a]	3, 4, 5, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 21, 22, 26, 29, 32, 35, 38, 39, 40, 41, 45, 47, 48, 52, 54, 55, 56, 60	2, 3, 5, 6, 7, 11, 13, 21, 24, 25, 26, 28, 29, 31, 39, 43, 45, 47, 49, 51, 52, 55, 59, 60	1, 2, 6, 8, 13, 17, 19, 22, 23, 24, 25, 27, 28, 30, 37, 44, 53, 55, 58, 59	8, 20, 33, 34, 36, 46, 50

[a] Articles are numbered according to the numbering specified in Supplementary materials.

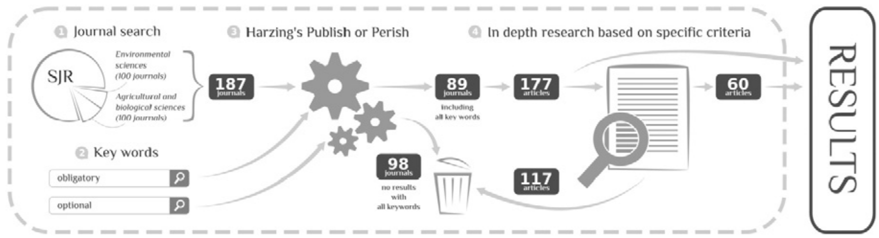

Fig. 1. The steps of BA realized.

1992). In addition, this growing interest could be also connected with the launch, in the mid-1990s, of "The International Geosphere–Biosphere Programme and International Human Dimensions Programme" aimed at the study of basic changes in land use (Meshesha et al., 2014). The highest number of studies (27) was carried out in 2011, since then research has dropped off (4 studies in 2013). It is difficult to explain this sharp drop. It will be necessary to follow the trends for the next few years before drawing any conclusions.

According to our research results, there are a large number of methods that in one way or another relate to land use impact assessment. We found Material Flow Analysis (MFA), Input–Output Analysis (IOA), Life Cycle Assessment (LCA), Environmental Impact Assessment (EIA), Strategic Environmental Assessment (SEA), Substance Flow Analysis (SFA), Risk Assessment (RA), Intervention Analysis, Before After Control Impact Analysis (BACI), Well-to-Wheel Analysis, Detrended Correspondence Analysis (DCA), Canonical Correspondence Analysis, Ecological Footprint (EF), Cost–Benefit Analysis (CBA), Cost& Efficiency Analysis (CEA) and Integrated Assessment and Technology Assessment. We decided to focus only on the more frequently used ones, namely LCA, MFA & IOA,[1] EIA and EF (Fig. 3), which appeared during the first screening. A brief description of their characteristics in the order of their frequency of occurrence in the studied sample of our bibliometric analysis is given below.

3.1.1. Life cycle assessment

LCA was the most frequently used method within the sample with 96 out of 177 articles. LCA is a method of evaluating the potential environmental impact of a product or service through all the stages of its entire lifetime, i.e. from raw material extraction through manufacturing, transport, distribution and use to the end-of-life. It is a method for the communication and promotion of environmentally responsible production and consumption. Nevertheless it is not a compulsory method, but is often chosen due to the marketing advantages it offers.

The first environmental life cycle research was carried out in the USA in 1969 by Coca-Cola, by Harry E. Teasley Jr., one of their managers, and published in "Science Magazine" in 1976. It encouraged the foundation and development of methods of life cycle inventory analysis. However, the term "Life Cycle Assessment" only appeared in 1990, proposed by the Society of Environmental Toxicology and Chemistry (SETAC) (Giarola et al., 2012).

Nowadays LCA is a part of environmental management standards ISO 14001 (Hu et al., 2011). It has several functions: firstly to help minimize the negative impact of the studied system to the environment (air, water, land, etc.); secondly system compliance with the existing laws, standards and environmentally-oriented incentives, identifying the ways better environmental performance can be achieved.

There are four main stages in the LCA: goal and scope definition, inventory analysis, impact assessment and interpretation. Goal and scope definition is a key step which requires the explicit definition the aim of the study and the boundary of the studied system. The next step includes the collection of information, namely, input and output data to prepare inventory flows. The aim of the third step is to estimate potential environmental impact based on flow results. The last step includes the summarized result interpretation of inventory analysis and impact assessment stages. It is important to note that LCA provides an assessment of potential impacts on the basis of a chosen functional unit (Zhou et al., 2011).

3.1.2. Material flow and input–output analysis

MFA is a method that allows all the materials (even hidden flows) to be accounted for, to identify and quantify flows and stocks of materials in physical units (kilograms, tons) within a defined system on different spatial and temporal scales (Brunner and Rechberger, 2005). It is not a mandatory method, but it is widely used in rational and efficient resource use evaluation.

The history of MFA is in connection with IOA that is a quantitative method, representing the interrelation between the various sectors of national or regional economies. The Russian-born American economist Wassily Leontief (Leontief, 1986) contributed to the input–output model, estimating economic impacts and tracing the monetary flows that contributed to MFA development (Lenzen et al., 2004).

The method includes two fundamental principles: the system approach and the mass balance. The principle idea of the MFA approach is a simple model characterizing relations between economy and the environment. Thus, all the natural resources (water, raw materials etc.) are the inputs and transformed products become outputs (final products, air emissions, wastes etc.). According to physical laws, the MFA system should be balanced, i.e. total input and output should be equable.

3.1.3. Environmental impact assessment

EIA is a term proposed by the International Association for Impact Assessment (IAIA) aimed at identifying the intensity and risk level of any kind of planned project activity and its impact on the environment and human health. One of the most important features of Environmental Impact Assessment is that it should be available for all interested agents in the early stages of the project development. Thus, EIA has become necessary in making the decision whether a project should be carried out or not. Likewise, EIA has been defined as the main method for achieving sustainable development (Treweek, 2009).

As we were able to identify, this method is mandatory, and nowadays it is a compulsory instrument for some international organizations

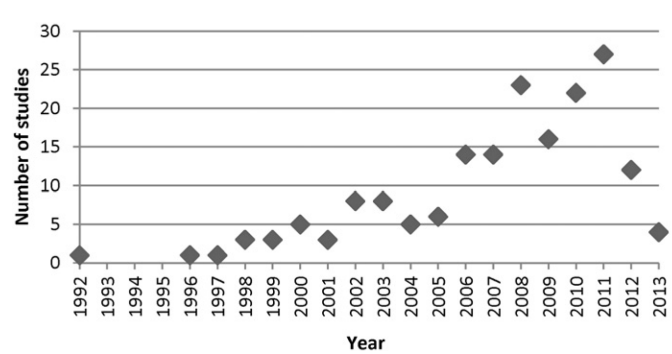

Fig. 2. The study of land use impact assessment.

[1] MFA and IOA were united because they are based on the same principle.

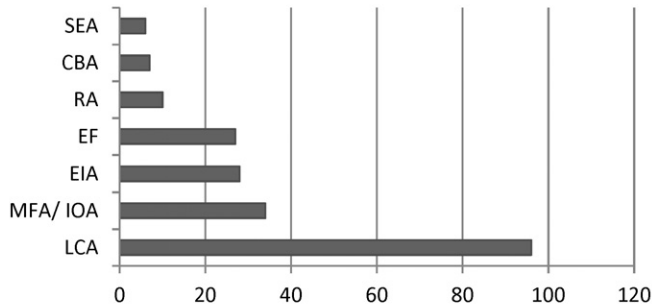

Fig. 3. The most widespread methods in the land use assessment identified according to our BA.

such as the Organization for Economic Co-operation and Development (OECD), the United Nations Environment Program (UNEP), the European Union, and the World Bank which are involved in the development of numerous world projects (Mandelik et al., 2005). Various countries also have EIA in a similar form (e.g. France, Russia) for new or reconstruction projects, even though the procedure can differ in some aspects from country to country.

The development of EIA started with the creation of the National Environmental Protection Act in USA adopted in 1969 (NEPA). It was one of the most important environmental policy decisions in the history of EIA and this idea was soon accepted by other countries and gave birth to EIA elsewhere.

Based on eight steps, namely screening, scoping, impact analysis, mitigation, reporting, review, decision-making and post-monitoring of the planned project, the general objectives of EIA are to ensure proper usage of resources, to protect and improve the environment in a way that does not result in damage to human health and to the natural systems.

3.1.4. Ecological footprint

EF is a method for measuring biologically productive areas, mainly land and sea, needed for human consumption to fulfill needs such as food, water, energy, construction materials etc. (Hong et al., 2009). In other words, it measures the human demand on the biocapacity of the Earth by comparing people's demands and the ability of nature to regenerate resources thus helping to provide a better understanding of resource efficiency in social, economic and environmental dimensions.

The history of EF is connected with the name of Mathis Wackernagel who described this concept and proposed a calculation method. The first publication that made this method well known and widespread was done by William E. Rees (Mathis Wackernagel's supervisor) in the early 1990 (Kitzes et al., 2009). The first version of it was an “appropriated carrying capacity” concept, but later it was changed to the current one.

The main steps of EF depend on its objective and scale: for calculation of a local EF, specific-local statistical data is necessary, for the national level internationally recognized information such as National Footprint Account (NFA) is needed. LCA databases are also commonly used for calculating various indicators in EF analysis (Huijbregts et al., 2008).

3.2. Second screening: review of 60 articles

The main results of our analysis are based on the 60 articles chosen out of 177 articles under the study during the in depth research (summary table of articles reviewed is presented in the supplementary materials).

3.2.1. Geographical distribution of the studies

Our first step was to analyze the geographical distribution of land use impact assessment studies. Fig. 4 shows the countries covered by the study field. This estimation was made according to the educational and scientific institutions where the articles originated. Since certain publications were developed by collaboration between educational establishments from different countries, these studies could be counted several times.

We can see that most of the studies in research on land use impact assessment come from European countries. There were few studies in South America and no study from African countries or Russia. It may be connected with different study orientations in South American countries (e.g. biofuels in Brazil) as well as the fact that the articles studied were in English, rather than Spanish or Portuguese. The African continent does not figure in the chosen sample. The Russian case could also be connected with the language problem, as no Russian journals were under study.

However, in some cases the institution locations could differ from the geographical location of the case study. So we also looked at the distribution of land use assessments within the studied articles. We identified countries that were studied by the above mentioned research teams. We found that the majority of studies do not refer to any specific country; the researchers adopt a generic approach to the impact assessment of the land use. Only 21 articles out of 60 were focused on a particular country-study and included mainly European countries. However, some studies were observed also in the Asia-Pacific region, Brazil, Mexico, Australia and the United States.

3.2.2. Data treatment

As mentioned above, information about the methods could be extracted based on their characteristic description (Table 2).

1. For the first criteria group we could distinguish two main methods: analytical and procedure-oriented. Procedure-oriented methods (EIA) are based on a set of procedures with involvement of different stakeholders, while analytical methods (LCA, MFA, EF) focus mainly on the technical issue and are based on analytical thinking and conclusions.
2. ‘Strategy’ is set of actions to achieve certain results in a long term. Both of the presented strategies (bottom up and top down) use information processing and knowledge ordering, but the top down approach (LCA, EF, EIA) is a hierarchical structure or process that progresses from a large, basic unit to smaller, detailed subunits, whereas the bottom up approach (MFA/IOA, EF) progresses from small or subordinate units to a larger or more important unit. As can be seen, EF has both strategies, which can be explained by its integration on different geographical scales.
3. ‘Necessity of use’ indicates if the method is imposed or used voluntarily. Obligation is usually accompanied with regulations or norms, while voluntary use can be by choice depending on the specific purpose. Unexpectedly, we found more studies on voluntary land use impact assessment methods rather than the imposed one (EIA). This could show the interest and viability of the method developments underpinned by some incentives.
4. ‘Main principle’ describes the basis of the method. Mass balance is the core principle in MFA: accounting materials entering and leaving the system, identifying unknown mass flows. LCA is based on a life cycle approach that integrates all the stages of product life and accounts contribution of the environmental impact in each life cycle stage. In EIA there are several principles, such as ‘participation’ meaning the existence of opportunity for interested people to take part in the process, ‘transparency’ signifying that all the processes should be clear for all the participants, ‘certainty’ meaning that the process should be logical, have identified objectives and time limits etc., all of which are aimed at environmental protection through prevention at quite a local level in an explicitly geographically delimited area. EF is based on the environmental impact in different levels (personal, enterprise, country).

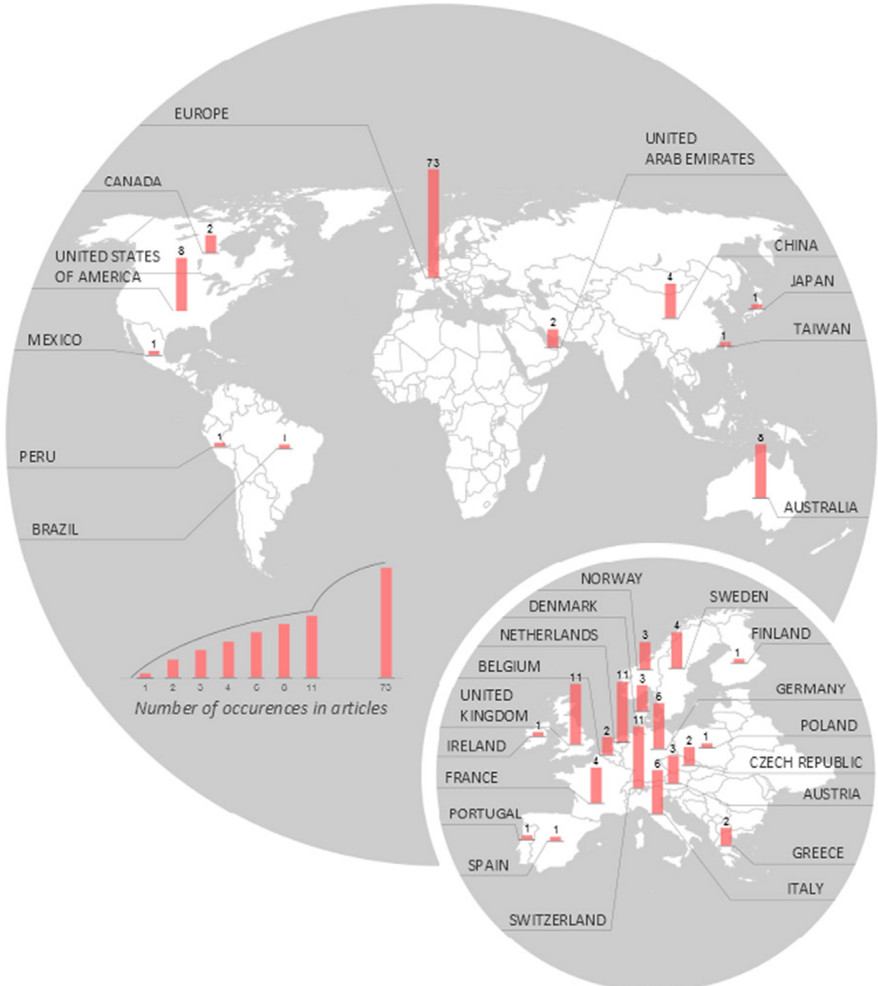

Fig. 4. Geographical distribution of land use impact assessment studies.

Table 3 presents the implicit comparative characteristics of methods based on the bibliometric analysis realized.

5. 'Driving forces' are strongly connected with policy decisions. They could explain to a significant extent the choice of method. We distinguished two main mechanisms that could drive the use of methods, namely regulations and standards with the obligation to comply, and market incentives, driving the behavior of the agents in the market sometimes with the use of the voluntary standard mechanism. That is why we divided our methods into those based on incentives and the ones whose use is reinforced by regulations. Thus, LCA is an incentive method based on the ISO 14001 standards, environmental management standards accredited by the European Committee for Standardization (CEN) giving a market advantage for products that comply with it (Zamboni et al., 2011; Schmidt, 2010; Morselli et al., 2008; Jijakli et al., 2012). MFA is also a voluntary instrument promoted by the companies that want to identify the energy balance or a region that wants to identify a source of pollution (Wiedmann, 2009). EIA, in the majority of cases, is an obligatory procedure. For example, in Europe the EIA Directive 2014/52/EU, side by side with the country specific regulations, imposes the assessment of the potential environmental impact of the planned activity. It aims to protect nature and the quality of living conditions by guaranteeing that projects which may have a negative environmental impact are subjected to an environmental impact assessment before their development is allowed (Treweek, 2009; Liu and Yu, 2009; Muñoz-Piña et al., 2008). EF takes into consideration environmental management systems (ISO 14001 and EMAS) and other kinds of certifications, so also a voluntary method.
6. 'Application area' shows the use in practice of one method or another. Thus, for LCA the most common application scale is product or service because LCA concerns the whole life cycle of the product or the service from raw material extraction to its end-of-life; it is also included in the manufacturing stages and product system in which LCA is applied as well (Canals et al., 2009; Schmidt, 2010; Nielsen et al., 2007; Gerbens-Leenes et al., 2003; Pfister et al., 2011). Since MFA deals with materials and associated flows, the efficient use of natural resources and energy in process chains within a defined space, its main application is materials, processes and territory (Wiedmann, 2009; Steen-Olsen et al., 2012; Wiedmann et al., 2007). The EF application scale is characterized by land capacity and territory, encapsulated in the method definition (Huijbregts et al., 2008; Bagliani et al., 2008; Kitzes et al., 2009; Santamouris et al., 2007; Sutton and Costanza, 2002; Denholm and Margolis, 2008). For EIA, project planning is an essential part together with a geographically delimited territory, since there is a significant impact from human activity (Treweek, 2009). It is also important to note that all the methods except LCA have a geographical context, although the first steps towards performing territory-based LCA have already been observed in some studies.
7. For 'target audience' means people that can be interested in or concerned by the use of the methods. LCA provides designers, engineers,

decision makers etc. with the necessary information for taking decisions at each life-cycle stage of a product or a system under a study (Halleux et al., 2008; Morselli et al., 2008; Heuvelmans et al., 2005). For companies and business it is a kind of demonstration of their "environmentally friendly" behavior, i.e. "green" marketing. MFA has a wide use in industrial areas, first of all for analyzing the efficiency of materials and energy. In addition, it is used for policy decision making in environmental and resource management (Steinberger et al., 2010). EF helps public authorities, business etc. to understand the ecological limits and evaluate future situations (Kitzes et al., 2009; Hong et al., 2009; Hoekstra, 2009). As well as LCA, in EF there is an environmentally sensitive vision, but it is aimed more at future marketing. EIA involves a complex evaluation of different types of potentially negative impacts of a planned activity which allows decision makers to find better ways of integrating environmental and socio-economic solutions (Brouwer and Van Ek, 2004). It is also very useful for industries in terms of organizing their management of environmental performance.

8. There are a large number of ways to define environmental indicators. In our work we used DPSIR approach (Driving forces–Pressures–State–Impact–Responses), in the base of which we analyzed the studied sources on Driving forces, Pressures, State, Impact, or Responses indicators used in the four chosen methods. 'Driving forces' are the factors (social, economic, ecological) that cause the system changes, for example, resource use, tourism development etc. Pressures are the anthropogenic factors that influence the system by causing the environmental changes, for example pollution. State is a system condition at the specific time; it can include a wide range of features from quantitative and qualitative description of ecosystems to human living conditions, for example, water quality. Impact of an activity is the effects of such activity on ecosystems and people health. Responses are the policy actions to prevent, reduce the possible negative consequences.

So, MFA provides environmental pressure indicators which define socio-economic activities that are the reason for the environmental impact, i.e. direct material input (DMI), total material output (TMO), domestic material consumption (DMC) (Wiedmann, 2009; Steinberger et al., 2010). LCA provides impact indicators, among which there are mid-point (potential) and end-point indicators. The mid-point indicators characterize different environmental concerns, such as climate change, acidification, eutrophication etc. The end point indicators refer to actual damage categories, such as damage to resources, human health and ecosystems (Morselli et al., 2008; Heuvelmans et al., 2005; Jijakli et al., 2012). In EIA there are different indicators (Brouwer and Van Ek, 2004) depending on the main purpose, for example, five indicators for environmental pollution (air, water, soil, solid wastes and noise) discussed in the study (Liu and Yu, 2009). EF is itself the indicator that accounts for an agent's (a person, a business or a country) demand on worldwide resources (Bagliani et al., 2008; Santamouris et al., 2007; Hong et al., 2009; Hoekstra, 2009).

9. Based on the paper analysis, we distinguished two principal types of data sources used in the studies: primary sources and secondary ones (Fig. 5). As primary data we included various kinds of experimental data including original sampling results, laboratory tests, remote-sensed data, i.e. all the information collected from the "first-hand" experience by the researchers. Secondary data included different types of databases and reports, case studies, reviews or statistics, i.e. not directly collected by the user.

According to Fig. 5 we can see that EIA and MFA use secondary data including databases, reports etc. Usually the MFA studies were based on data from Eurostat, and OECD sources (Steinberger et al., 2010; Schandl and West, 2010; Würtenberger et al., 2006), but some of MFA studies use the data sources depending on their purposes. For example, the Global Trade Analysis Project (Bruckner et al., 2012) also included data about trade policies. Another example is The United Nations Statistics Department's COMTRADE global trade database that was used to translate money and mass units into hectares in Morana et al.'s (2008). EF and LCA was found to use both data types. LCA is usually based on secondary data from recognized databases, but in our study we found that only half of the studies were based on databases, for example, Ecoinvent (Halleux et al., 2008; Huijbregts et al., 2008), and the other half used primary data such as sampling (Thomassen et al., 2009) (Fig. 5). The EF studies can consider a wide range of data sources, for example WWF Living Planet reports that contain EF data for European countries (Bagliani et al., 2008), United Nation Food and Agricultural Organization databases, the United Statistics Division, the International Energy Agency (Kitzes et al., 2009) as well as satellite data used for market and non-market value estimation (Sutton and Costanza, 2002).

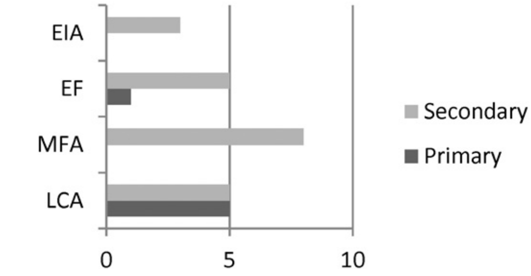

Fig. 5. Data types used in different methods.

10. Concerning the scale of the studies, we could distinguish global, national, regional, local and project scales (Fig. 6). In global scale we included all the studies about the environmental impact on the whole planet, the national scale we limited to country boundaries, the regional scale operates within different physical–geographical and administrative regions, local ones focus on small locally available areas (scale of inhabited localities, districts, parcels etc.) while project level operates within specified project activity.

LCA, MFA, EF and EIA could operate on different scales. LCA operates mainly on the regional scale (61.1%), less on the global (33.3%) and the local ones (5.6%). For example, Schmidt (2010) describes an LCA of rapeseed and palm oil on both local and global scales, Gerbens-Leenes et al. (2003) analyses food production systems on different scales including local, regional and global. A lot of authors (Morselli et al., 2008; Heuvelmans et al., 2005; Cederberg et al., 2010; Patterson et al., 2011) discuss LCA on the regional scale. MFA operates mainly on the national scale (64.7%) (Hong et al., 2009; Steinberger et al., 2010), because of the availability of data, for example Eurostat for Europe; less on the regional (29.4%) (Schandl and West, 2010; Morana et al., 2008) or global (5.9%) (Bruckner et al., 2012). EF operates on various scales from local (25%) to global (9.4%) as described by (Santamouris et al., 2007;

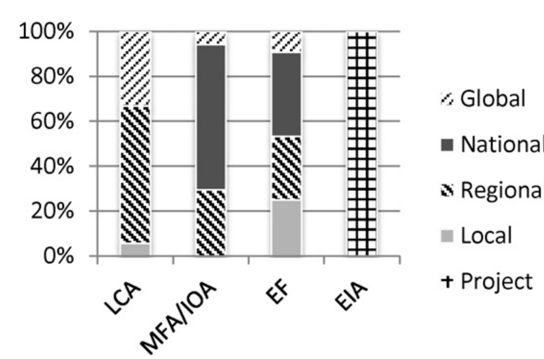

Fig. 6. Scale distribution in methods.

Denholm and Margolis, 2008; Kitzes et al., 2009; Chen and Chen, 2007) etc. EIA operates on the project scale, point-source oriented evaluation of environmental impacts, taking into account the specific local situation and environmental conditions (Nielsen et al., 2007; Brouwer and Van Ek, 2004; Muñoz-Piña et al., 2008).

11. When none of the methods could give exhaustive assessments, some studies used several complementary methods. We identified this as the "combination of methods" criterion, i.e. when different methods have implicit interconnections (e.g. LCA and MFA), and the output of one (here MFA) could be used as an input for the other (here LCA), thus they have the potential of being used together to give a more explicit assessment. According to our analysis, the most common combination of methods is: LCA–MFA/IOA — 10 times, LCA–EF — 10, MFA–EF — 7, EIA–EF — 2 and EIA–MFA — once. For example, in the study of waste incineration (Morselli et al., 2008) mainly uses the LCA method, but when knowledge of the associated flows and processes was required for environmental evaluation, MFA was used as an additional method to identify these flows for the LCA study. In Huijbregts et al. (2008), the Ecological Footprint concept includes product life cycle analysis (LCA) by calculating product EF from LCA data of more than 2500 services and products, including different LCA stages. Thus, in some cases one method can complement another depending on the purpose of the research.
12. To identify which land occupation and use has received most attention, we analyzed the land use types mentioned in the articles. Among existing classifications, we decided to choose European database *Corine Land Cover* (CLC) (Corine Land Cover) widely used in European countries. This includes five general land uses with subdivisions. It was adopted as a basis of this work to analyze land uses of four methods (LCA, MFA–IOA, EF, EIA). Among the five CLC land uses only four were found in our study sample: *artificial surfaces* including built-up land, road and rail networks, and green urban areas; *agricultural land* including pasture, arable and croplands; *forests* and *wetland* (Fig. 7). In Fig. 7 we can see that agricultural land use is the most studied of the four categories, accounting for 47.6% and 20 articles, followed by forests with 28.6% and 12 articles, artificial surfaces 21.4% and 9 articles, and finally wetlands were the least studied with 2.4% and 1 article. This is undoubtedly due to the fact that agricultural land use is the one with the highest direct land use per unit of output.

In LCA and EF agricultural land is the most studied land use type (Bagliani et al., 2008; Kitzes et al., 2009; Karp and Shield, 2008; Halleux et al., 2008; Huijbregts et al., 2010; Gerbens-Leenes et al., 2003; Sutton and Costanza, 2002; Denholm and Margolis, 2008), etc. LCA focuses mainly on the environmental impact of different agricultural products (e.g. crops, vegetables). In EF the main focus is the land required for human habitation, so it is not surprising to observe a lot of studies on agricultural land as well as forest studies. In MFA agricultural land is also of interest (Karp and Shield, 2008), mostly in terms of agricultural flows of imports and exports within land use. In EIA more attention is paid to forests (Muñoz-Piña et al., 2008), less to agricultural land and wetland (Findlay and Bourdages, 2000). We should note that EIA is the only methods to cover impact assessment on wetlands, but it does not include artificial surfaces. Forests are under the spotlight because any project activity could lead to forest degradation and could have damaging effects on forests which have a high biodiversity value due to the ecosystem services they provide.

13. Despite the fact that integration of GIS and RS is widely used in land use impact assessment studies (Meshesha et al., 2014; Chen et al., 2015; Yang et al., 2015), our analysis showed that the application of these tools was performed only in 8 articles out of 60. As we can see, GIS and RS within land use are generally found in the more recent studies, and were poorly regarded in earlier years, also noted by Chen et al. (2015). In Fig. 8 the frequency of GIS and RS application in the methods within the studied articles is shown (the numbers represent the quantity of articles; one article could contain several methods). In addition, GIS was mentioned in 3 articles, but this tool was not actually used. According to our results, remote sensing is used more often than GIS in LCA and EF studies. No information was found about RS for EIA. For example, in the article of Pfister et al. (2011) remote sensing data is used for spatial distributions of yield and production volumes of crops in LCA and EF. In the study of Steinberger et al. (2010) GIS data was used to obtain the centroid latitude of a country's land mass in MFA/IOA and EF. Curran et al. (2011) synthetize the use of both remote sensing and GIS data within biodiversity indicators across hierarchical components in LCA.
14. To better understand the outcomes of our research, we also looked at the specific subjects the land use impact assessment encompassed (Fig. 9). The subjects were grouped as follow by their content: 'Consumption and production' subject relates mainly to consumption of resources and materials, food production, production within international trade. 'Biodiversity and ecosystem services' describes mainly changes in biodiversity and in the environment caused by anthropogenic activity. 'Emission and wastes' describes different types of emissions and wastes, their impact and ways of reduction. 'Agricultural' focuses on agricultural systems, their environmental impact, use of fertilizers, or farming practices. In 'Energy, including bioenergy and biofuels' different types of renewable energy sources, fossil energy; biomass materials are discussed. To exclude double counting, the articles on biofuels were not included in the 'Production and consumption' category. 'Specific subjects' covers studies aiming at descriptive characteristics of methods, their adaptation and utilization in the general way. 'Others' included the topics that did not fit to any other categories.

The topics presented in the articles vary significantly, so several subjects can be studied in one article. In addition, since several methods could be discussed in one article, the same subject could be studied by each method.

In Fig. 9 we can see that 'Consumption and production' is the most widespread area of land use impact assessment within the LCA, MFA and EF (Bagliani et al., 2008; Ridoutt and Pfister, 2010; Wiedmann

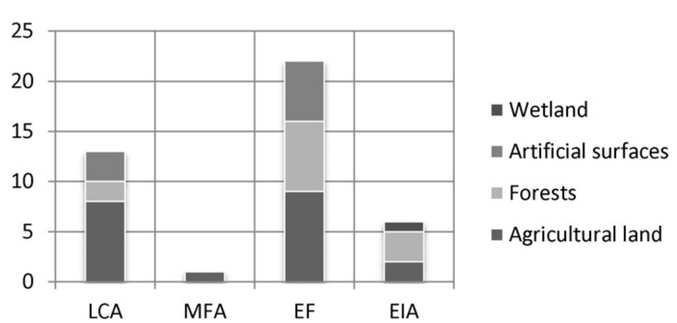

Fig. 7. Land use types studied within LCA, MFA, EF, and EIA.

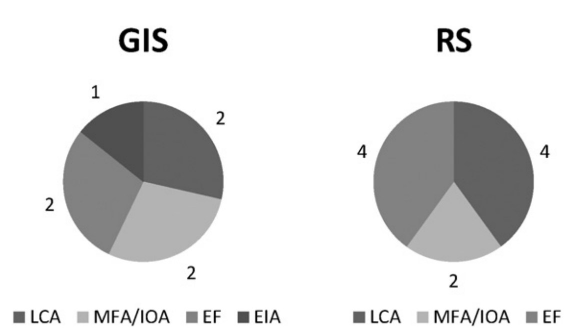

Fig. 8. Frequency of GIS and RS application in methods.

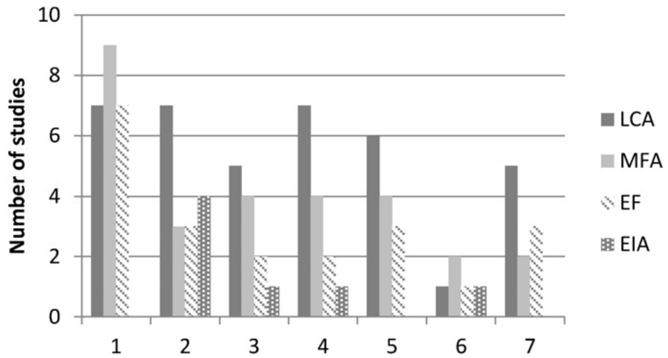

Fig. 9. Subject division: 1 — Consumption and production, 2 — Biodiversity and ecosystem services, 3 — Emissions and wastes, 4 — Agriculture, 5 — Energy, including bioenergy and biofuels, 6 — Specific subjects, 7 — Others.

et al., 2006; Steen-Olsen et al., 2012; Pfister et al., 2011; Wiedmann et al., 2007; Bruckner et al., 2012; Chen and Chen, 2007; Peters et al., 2010). This is probably due to the growing interest in sustainable production and consumption of products in recent decades. LCA covers all topics but the 'specific subject' studied the least. MFA focuses on agriculture, energy, bioenergy, and biofuels, but less attention is paid to biodiversity and ecosystem services (Morselli et al., 2008; Hong et al., 2009; Steinberger et al., 2010; Schröder et al., 2011; Patterson et al., 2011). EF gives more consideration to biodiversity and ecosystem services, energy and biofuels than to emissions, wastes, or agriculture (Zhang, 2008; Huijbregts et al., 2010; Hong et al., 2009; Sutton and Costanza, 2002). Almost half of EIA papers focused on biodiversity and ecosystem services with the purpose of integrating biodiversity considerations and decisions into the EIA process (Treweek, 2009; Findlay and Bourdages, 2000; Zhang, 2008; Liu and Yu, 2009).

4. Conclusion and discussion

4.1. Conclusion

We reviewed a wide range of articles, using various criteria to obtain the best comprehension of methods and identify which method is the most useful and widespread in land use assessment. It was found that there is a variety of methods that could be used in this issue, but the most common are LCA, MFA/IOA, EIA and EF. It is quite difficult to state which one is the most promising because each has their own particularities and specific features. According to our analysis, LCA is the most widespread nowadays, but it does not mean it is the most useful one. Some of the studies included a combination of methods that seems to us a good strategy to deal with the challenges of a single method use in the land use assessment research. We therefore recommend using this approach which can give a fuller research vision and better results by combining the different aspects of each method. The choice of method combination depends on the individual study.

Our analysis has shown the sharp increase of interest on land use impact assessment since 1992. Even though the bibliometric analysis was done for the period of 1975–2013, little research was done between 1976 and 1991.

It is important to note that LCA and EIA were created simultaneously and both methods appeared as a result of growing awareness of the environmental issues (energy resources scarcity, need of increase in resource efficiency, pollution issues etc.).

According to the geographical distribution analysis of land use impact assessment studies (Fig. 4), Europe is characterized by a large number of studies. This indicates that, despite being highly developed industrially, the agricultural sector remains one of the most important in European countries, especially given the importance of issues such as food self-sufficiency in European countries and research on new ways to valorize agricultural residues as a renewable energy sources.

As can be seen from Table 2, there is, in fact, only one mandatory assessment method was identified: EIA. The others are voluntary. This raises the question 'why is EIA not the most widespread method in the study, if it is compulsory? This could be explained by the fact that industries often fund the research and favor LCA which offers them opportunities to find niche markets with so-called environmentally friendly products, while EIA is a more formal approach.

4.2. Discussion

4.2.1. Limits

The first limit we faced was the absence of generally accepted definitions of "method", "tool" and "methodology", which could be confusing. For example, in Nielsen et al. (2007); Roberts et al. (2010) LCA is identified as a tool, but in the articles of Brentrup et al. (2002); Basset-Mens et al. (2006), and Morselli et al. (2008) LCA described as a methodology, while in the work of Thomassen et al. (2009) and Würtenberger et al. (2006) LCA is presented as a method. In addition, in articles of Andersson and Ohlsson (1999) and Finnveden (2000), the authors used both "methodology" and "tool" to describe LCA. Ecological Footprint is described by Chen and Chen (2007) (p. 356), Hong et al. (2009); Kitzes et al. (2009) as a method, but by Bagliani et al. (2008) as a methodology. Environmental Impact Assessment is presented by Treweek (2009) as "a potential mechanism for implementing principles of sustainability and "wise use". Liu and Yu (2009) define EIA "as the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals before major decisions are taken and commitments made". Finnveden (2000) (p. 229) defines EIA as a tool. Finnveden (2000) (p. 229) defines SFA and MFA as environmental system analysis tools. To clarify the heterogeneity of definitions we identified all three terms (presented in the Introduction) explaining the way we used them in our study.

It has to be admitted that the geographical distribution analysis did allow one article to be counted several times, depending on the number of institutions taking part in the research. Thus, in the article «A research agenda for improving national Ecological Footprint accounts» (Kitzes et al., 2009) for example, 13 international research centers participated. This led to each country taking part in the study being counted.

As previously mentioned, data sources were divided into two types: primary and secondary. However, in some articles the explicit information about data sources was absent so that, in some cases, we had to make hypotheses about the data sources.

In addition, the information about land use type was also limited and the majority of articles studied were based on general land use research.

Another weak point of the analysis could be different understandings of the notion of 'scale' in our sample, especially for local and regional ones that were understood differently in different articles. First of all, the terms scale and level were quite often used interchangeably, thus causing some confusion. In some articles regional scale is equivalent to regional level i.e. the level of regional administrative organization (Wiedmann et al., 2006; Morselli et al., 2008; Zhang, 2008; Wiedmann, 2009; Patterson et al., 2011). In other studies the region is used as an equivalent to "country" (e.g. Huijbregtsa, 2007). Some authors use the term 'regions' to name economic development areas such as Europe, Latin America, or Asia (Steen-Olsen et al., 2012; Uherek et al., 2010) that may have similar technology or a similar economic structure (e.g. Bruckner et al., 2012), or regions of a socio-economic development such as Asia-Pacific region (e.g. Schandl and West, 2010). Some other authors, when describing regional scale, mean natural regions such as the biomes, biogeographic or climatic regions (Brentrup et al., 2002; Heuvelmans et al., 2005; Koellner et al., 2013). What is more, some use different understandings of regional scale in the same article, for example Wiedmann et al. (2007) describe a country under regional scale, and an administrative region within a country, as well as world regions with the same technology, and regions as an area of the socio-economic activity. Basset-

Mens et al. (2006) use the notion of a region as an administrative unit, region of intensive agriculture and agro-climatic (sub) region in the same article. The understanding of local scale could also be confusing, for example Schmidt (2010) understands 'European' as a local scale opposing it to the global one; Santamouris et al. (2007) under 'local' understand community level. This different use of region scale terminology often poses problems in interpretation of the results, so should be considered when using the output of each study.

It should be noted that the studied methods support land use planning decisions that are crucial for land consumption, in different manner. The only method identified in our study to be directly applied to land use planning is EIA. Nevertheless, in our sample just a marginal number of articles used this method, and furthermore these studies found that EIA alone is not sufficient for a full assessment. So Brouwer and van Ek (2004) advised integrating ecological, economic and social impact assessment or multi-criteria analysis to establish alternative flood control policies in the Netherlands, rather than just EIA; Muñoz-Piña et al. (2008) propose completing the EIA policy measure by Payment for Hydrological Environmental Services (PSAH) Program in Mexico's forests confronted by high deforestation and water scarcity problem. The other three methods are analytical MFA, EF, and LCA. MFA and EF in their turn could be indirectly used in land use planning in local and regional levels to compare certain parameters, e.g. land consumption dedicated to a studied product within one country (Denholm and Margolis, 2008). These methods could be used to compare resource consumption, including land, in different countries (Bagliani et al., 2008; Siche et al., 2008; Hoekstra, 2009; Steen-Olsen et al., 2012), and sometimes within national Ecological Footprint accounts (Wiedmann et al., 2006; Chen and Chen, 2007; Kitzes et al., 2009). Most LCA studies (e.g. Gerbens-Leenes et al., 2003; Halleux et al., 2008) are made at regional, national, and global scales focusing on comparison of production chains, using a simplified land use change indicator and are too generic to be used for land use planning.

4.2.2. Perspectives

One of the promising directions for increasing the quality and completeness of methods for land use impact assessment is understanding the impact of land use on biodiversity and ecosystem services. In the studied literature we found out at least four publications offering methods for biodiversity and/or ecosystem services accounting within the land use impact assessment, the ones devoted to LCA. Some authors (Curran et al., 2011) point out that functional and structural attributes of biodiversity are largely neglected at present. Nevertheless, three of the five drivers of biodiversity loss and ecosystem services as identified by the Millennium Ecosystem Assessment are represented in current impact categories of LCA, namely habitat change, climate change and pollution, although the other two, invasive species and overexploitation are missing. We are strongly agree with Michelsen (2008) who states that more work is needed to establish a methodology for land use impact on biodiversity in LCIA. The author proposes the application of indirect indicators (Ecosystem Scarcity, Ecosystem Vulnerability, and Conditions for Maintained Biodiversity) to assess the impact on biodiversity from land use changes in LCIA applied with globally available data on ecoregions, and identifies the challenge as developing sound key factors for the relevant ecosystems. To enhance the role of ecosystems in engineering decision-making, Zhang et al. (2010) propose an approach that includes the direct and indirect role of ecosystems in LCA through ecosystem services concept. His Ecologically Based LCA includes a number of provisioning, regulating, and supporting ecosystem services as inputs to a life cycle model on the process or economy scale. Finally, Koellner et al. (2013) propose methods for land use impact assessment in LCA with the modeling of several impact pathways covering biodiversity and ecosystem services, but on a global scale. Further research on indicators and the ways land use impact could be assessed is needed to deepen the current study, starting with local scale research.

The other promising directions that should be mentioned are deepening the research on the driving forces of land use impact on the environment, more detailed research of the temporal and spatial components is needed in this field, especially the use of such tools as remote sensing and GIS and spatial models. The driving forces of existing and future land use studies are of importance. For instance in Table 3 we found that the most used methods in the sample are incentive driven (e.g. LCA, MFA), and only one method under the analysis (EIA) is regulation driven (EIA), even though the importance of the existing and new published research in Environmental Impact Assessment should be noted (e.g. Recatalá and Sacristan, 2014; Chen et al., 2015). Nevertheless, we emphasize the need for more research in incentive mechanisms that will be useful in the EIA application. One of the advantages of this last method is that it uses the finest scale among the ones studied (Fig. 6) which improves the level of detail in the assessments. Moving from global to local scales/levels (small administrative units level, or catchment scale) in future research is also essential. Moreover, up to date research found it was important to elaborate spatio-temporal assessments, for instance in the works of Chen et al. (2014) or Chen et al. (2015). The use of GIS, remote sensing and spatial models could help this task. Meshesha et al. (2014) therefore promote satellite image use in the socio-environmental impact of land use change and land degradation, and Mouri and Aisaki (2015) show the advantages of the mass-balance model used together with a GIS-based analytical tool to represent the total and specific impacts of human as well as livestock activities in rural catchment conditions.

In conclusion we should emphasize the necessity of a common agreement in the scientific community on clear definitions of methods, methodologies and tools, as well as a common classification of scales and levels which would significantly improve communication and articulation among the studies.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.eiar.2016.02.002.

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References

Andersson, K., Ohlsson, T., 1999. Life cycle assessment of bread produced on different scales. Int. J. Life Cycle Assess. 4 (1), 25–40.

Bagliani, M., Bravo, G., Dalmazzone, S., 2008. A consumption-based approach to environmental Kuznets curves using the ecological footprint indicator. Ecol. Econ. 65 (3), 650–661.

Baneyx, A., 2008. "Publish or perish" as citation metrics used to analyze scientific output in the humanities: international case studies in economics, geography, social sciences, philosophy, and history. Arch. Immunol. Ther. Exp. 56, 363–371.

Basset-Mens, C., Anibar, L., Durand, P., van der Werf, H.M.G., 2006. Spatialised fate factors for nitrate in catchments: modelling approach and implication for LCA results. Sci. Total Environ. 367, 367–382.

Brentrup, F., Kfisters, J., Lammel, J., Kuhlmann, H., 2002. Life cycle impact assessment of land use based on the hemeroby concept. Int. J. Life Cycle Assess. 7 (6), 339–348.

Brouwer, R., Van Ek, R., 2004. Integrated ecological, economic and social impact assessment of alternative flood control policies in the Netherlands. Ecol. Econ. 50 (1–2), 1–21.

Bruckner, M., Giljum, S., Lutz, C., Wiebe, K.S., 2012. Materials embodied in international trade — global material extraction and consumption between 1995 and 2005. Glob. Environ. Chang. 22 (3), 568–576.

Brunner, P., Rechberger, H., 2005. Practical Handbook of Material Flow Analysis.

Canals, L.M., Chenoweth, J., Chapagain, A., Orr, S., Antón, A., Clift, R., 2009. Assessing freshwater use impacts in LCA: part I—inventory modelling and characterisation factors for the main impact pathways. Int. J. Life Cycle Assess. 14, 28–42.

Cederberg, C., Persson, U.M., Neovius, K., Molander, S., Clift, R., 2010. Including carbon emissions from deforestation in the carbon foot print of Brazilian beef. Environ. Sci. Technol. 45 (5) (pages A-G).

Chen, B., Chen, G.Q., 2007. Modified ecological footprint accounting and analysis based on embodied exergy—a case study of the Chinese society 1981–2001. Ecol. Econ. 61 (2–3), 355–376.

Chen, L., Ang, X., Chen, L., Potter, R., Li, Y., 2014. A state-impact-state methodology for assessing environmental impact in land use planning. Environ. Impact Assess. 46, 1–12.

Chen, L., Yang, X., Chen, L., Li, L., 2015. Impact assessment of land use planning driving forces on environment. Environ. Impact Assess. 55, 126–135.
Coroama, V.C., Hilty, L.M., 2014. Assessing Internet energy intensity: a review of methods and results. Environ. Impact Assess. 45, 63–68.
Curran, M., de Baan, L., de Schyver, A.N., van Zelm, R., Hellweg, S., Koellner, T., 2011. Toward meaningful end points of biodiversity in life cycle assessment. Environ. Sci. Technol. 45, 70–79.
Denholm, P., Margolis, R.M., 2008. Land-use requirements and the per-capita solar footprint for photovoltaic generation in the United States. Energ Policy 36 (9), 3531–3543.
Doka, G., Hillier, W., Kaila, S., Kollner, T., Kreibig, J., Muys, B., Quijano, J.G., Salpakivi-Salomaa, P., Schweinle, J., Swan, G., Wessman, H., 2002. The assessment of environmental impacts caused by land use in the life cycle assessment of forestry and forest products. Final Report of Working Group 2 "Land Use" of COST Action E9.
Findlay, C.S., Bourdages, J., 2000. Response time of wetland biodiversity to road construction on adjacent lands. Conserv. Biol. 14 (1), 86–94.
Finnveden, G., 2000. On the limitations of life cycle assessment and environmental systems analysis tools in general. Int. J. Life Cycle Assess. 5 (4), 229–238.
Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., et al., 2005. Global consequences of land use. Science 309 (5734), 570–574.
Gerbens-Leenes, P.W., Moll, H.C., Schoot Uiterkamp, A.J.M., 2003. Design and development of a measuring method for environmental sustainability in food production systems. Ecol. Econ. 46 (2), 231–248.
Giarola, S., Shah, N., Bezzo, F., 2012. A comprehensive approach to the design of ethanol supply chains including carbon trading effects. Bioresour. Technol. 107, 175–185.
Halleux, H., Lassaux, S., Renzoni, R., Germain, A., 2008. Comparative life cycle assessment of two biofuels ethanol from sugar beet and rapeseed methyl ester. Int. J. Life Cycle Assess. 13 (3), 184–190.
Heuvelmans, G., Muys, B., Feyen, J., 2005. Extending the life cycle methodology to cover impacts of land use systems on the water balance (7 pp). Int. J. Life Cycle Assess. 10 (2), 113–119.
Hoekstra, A.Y., 2009. Human appropriation of natural capital: a comparison of ecological footprint and water footprint analysis. Ecol. Econ. 68, 1963–1974.
Hong, L., Dong, Z.P., Chunyu, H., Wang, G., 2009. Evaluating the effects of embodied energy in international trade on ecological footprint in China. Ecol. Econ. 62, 136–148.
Hu, X., Zhu, J., Ding, Q., 2011. Environmental life-cycle comparisons of two polychlorinated biphenyl remediation technologies: incineration and base catalyzed decomposition. J. Hazard. Mater. 191 (1–3), 258–268.
Huijbregts, M.A.J., Hellweg, S., Frischknecht, R., Hungerbühler, K., Hendriks, A.J., 2008. Ecological footprint accounting in the life cycle assessment of products. Ecol. Econ. 64, 798–807.
Huijbregts, M.A.J., Hellweg, S., Frischknecht, R., Hendriks, H.W.M., Hungehbühler, K., Hendriks, A.J., 2010. Cumulative energy demand as predictor for the environmental burden of commodity production. Environ. Sci. Technol. 44 (6), 2189–2196.
Jijakli, K., Arafat, H., Kennedy, S., Mande, P., Theeyattuparampil, V.V., 2012. How green solar desalination really is? Environmental assessment using life-cycle analysis (LCA) approach. Desalination 287, 123–131.
Karp, A., Shield, I., 2008. Bioenergy from plants and the sustainable yield challenge. New Phytol. 179 (1), 15–32.
Kitzes, J., Galli, A., Bagliani, M., Barrett, J., Dige, G., Ede, S., et al., 2009. A research agenda for improving national ecological footprint accounts. Ecol. Econ. 68 (7), 1991–2007.
Koellner, T., Scholz, R.W., 2007. Assessment of land use impacts on the natural environment. Part 1: an analytical framework for pure land occupation and land use change. Int. J. Life Cycle Assess. 12 (1), 16–23.
Koellner, T., de Baan, L., Beck, T., Brandao, M., Civit, B., Margni, M., et al., 2013. UNEP-SETAC guideline on global land use impact assessment on biodiversity and ecosystem services in LCA. Int. J. Life Cycle Assess. 18, 1188–1202.
Lambin, E., Meyfroid, P., 2011. Global land use change, economic globalization, and the looming land scarcity. PNAS 108 (9), 3465–3472.
Lenzen, M., Dey, C., Foran, B., 2004. Energy requirements of Sydney households. Ecol. Econ. 49 (2004), 375–399.
Leontief, W., 1986. Input–Output Economics. Published by Oxford University Press, New York.
Liu, K.F.R., Yu, C.W., 2009. Integrating case-based and fuzzy reasoning to qualitatively predict risk in an environmental impact assessment review. Environ. Model. Assess. 24, 1241–1251.
Loiseau, E., Junqua, G., Roux, P., Bellon-Maurel, V., 2012. Environmental assessment of a territory: an overview of existing tools and methods. J. Environ. Manag. 112, 213–225.
Mandelik, Y., Dayan, T., Feitelson, E., 2005. Planning for biodiversity: the role of ecological impact assessment. Conserv. Biol. 19, 1254–1261.
McGregor, S.L., Murname, J.A., 2010. Paradigm, methodology and method: intellectual integrity in consumer scholarship. Int. J. Consum. Stud. 34 (4), 419–427.
Meshesha, D.T., Tsunekawa, A., Tsubo, M., Ali, S.A., Haregeweyn, N., 2014. Land-use change and its socio-environmental impact in Eastern Ethiopia's highland. Reg. Environ. Chang. 14, 757–768.
Michelsen, O., 2008. Assessment of land use impact on biodiversity. Proposal of a new methodology exemplified with forestry operations in Norway. Int. J. Life Cycle Assess. 13 (1), 22–31.
Morana, D.D., Wackernagel, M.C., Kitzes, J.A., Heumann, B.W., Phan, D., Goldfinger, S.H., 2008. Trading spaces: calculating embodied ecological footprints in international trade using a Product Land Use Matrix (PLUM). Ecol. Econ. 68 (7), 1938–1951.
Morselli, L., De Robertis, C., Luzi, J., Passarini, F., Vassura, I., 2008. Environmental impacts of waste incineration in a regional system (Emilia Romagna, Italy) evaluated from a life cycle perspective. J. Hazard. Mater. 159 (2–3), 505–511.
Mouri, G., Aisaki, N., 2015. Using land-use management policies to reduce the environmental impacts of livestock farming. Ecol. Complex. 22, 169–177.
Muñoz-Piña, C., Guevara, A., Torres, J.M., Braña, J., 2008. Paying for the hydrological services of Mexico's forests: analysis, negotiations and results. Ecol. Econ. 65 (4), 725–736.
Nielsen, P.H., Oxenbøll, K.M., Wenzel, H., 2007. Cradle-to-gate environmental assessment of enzyme products produced industrially in Denmark by novozymes A/S. Int. J. Life Cycle Assess. 12 (6), 432–438.
Patterson, T., Esteves, S., Dinsdale, R., Guwy, A., 2011. Life cycle assessment of biogas infrastructure options on a regional scale. Bioresour. Technol. 102 (15), 7313–7323.
Peters, R., Rowley, H.V., Wiedemann, S., Tucker, R., Short, M.D., Schulz, M., 2010. Red meat production in Australia: life cycle assessment and comparison with overseas studies. Environ. Sci. Technol. 44, 1327–1332.
Pfister, S., Bayer, P., Koehler, A., Hellweg, S., 2011. Environmental impacts of water use in global crop production: hotspots and trade-offs with land use. Environ. Sci. Technol. 45, 5761–5768.
Recatalá, L., Sacristan, D., 2014. A minimum indicator set for assessing resources quality and environmental impacts at planning level in a representative area of the European Mediterranean region. Ecol. Indic. 45, 160–170.
Reid, R., Kruska, R., Muthui, N., Taye, M., Wotton, S., et al., 2000. Land-use and land-cover dynamics in response to changes in climatic, biological and socio-political forces: the case of southwestern Ethiopia. Landsc. Ecol. 15, 339–355.
Ridoutt, B.G., Pfister, S., 2010. A revised approach to water footprinting to make transparent the impacts of consumption and production on global freshwater scarcity. Glob. Environ. Chang. 20, 113–120.
Roberts, K.G., Gloy, B.A., Joseph, S., Scott, N.R., Lehmann, J., 2010. Life cycle assessment of biochar systems: estimating the energetic, economic, and climate change potential. Environ. Sci. Technol. 44, 827–833.
Russell, M., Rogers, J., Jordan, S., Dantin, D., Harvey, J., Nestlerode, J., et al., 2011. Prioritization of ecosystem services research: Tampa Bay demonstration project. J. Coast. Conserv. 15, 647–658.
Santamouris, M., Paraponiaris, K., Mihalakakou, G., 2007. Estimating the ecological footprint of the heat island effect over Athens, Greece. Clim. Chang. 80 (3–4), 265–276.
Schandl, H., West, J., 2010. Resource use and resource efficiency in the Asia-Pacific region. Glob. Environ. Chang. 20 (4), 636–647.
Schmidt, J.H., 2010. Comparative life cycle assessment of rapeseed oil and palm oil. Int. J. Life Cycle Assess. 15 (2), 183–197.
Schröder, J.J., Smit, A.L., Cordell, D., Rosemarin, A., 2011. Improved phosphorus use efficiency in agriculture: a key requirement for its sustainable use. Chemosphere 84, 822–831.
SCImago Journal & Country Ran. n.d. Retrieved from http://www.scimagojr.com/
Siche, J.R., Agostinho, F., Ortega, E., Romeiro, A., 2008. Sustainability of nations by indices: comparative study between environmental sustainability index, ecological footprint and the energy performance indices. Ecol. Econ. 66, 628–637.
Steen-Olsen, K., Weinzettel, J., Cranston, G., Ercin, A.E., Hertwich, E.G., 2012. Carbon, land, and water footprint accounts for the European Union: consumption, production, and displacements through international trade. Environ. Sci. Technol. 46, 10883–10891.
Steinberger, J.K., Krausmann, F., Eisenmenger, N., 2010. Global patterns of materials use: a socioeconomic and geophysical analysis. Ecol. Econ. 69 (5), 1148–1158.
Sutton, P.C., Costanza, R., 2002. Global estimates of market and non-market values derived from nighttime satellite imagery, land cover, and ecosystem service valuation. Ecol. Econ. 41 (3), 509–527.
Thomassen, M.A., Dolman, M.A., Van Calker, K.J., de Boer, I.J.M., 2009. Relating life cycle assessment indicators to gross value added for Dutch dairy farms. Ecol. Econ. 68 (8–9), 2278–2284.
Treweek, J., 2009. Ecology and environmental impact assessment. J. Appl. Ecol. 33, 191–199.
Uherek, E., Halenka, T., Borken-Kleefeld, J., Balkanski, Y., Berntsen, T., Borrego, C., Gauss, M., Hoor, P., Juda-Rezler, K., Lelieveld, J., Melas, D., Rypdal, K., Schmid, S., 2010. Transport impacts on atmosphere and climate: land transport. Atmos. Environ. 44, 4772–4816.
UNCED, 1992. Rio Declaration and Agenda 21 — United Nations Conference on Environment and Development, Rio de Janeiro, Brazil (June 3-14 1992, 351 pp.).
Wiedmann, T., 2009. A review of recent multi-region input–output models used for consumption-based emission and resource accounting. Ecol. Econ. 69, 211–222.
Wiedmann, T., Minx, J., Barrett, J., Wackernagel, M., 2006. Allocating ecological footprints to final consumption categories with input output analysis. Ecol. Econ. 56, 28–48.
Wiedmann, T., Lenzen, M., Turner, K., Barrett, J., 2007. Examining the global environmental impact of regional consumption activities — part 2: review of input–output models for the assessment of environmental impacts embodied in trade. Ecol. Econ. 61, 15–26.
Würtenberger, L., Koellner, T., Binder, C.R., 2006. Virtual land use and agricultural trade: estimating environmental and socio-economic impacts. Ecol. Econ. 57 (4), 679–697.
Yang, X., Chen, L., Li, Y., Xi, W., Chen, L., 2015. Rule-based land use/land cover classification in coastal areas using seasonal remote sensing imagery: a case study from Lianyungang City, China. Environ. Monit. Assess. 187, 449.
Zamboni, A., Murphy, R.J., Woods, J., Bezzo, F., Shah, N., 2011. Biofuels carbon footprints: whole-systems optimisation for GHG emissions reduction. Bioresour. Technol. 102, 7457–7465.
Zhang, Z., 2008. Asian energy and environmental policy: promoting growth while preserving the environment. Energ Policy 36, 3905–3924.
Zhang, Y.I., Baral, A., Bakshi, B.R., 2010. Accounting for ecosystem services in life cycle assessment, part II: toward an ecologically based LCA. Environ. Sci. Technol. 44, 2624–2631.
Zhou, J., Chang, V.W.C., Fane, A.G., 2011. Environmental life cycle assessment of reverse osmosis desalination: the influence of different life cycle impact assessment methods on the characterization results. Desalination 283, 227–236.