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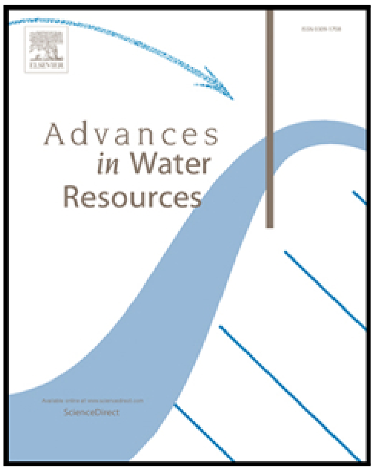

European large-scale farmland investments and the land-water-energy-food nexus

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PII: S0309-1708(17)30827-8
DOI: 10.1016/j.advwatres.2017.08.012
Reference: ADWR 2925

To appear in: *Advances in Water Resources*

Received date: 19 January 2017
Revised date: 16 August 2017
Accepted date: 20 August 2017

Please cite this article as: Giuseppina Siciliano , Maria Cristina Rulli , Paolo D' odorico , European large-scale farmland investments and the land-water-energy-food nexus, *Advances in Water Resources* (2017), doi: 10.1016/j.advwatres.2017.08.012

Highlights

- We explore the water-energy-food nexus for EU farmland investments
- We estimate virtual water from crop production in the target countries
- Virtual water is mostly green water consisting of 76% of the total water acquired
- We analyse freshwater use between flexible, food and energy crops
- Flexible/energy crops are responsible for most of the water acquired by EU investors

European large-scale farmland investments and the land-water-energy-food nexus

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Abstract

The escalating human demand for food, water, energy, fibres and minerals have resulted in increasing commercial pressures on land and water resources, which are partly reflected by the recent increase in transnational land investments. Studies have shown that many of the land-water issues associated with land acquisitions are directly related to the areas of energy and food production. This paper explores the land-water-energy-food nexus in relation to large-scale farmland investments pursued by investors from European countries. The analysis is based on a "resource assessment approach" which evaluates the linkages between land acquisitions for agricultural (including both energy and food production) and forestry purposes, and the availability of land and water in the target countries. To that end, the water appropriated through agricultural and forestry productions is quantitatively assessed and its impact on water resource availability is analysed. The analysis is meant to provide useful information to investors from EU countries and policy makers on aspects of resource acquisition, scarcity, and access to promote responsible land investments in the target countries.

1. Introduction

The increasing human demand for food, energy, fibres and construction materials, has enhanced the human pressure on productive land. As a result, the land is increasingly seen as a scarce and contested resource (Weinzettel et al., 2013). It has been estimated that, to satisfy the food and feed requirements of the human population, by 2050 agricultural production would have to grow by approximately 70% and agricultural land would have to expand by about 10% globally (by 20% in developing countries) (Bruinsma et al., 2009; Davis et al., 2014). As a result, demand for water resources for agricultural production will also increase by around 30% by 2050 (De Fraiture et al., 2007). An additional 18-44 million ha of agricultural land will be needed by 2030 for producing biofuel feedstock (ERD, 2012; Davis et al., 2014a; Rulli et al., 2016). Moreover, it has been predicted that by 2050, 59% of the world population will face shortage of “blue water” (i.e. water in rivers, lakes, and aquifers), and 36% will face green (i.e. rainwater) and blue water shortage (Rockstrom et al., 2009).

Land and water shortages are therefore projected to escalate in the years to come, due to increasing demand but also resource degradation. The Food and Agriculture Organization of the United Nations estimates that about 25% of the world’s total land is already highly degraded, 8% is moderately degraded and 36% is slightly degraded (FAO, 2011). In response to energy policies and resource scarcity, commercial pressures on land are increasing and have been associated with foreign purchase or lease of farmland (Dell’Angelo et al. 2017). Also known as “land grabbing” (Grain, 2008; von Braun and Meinzen-Dick 2009; Borras et al., 2011) this phenomenon of foreign large scale land acquisitions (LSLAs) is increasing worldwide, with many land deals being currently negotiated, mainly in developing countries in Asia, Africa and South America (Hoff, 2011; Antonelli et al., 2015). According to the Land Matrix, an independent initiative for monitoring land deals at the global scale, between 2000 and 2014 the land acquired through concluded transnational agreements accounts for about 39 million hectares (Land Matrix, 2014).

In the land rush literature acquiring land is intimately linked to gaining access to water (Woodhouse, 2012; Rulli et al. 2013) for energy and food production. The majority of land agreements are in fact concluded for agricultural or forestry purposes, and therefore entail the appropriation of land and water resources for the production of trees or crops for food, renewable energy (i.e. biofuel), and other industrial uses (Land Matrix, 2014; Antonelli et al., 2014; Rulli and D’Odorico, 2014, Rulli et al., 2013; Cotula et al., 2014). Thus, the drivers and impacts of LSLAs can be better understood within the context of the land-water-energy-food nexus.

Research on the land-water-energy-food nexus focuses on the integrated analysis of the linkages among these sectors with the aim of increasing resource use efficiency and securing human rights to water, energy and food (Hoff, 2011; Howells et al., 2013). Quantitative analyses of the nexus can be categorised in two main groups: (i) an assessment analysis of the status of the resources in terms of availability, access and scarcity with respect to uses and pressures, to better understand resource constraints and inform integrated assessments and policies (FAO, 2014a) and (ii) scenario or impact analysis which allows for the simultaneous exploration of the relationships and interdependencies between water, food and energy systems, and the trade-offs of specific policies or environmental constraints (Liu at al., 2014; Howells et al., 2013). The analysis of the nexus can be performed with a variety of approaches (Brazilian et al. 2011), depending on the type of natural resource in question. If a water perspective is taken, then food and energy systems use the resource. Likewise, from a food perspective, water and energy are inputs, and from an energy perspective water is the input and food is the output.

Looking at the literature on LSLAs and the nexus, most of the studies provide an assessment analysis by looking primarily at land and water use competition between different uses, mainly food vs. energy (Schoneveld 2014; Cotula et al., 2014; Messerli et al. 2014; Rulli et al., 2013; Rulli and D’Odorico, 2014).

However, studies that explicitly combine aspects related to resource acquisition, availability and scarcity in the target countries are still missing. This paper advances previous studies on water appropriation analysis (see Rulli et al., 2013) by providing a more accurate estimation of the blue and green water required by crop production using georeferenced data on soil properties and climate conditions characteristic of the areas where the land is acquired. Moreover, this paper uses a resource assessment approach in which the use of water and land resources from LSLAs for forestry, agricultural production and food and energy scopes, are analysed with respect to the availability and scarcity of local natural resources at the country level.

The linkages between LSLAs and the nexus are here explored with reference to large-scale farmland investments pursued by investors from European countries. The aim is to inform European policies and regulations for the development of best practices on the presence of European land investments in the global South and their implications with respect to the land-water-energy-food nexus. The debate on the possible negative impacts of EU investments on the recipient countries is made explicit in various EU policies, reports and directives. The EU policy framework (2011), for example, calls for consultation of civil society and participation of elected representatives of local and regional authorities to ensure transparency of contract negotiations to prevent negative effects on local water and food security, as well as to protect land use rights of small local farmers, especially in regions (e.g., Africa) where land acquisitions have happened at an alarming extent over the last few years. Moreover, the Renewable Energy Directive (RED) establishes that bilateral and multilateral agreements with “third countries” (i.e. countries outside the EU) for the production of energy, especially biofuel, have to comply with sustainability criteria (EU Directive, 2009). In this paper the analysis of the linkages between the nexus and EU’s LSLAs is performed first by estimating the amount of farmland acquired by EU investors at the global level and the crops grown in the land; we then estimate the amount of “virtual” water acquired through crop productions by using an innovative site-specific approach based on georeferenced soil and climate information of the places where land agreements are finalised. Soil characteristics and climate information are provided by global datasets such as the Harmonized World Soil Database (FAO, 2008) and the agro-ecological zones (AEZ) system, for soil characteristics, and National Climate Data Center of National Oceanic and Atmospheric Administration (NOAA, 2014) for climate data. The amounts of water and land acquired are then analysed with respect to resource availability, scarcity and access in the target countries (FAO, 2009a; FAO AQUASTAT, 2014b).

The information on the amount of land acquired by EU investors, the type of trees or crops grown on the land and the geographical localization of the deals is provided by the Land Matrix database (Land Matrix, 2013). The Land Matrix database is a global-scale inventory developed as a joint initiative of several research and development institutions to collect data on land deals that entail (i) a transfer of user rights from smallholders or collective uses to commercial uses; (ii) cover an area greater than 200 hectares; (iii) refer to land agreements announced or concluded since 2000; (iv) refer to sale, lease or concessions (Anseeuw et al., 2012). In general, global-scale inventories of land deals are difficult to compile because the acquisition and development of agricultural land are a highly dynamic process and access to the data is often limited due to lack of openness in the agencies that record land transactions, concessions, titles, and licenses; moreover, data can have different degrees of reliability depending on the main source of information (i.e. media reports, policy reports, companies’ information, official government records, international and non-governmental organizations and academics) (Messerli et al., 2014; Shoneveld, 2014; Anseeuw et al., 2013). To overcome some of the above limitations the Land Matrix database distinguishes the different stages (concluded, intended, or failed) in the granting process and indicates data sources in order to provide a refined and more differentiated picture of the phenomenon (Anseeuw et al., 2013). Thus, to avoid the inclusion of less reliable data, deals reported as incorrect or dubious and/or classified as failed (e.g. intended deals or for which the project has been abandoned) were not considered in our study and only land deals reported in the Land Matrix database as finalised for agricultural and forestry purposes and classified as concluded and/or in operation were included in our analysis. Nevertheless, this study does not aim to provide the exact picture of farmland acquisitions by the EU, since the available data may be biased by the media attention to a particular geographical area or the strengths of partner networks reporting land deals (Messerli et al., 2014). Rather, the main objective here is to identify general patterns and processes useful to support the current policy debates on the potential negative implications of European farmland investments on natural resources (i.e., land and water) and their accessibility by the local population in the recipient countries (EU policy framework, 2011). Large scale land acquisitions (LSLAs), especially from developed to developing countries (or "north-south investments"), can be beneficial to local economies if capital and technology is transferred through land investments, local natural resources are not degraded, and investors ensure an equitable distribution of benefits with the local population. However LSLAs have been widely questioned with regard to their ability to support development in the recipient countries, as well as in relation to their negative environmental impacts. In this regard, a vast body of literature from academia and international organizations has investigated land grabbing by looking particularly at the appropriation of natural resources, such as land, water, wood and minerals in the countries where land agreements are finalised (Cotula et al., 2009; Hall, 2011; Borras et al., 2011; World Bank, 2011; Scheidel and Sorman, 2012; Rulli et al., 2013; Allan et al., 2013; D'Odorico and Rulli, 2014; Porter, 2014; Cotula et al., 2014; Davis et al., 2016; D'Odorico et al., 2017).

Even though in principle these investments cannot be labelled as "good" or "bad" without an in-depth analysis of each agreement with a case-specific evaluation, an aggregated assessment of the potential pressure of land acquisitions on local natural resources such as water and food is a fundamental initial step toward more informed response of the EU through strategies and policies based on solid understanding of the food-water-energy nexus. The paper in particular responds to the following research questions: What are the main purposes, distinguishing between food, forestry and energy productions of land investments pursued by EU based investors by looking at the best available information on land deals at the global level? What are the water requirements of these land productions? What is the portion of the land and water acquired by EU based investors with respect to the water and land availabilities of the target countries? What is the water access, land scarcity and food security situation of the countries targeted by EU based land investors? Are there potential competitions between freshwater use for energy and food production in countries prone to malnutrition? The rest of the paper is organized as follows. Section 2 describes the methods and materials used for the analysis of the land and water resources availability and acquisition by EU investors in the target countries from a resource assessment perspective. Section 3 discusses the main results. The final Section draws some conclusions.

2. Material and methods

The analysis of the potential implications of European farmland investments on local resources in the target countries has been based on a resource assessment approach which provides: (i) an estimation of the "virtual" water resources acquired by the investor countries (for forestry, food and energy production); (ii) an accountability of the water and land resources available in the target countries; and (iii) an analysis of resource access and scarcity in the target countries (Fig. 1). The "virtual" water (Allan, 2011) refers to the water needed for the production of trees or crops; each land acquisition for agricultural or forestry purposes implies also an acquisition of virtual water, a phenomenon also known as "water grabbing" (Rulli et al., 2013).

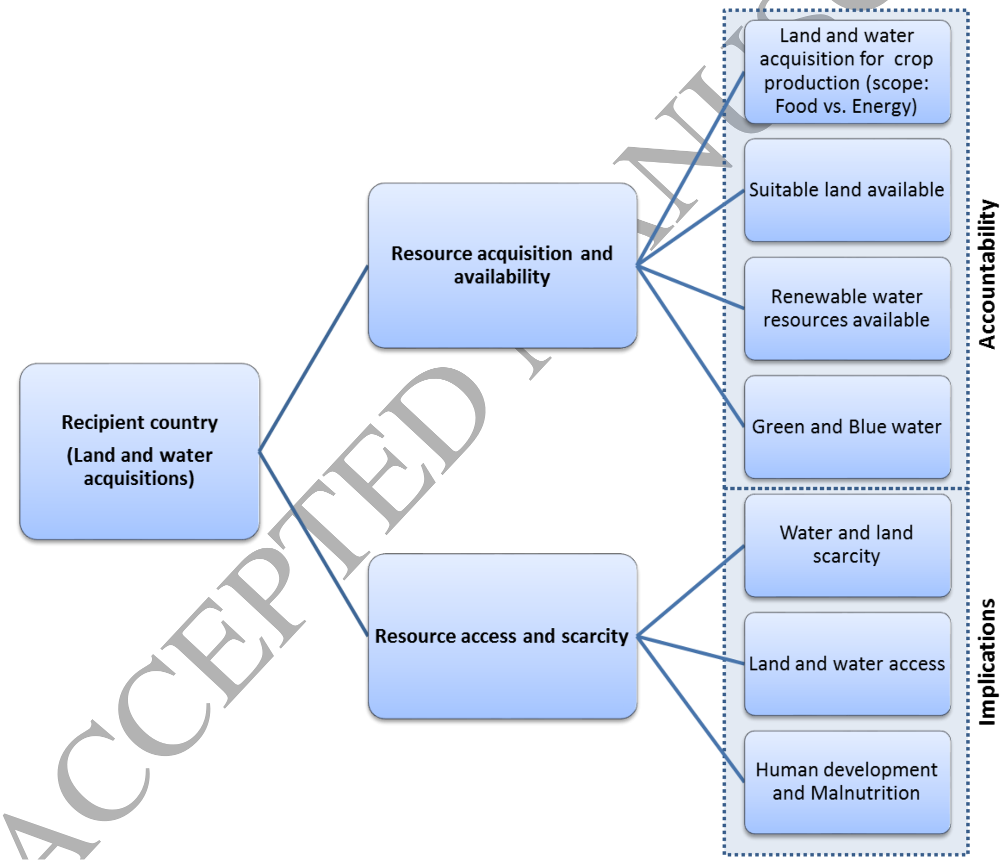


Fig. 1 A resource assessment approach linked to transnational land investments and the land-water-energy-food nexus

2.1 Natural resource availability and acquisition

Natural resource availabilities are analysed based on the context status of the water and land resources available at the national level and for each target country. The status of the land resource is analysed in terms of "quantity", such as the area of available arable land (FAOSTAT, 2009) and the amount of land already cultivated in each target country, but also in terms of its "quality", such as the amount of suitable land available for agriculture[1].

A similar analysis is applied to the water resources, considering the total renewable available water and the water used for food and feed production. The latter information is used to look at the portion of water acquired through LSLAs for the production of food or biofuel with respect to the water already used for domestic crop production in the target countries. Data on land and water availability by country are provided by FAOSTAT (FAO, 2009a; FAO 2012b) and FAO AQUASTAT (FAO AQUASTAT, 2014b), respectively. Data on water used for feed and food production for domestic consumption in the target countries are taken from Mekonnen and Hoekstra (2011).

Even though the Land Matrix database does not explicitly provide a distinction between investments for international or domestic markets, an analysis based on a sample of selected deals has shown how production for export markets is by far the main objective of the use of the acquired land (Schaffnit-Chatterjee, 2012; Cotula, 2013). Moreover, private investments aiming at increasing agricultural productivity in developing countries are mostly done in commercial farming for export markets (Daniel, 2011) with potentially negative consequences for the world's rural poor and traditional farming methods utilized by millions of small farmers.

Land and water acquisitions are here estimated based on the amount of the land acquired in each target country and the type of trees and crops planted in the purchased/leased land to account for their different water requirements of crops or trees. Moreover, based on the information on the crops and trees grown in the land we analysed the main scope of land acquisitions by EU based investors, e.g. food, energy (i.e. biofuel) or industrial production. As anticipated in the introduction, the size of the acquired land and its intended use are based on the information provided by the Land Matrix database (Land Matrix, 2013).

In terms of land acquisition, the Land Matrix provides three different variables to measure the area of deals. Intended area is the acquired land in hectares that was formerly or is currently intended to be acquired by the investors. In many cases, this is the area announced before or during the negotiation phase of an investment. However, it may also reflect the intention of future expansion. The area under contract refers to concluded deals, i.e., the area that has been leased to or purchased by the investor. The area defined as operational refers to the current area that is already in production (Land Matrix, 2015). Our analysis takes into account the area under contract and the area defined as operational. The intended area is included in the analyses only when the contract is concluded but the contract or operational areas are not available. This is due to the fact that, as anticipated in the introduction, the status of land deals is characterised by rapid changes, especially for what concerns intended deals and the intended production area. For these deals the data are less reliable because some negotiations could never materialise or projects could collapse (Anseeuw et al., 2013).

[1] Land suitability is the fitness of a given type of land for a defined use (FAO 1976). In our analysis we consider the very suitable, suitable or moderately suitable land available in each country for all crops excluding fodder for mixed level of input and under rainfed and/or irrigation conditions (FAO 2009a; FAO 2012b).

For what concerns the methodological challenges related to large-scale global inventories and their reliability, Table 1 provides a classification of the main sources of information related to the European deals analysed. The classification is based on a reliability order provided by Land Matrix, in which the first source, i.e. government, is the most reliable one followed by company source, policy/research reports, contract, media report, and personal information. As indicated in Table 1 more than 70% of the information analysed in this paper refer to the first three most reliable sources of information. For 23% of the deals included in this study the Land Matrix did not provide the source of information; we considered, however, only deals for which at least the information on the investors' company was available.

Table 1 Farmland investments by type of data source

Reliability order		%
Government source	GS	20
Company source	CS	48
Policy/Research	PR	6
Contract	CO	0
Media report	MR	3
Personal information	PI	1
Unknown		23

Source: Authors' elaboration (Land Matrix, 2013, dataset as of 15 October 2013)

Water acquisitions are estimated adopting a site-specific approach. To that end we distinguish between green (i.e. the rainwater used by crops planted in the acquired land) and blue water (i.e. irrigation water withdrawn from rivers, lakes, and aquifers) appropriations (Falkenmark and Rockstrom, 2006). The site specific approach used here is a combination of the method used in Rulli et al. (2013) and Rulli and D'Odorico (2014) for the estimation of water grabbing, with a Geographical Information System (GIS) based method which includes information on the geographical location of the land deals provided by the Land Matrix database (see the Appendix, for more details on the method used for the estimation of water acquisition, i.e., water used by crops planted in the acquired land).

While land acquisitions are implicitly associated with an appropriation of the fraction of rainwater used by vegetation in the process of evapotranspiration (green water), blue water acquisition occurs only if the land is irrigated, which requires the availability and use of irrigation infrastructures (see Figure A1 in the Appendix). In the estimation of blue water we assumed the availability of both irrigation infrastructures and an amount of water sufficient to maximize agricultural production. We therefore assumed that part of the investments is also meant to develop better irrigation infrastructure in the area where land agreements are finalised and put under production. It is therefore an overestimate of the irrigation water appropriated by land investors, and provides an upper bound for blue water acquisitions (i.e., the amount of blue water potentially appropriated by land investors if irrigation infrastructure is developed and blue water resources that are actually available). In addition, the acquisition of blue water is estimated only when the purchased land is already under production. Moreover, we consider that the combination of water intensive crops and dry climates is associated with higher shares of blue water consumption. Conversely, wet climates usually rely mostly on rainfall water (green water) for crop production.

2.2 Resource scarcity and access

Land scarcity in the target countries is analysed based on the definition of land scarcity provided by FAO (2003), according to which a country can be considered land scarce if the suitable land already in use is above 60% of the total suitable available land. In other words, to analyse land scarcity in each target country we use as an indicator suitable land already in use. The suitable land "not yet in use" is classified in global dataset as marginal or idle lands which are not used by the local population. However, various studies have argued that in countries where the portion of the population still living in rural areas is high, marginal and idle lands are likely to be used by the local population and therefore cannot be classified as unproductive lands (Cotula et al., 2009). It is for this reason that we distinguish here between the suitable land already in use, which is the suitable land already used for *intensive agriculture* or other *commercial uses*, and the remaining portion of suitable land as land that could be used by the local population for non-commercial uses, such as self-subsistence purposes (this limitation of using global dataset on land availability is further discussed in section 3.3.1). Moreover, in the majority of the African countries land access is a problematic issue for the lack of no formal land titling or registration system, which often are not recognised by the state creating tenure insecurity and more possibilities of land evictions of the local population (UN-Habitat, 2014).

In terms of water scarcity, available volumes of 1,700 m^3 per capita and 1000 m^3 per capita per year are used as the thresholds between water stressed and water scarce countries, respectively. In other words, based on Falkenmark et al. (1989), if renewable water is below 1,700 m^3 per person per year, that country is said to be *water stressed;* while below 1,000 m^3 it is said to be experiencing water scarcity, and below 500 m^3, absolute water scarcity[2]. These data are contrasted with the amount of land and water acquired by EU investors in each target country. Resource access is discussed in relation to socio-economic considerations based on the level of economic water scarcity and malnutrition of the target countries (Molden et al., 2007; FAO, 2016). According to UN data almost one quarter of the world's population face economic water shortage (where countries lack the necessary infrastructure to take water from rivers and aquifers) (UNESCO, 2012). Moreover, malnutrition occurs in many of the countries targeted by LSLA. Responsible land investments, which provides water infrastructure for local food productions and avoid competition of freshwater use between energy and food productions, could therefore do much to reduce economic water scarcity and food insecurity in developing countries.

[2] The Falkenmark's water stress indicator has a number of limitations (Rijsberman 2006; Hoekstra and Mekonnen, 2011) because it does not account for local water scarcity, seasonal fluctuations in water availability, and the effect of infrastructure water availability. Despite these limitations the Falkenmark's indicator is still useful in studies such as those presented in this paper that provide a coarse, country-scale analysis of water appropriation through large scale land acquisition.

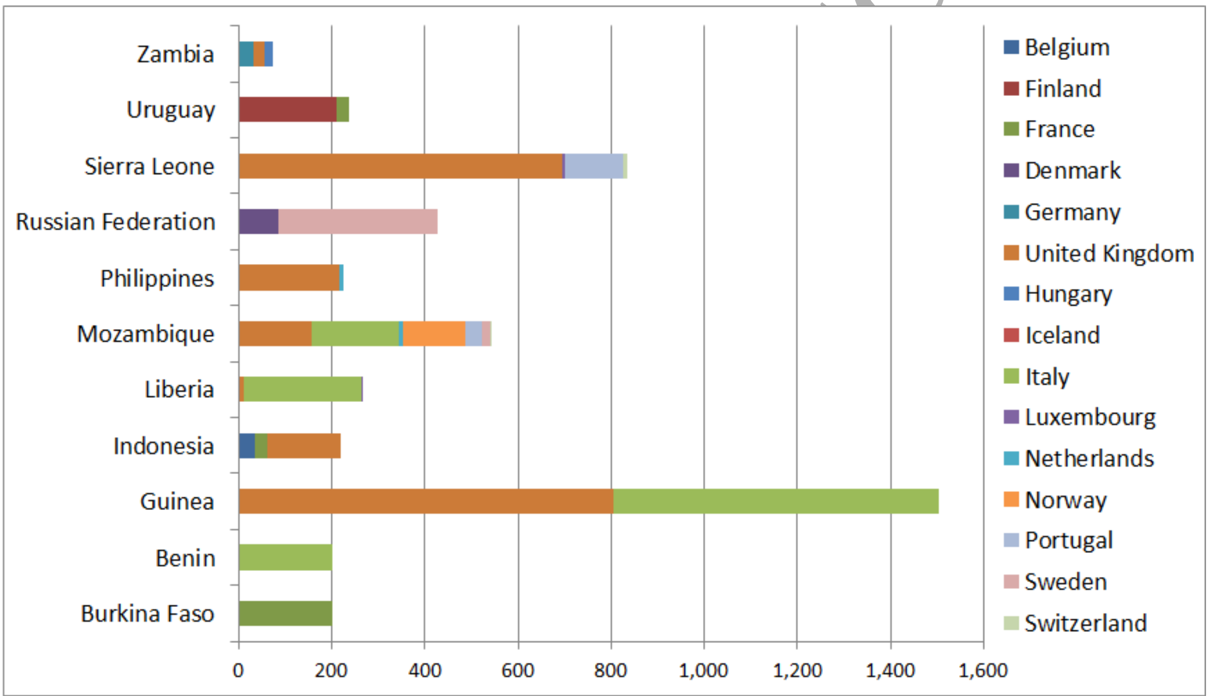
3. Results and discussion

3.1 Understanding patterns of European investments: size, geography and scope

3.1.1 Size and geography of European large-scale farmland investments

This section presents the results of the analysis of the major European investment destinations (Fig. 2). The analysis is based on the information provided by Land Matrix on farmland investments for agricultural and forestry purposes pursued by European individuals, companies, including investment funds, or state agencies that acquire land (Land Matrix, 2013)[3].

Fig. 2 Major investment destinations (80% of total investments from EU located investors), by total land area acquired (in thousand hectares) for agricultural and forestry purposes - realised land deals (concluded and in operation agreements)



Source: Authors' elaboration (Land Matrix, 2013, dataset as of 15 October 2013)

The major countries targeted by European investments (i.e. investments pursued by investors from a EU country) are located in Africa (77%), followed by Asia and Eurasia (18%) and South America (5%) (Fig. 2). Of the 118 land deals analysed, 17 investments are realized by EU based investors in collaboration with investors from the target countries (i.e. "domestic" investments), while the remaining 111 deals are pure transnational investments pursued either by just one European country (i.e. investor from a EU country) or in collaboration with other investors from a EU country and non-EU based investors. The major investors in terms of the

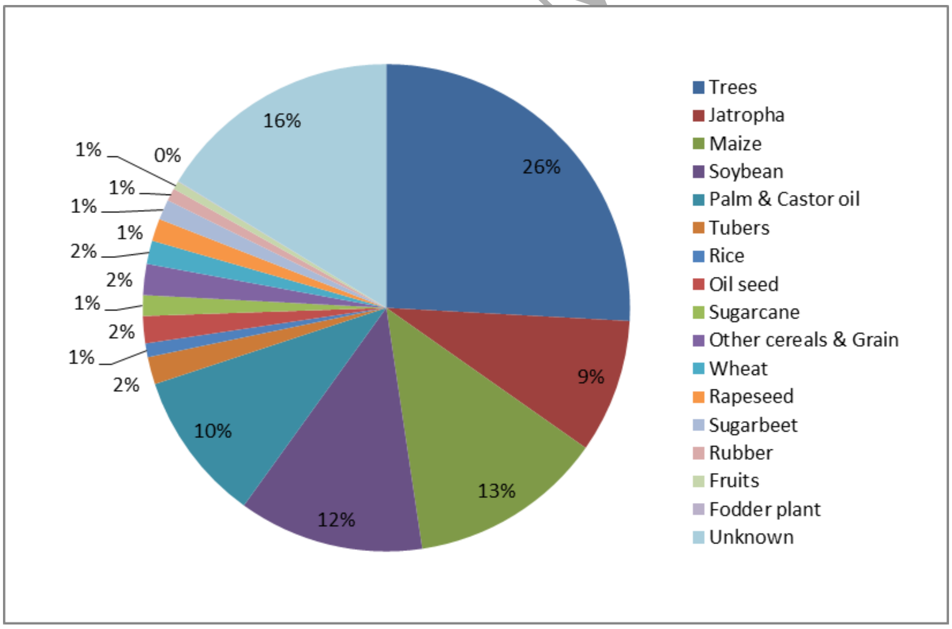
[3] The total lan associated to multiple-investor agreements has been divided in equal parts among the countries participating in the deal. Using this method the amount of land acquired by each European country excludes the portion associated with other international or domestic investors. In this way the total area involved in large scale investments is maintained.

amount of land acquired are from United Kingdom and Italy. While the major targeted countries are Guinea, Sierra Leone and Mozambique (Fig. 2).

3.1.2 Scope: flexible crops, crops for food and crops for energy

This Section highlights the nexus between land, forestry, energy and food production by looking at the main intended use of EU transnational land investments. Based on the analysis of the crops and trees grown in the land acquired by investors from EU countries at the global level, almost 60% of the acquired land is used for the cultivation of "flexible" crops[4] (50%), which are suitable both for food and biofuel production (e.g., sugarcane, rapeseed, maize, soybean) and crops suitable only for biofuel or industrial uses (10%), such as, jatropha and rubber. About 26% of the acquired land is mainly used for forestry purposes (i.e. tree plantations); 2% for food only (e.g. fruits) (Fig. 3), while, for 16% of the deals reported by the Land Matrix no information on the intended use of the land (i.e. whether for crops or forestry, and the crop type) was provided (shown in Fig. 3 as *unknown crop*). For the purposes of water acquisition calculations, we assumed that these land deals are cultivated with the same crops (and in the same proportions) as in the rest of the acquired land (within the same country) for which crop types are reported by the Land Matrix (2013) (for an overview of the crop cultivations identified in each country the reader is referred to Table A3 in the Appendix).

Fig. 3 Primary crop (type) cultivated, as proportion of total land area acquired (80% of total investments from EU located investors) for realised deals



Source: Authors' elaboration (Land Matrix, 2013, dataset as of 15 October 2013)

[4] Flexible crops are defined as crops that can have multiple uses, such as food, feed, fuel, industrial material, such as soya (feed, food, biodiesel), sugarcane (food, ethanol), oil palm (food, biodiesel, commercial/industrial uses) and maize (food, feed, ethanol) (Borras et al., 2014).

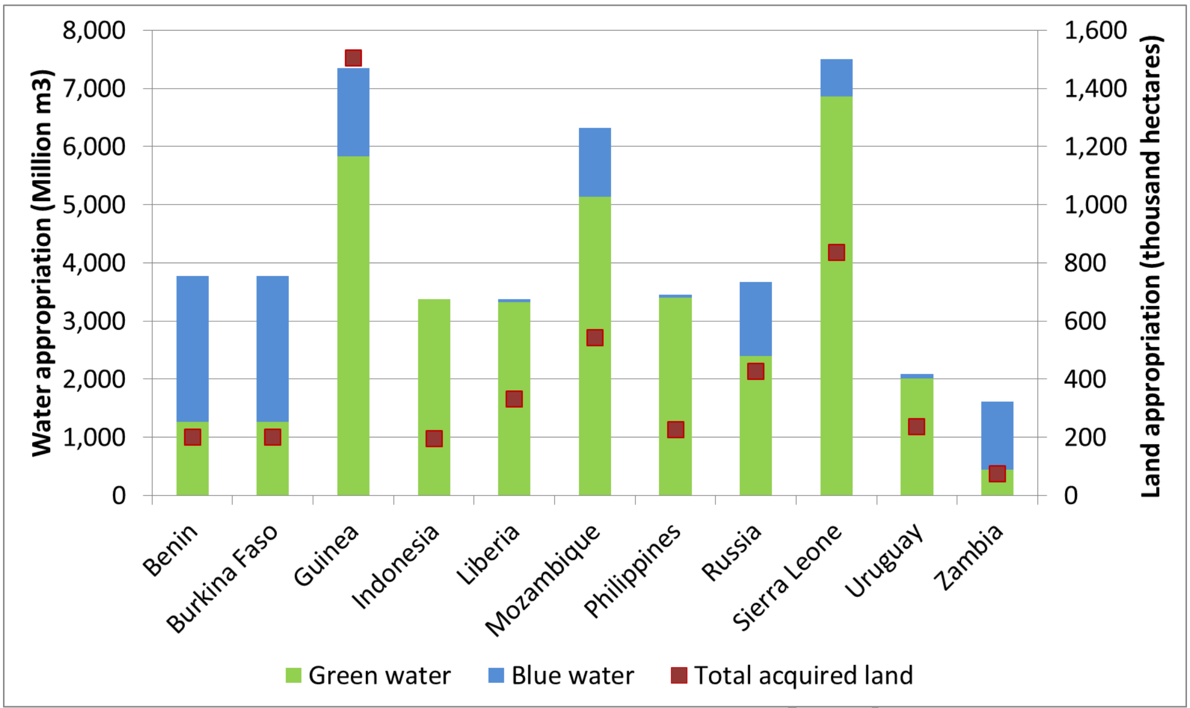
According to our analysis, the cultivation of flexible crops is the main reason driving the majority of the investments pursued by European investors. This finding highlights the importance of the energy-food nexus to the understanding of large scale European investments in farmland. One of the main reasons for investing in flexible crops is due to the fact that investors can easily switch between, food and biofuel uses, depending on end-market price differentials, thereby enabling producers to hedge against market fluctuations (Schoneveld, 2014). Moreover, the investors' interest in these crops is also associated with the rise in demand for first-generation biofuels, mainly driven by binding European energy and climate targets (Davis et al., 2015b; Antonelli et al., 2015). Carroccio et al. (2016) shows that investments pursued by EU Member States are mainly driven by the need to reduce the energy deficit in view of the achievement of the objectives set out in the "Europe 2020". In addition, some of the biofuel crops having high energy efficiency, such as oil palm and sugar cane, need climate conditions that cannot be found in European countries. Therefore, climate related drivers play also an important role in European investments, especially in the global south.

Sections 3.2 and 3.3 analyse the potential implications of EU land investments by estimating the amount of water acquired by investors for crop production, and by contrasting these estimates with resource availability and scarcity in the main target countries. This analysis gives some important insights into the water-energy-food nexus associated with European transnational investments.

3.2 Water acquisitions by European large-scale farmland investments

This Section shows the results of the site-specific approach applied to the estimation of the water appropriation associated with European farmland acquisitions in the 11 most targeted countries (Fig. 4). The total amount of water acquired by investors from EU countries accounts for approximately 46 billion m^3 per year. The most targeted continents are Africa and Asia, while Eurasia and South America are only minor contributors to the water acquired by the EU member states. Overall, water acquisition is mostly in the form of green water with 35 billion m^3 per year; while blue water (i.e. irrigation water) potentially appropriated by land investors (i.e., depending on local availability and willingness to invest in irrigation infrastructure and its management) accounts for approximately 11 billion m^3 per year. According to our estimates, the top three target countries in terms of total water acquired (green plus blue) through EU LSLAs are Mozambique, Sierra Leone and Guinea (Fig. 4). The amount of water acquired in each country can be explained by different factors: the extent of land acquisition in hectares, the type of crop production and differences in climate.

Fig. 4 Green and blue water appropriations by investors from EU countries in the main targeted countries (million m^3) and total acquired land (realised land deals)



Sources: Land Matrix, 2013 (acquired land) and authors' elaboration (water appropriation)

Patterns of water appropriation through land acquisitions in Mozambique, Sierra Leone, Guinea, Russia and Uruguay are mainly explained by the extent of the (total) acquired land. In Sierra Leone the high volumes of water acquisitions are partially explained also by the cultivation of water intensive crops, such as sugar cane and oil palm (values of crop water requirements in the target countries are reported in Table A3 in the Appendix). The wet tropical climate of Sierra Leone and Guinea, explains also the high amount of rainwater use (i.e. green water). Benin, Burkina Faso and Zambia present a combination of dry climate and water demanding crops, therefore in these countries the share of blue water consumption is high (see Table A3 in the Appendix). In the Philippines land investors plan to plant water intensive crops (especially oil palm, sugar cane and jatropha). Because of the wet climate (i.e., high precipitation) in the Philippines and Indonesia (Fig. 4) the crop water requirements are met without requiring irrigation (i.e., only green water consumption). Generally, the analysis of the water requirement per crop in the target countries shows that flexible crops, such as sugar cane and palm oil, and crops used only for biofuel, such as jatropha, require a higher amount of water with respect to food crops, which highlights a potential competition for freshwater between the food and energy sectors. Moreover, the analysis shows that while in these countries tree plantation are in general not particularly water intensive, the cultivation of rubber trees, which are mainly used for industrial production, requires a high amount of water.

3.3 Resource competition analysis: availability, acquisition and resource scarcity in the target countries

3.3.1 European land acquisitions and land availability in the target countries

The analysis of country-specific values of the area suitable for agriculture (i.e. land suitable for all crops excluding fodder, for mixed level of input and under rainfed and/or irrigation conditions), shows that most of the countries targeted by investors from EU countries still have a substantial amount of land suitable for agriculture that is not under intensive commercial agricultural uses. Table 2 shows that in most of the targeted countries the area of suitable land already in use for commercial purposes is below the FAO identified threshold of land scarcity, which is set at 60 percent. We need to stress, however, that this land could be *de facto* used by the local communities for non-commercial activities (e.g., for firewood, timber, agroforestry, thatch grass) especially in developing countries where idle and marginal lands are usually vital for the livelihoods of small-scale farmers, pastoralists, women and indigenous peoples (The Gaia Foundation, 2008). Therefore, even in countries that could appear to have a relatively large portion of suitable land still available (Table 2), land acquisitions could result in negative impacts on the local population due to land eviction and expropriation (Cotula at al., 2009). For instance, evictions due to the acquisition of land classified as idle or marginal have been reported in Mozambique (Nhantumbo and Salomao, 2009; Hall et al., 2015). Thus, the suitable land available for agriculture based on FAO dataset is here interpreted not as land “not in use” but as suitable land which is not under *intensive* agricultural or other *commercial* uses but that could be currently used by the local population for self-sufficiency purposes. Land investments targeting these types of lands could be beneficial to increasing agricultural productivity (e.g., Rullli et al., 2014) and at the same time improving the livelihoods of the land users. However, this would be possible only if land eviction and expropriation is avoided and the benefits are equally shared with the local land users (Hall et al., 2015).

It is also interesting to point out that in the case of Philippines and Indonesia the suitable land available is even less than the land already cultivated, indicating an ongoing overexploitation of the land suitable for agriculture as well as of land that cannot be sustainably cultivated. Therefore, even if the portion of land acquired by investors from EU countries in the Philippines and Indonesia is small compared with the land acquired elsewhere (e.g., Guinea and Mozambique) (Table 2), in these two countries further land acquisitions are likely to result in the exploitation of marginal land and forests, with important environmental impacts due to deforestation. Cases of deforestation related to land acquisitions for biofuel production (i.e., for oil palm plantations) have already been reported in Indonesia and the Philippines (World Watch Institute, 2009; Borras and Franco, 2011; Friends of the Earth Europe, 2013; Ejolt, 2014). Moreover, our analysis shows that in the case of Guinea and Sierra Leone the amount of acquired land is an important share (20% and 36%, respectively) of the suitable land available for agriculture (Table 2), indicating the relevance of foreign-owned concentration of productive land in these countries.

Table 2 Share of land acquisitions by investors from EU countries with respect to suitable land available for agriculture in the target countries

Target countries	Suitable land available for agriculture (thousands ha)	Suitable land already in use (%)	Realised land deals (thousands ha)	Realised land deals/suitable land available (%)
Benin	6,660	30	200	3.0%
Burkina	12,900	31	200	1.6%
Guinea	7,630	32	1,504	19.7%
Indonesia	0	100	195	>100
Liberia	3,960	14	409	10.3%
Mozambique	48,600	10	543	1.1%
Philippines	0	100	225	>100
Russia	125,000	50	426	0.3%
Sierra Leone	2,310	35	836	36.2%
Uruguay	12,300	13	236	1.9%
Zambia	47,000	7	136	0.3%

Sources: Authors' elaboration based on FAO, 2009, FAO, 2009a and Land Matrix, 2013, dataset as of 15 October 2013. **Note:** Suitable land available for agriculture is the difference between the total suitable land available and the suitable land already cultivated for commercial purposes.

3.3.2 European water acquisitions and water availability in the target countries

Water acquisition associated with large scale land deals for forestry and agriculture has been compared with the total renewable water resources available in the target countries (FAO AQUASTAT, 2014). This analysis is meant to provide a better understanding of the implications that an appropriation of water resources thorough land acquisitions could have on the availability of water resources in the target countries.

Results show that in Burkina Faso and Benin the water acquisitions associated with land deals by investors from EU countries account for an important share of their total renewable water resources (about 30% and 14%, respectively; see Table 3). Moreover, country-specific values of per capita water availability (Table 3), indicate that Burkina Faso is water stressed, since in this country the average amount of water available per capita[5] (715 m^3 per capita per year) is below the identified threshold of water scarcity (1,000 m^3 per capita per year). Conversely, in Benin the water resources available per capita (2,822 m^3 per capita per year) are above the water security threshold, but still lower than in the other target countries (Table 3). The analysis of water acquisitions in Benin and Burkina Faso (see Section 3.2, Tables A2 & A3 in the Appendix) shows that the crops grown in the acquired land are mainly water

[5] Calculated as the ratio of total renewable freshwater resources and population size.

intensive (e.g., jatropha). In countries prone to water scarcity per capita, land investments should avoid competition between freshwater use for domestic and water intensive crop productions, especially in areas where water scarcity is particularly severe.

In addition, all of these countries targeted by EU investments are experiencing economic water scarcity. Economic water scarcity occurs when a lack of human, institutional, and financial capital limits access to water even though water in nature is available. Signs of economic water scarcity include poor infrastructure development, which usually undermines people's access to water for agriculture or drinking, thereby contributing to undernourishment (Molden, 2007). Much of Sub-Saharan Africa is characterized by economic scarcity; therefore, further development of water infrastructure for agricultural production for domestic consumption (rather than the export market) could go a long way to reduce poverty and malnutrition in the Sub-Saharan African countries targeted by EU investments. It has often been speculated that the development of water infrastructure would trigger economic development in countries strongly dependent on agriculture and affected by strong fluctuations in water availability (Hanrja et al., 2009). There are, however, some important environmental impacts that should also be considered and possibly avoided by developing smaller storages and applying new agricultural techniques (e.g., Karpouzoglou, et al., 2014).

Table 3 Share of water acquisition with respect to the actual total renewable water resources in the target countries (realised land acquisitions)

Target countries	**Total renewable water (million m^3/yr)**	**Total renewable water per capita (m^3/cap/yr)**	**Water acquisition (million m^3)**	**Water acquisition /total renewable water (%)**
Benin	26,400	2,822	3,774	14
Burkina Faso	12,500	715	3,777	30
Guinea	226,000	21,563	7,345	3
Indonesia	2,020,000	8,249	3,379	0
Liberia	232,000	54,653	3,376	1
Mozambique	217,000	8,870	6,313	3
Philippines	479,000	4,965	3,456	1
Russian Fed.	4,510,000	31,590	3,676	0
Sierra Leone	160,000	26,118	7,504	5
Uruguay	139,000	40,991	2,091	2
Zambia	105,000	7,577	1,618	2

Source: Authors' elaboration based on FAO AQUASTAT, 2014b, World Bank, 2013 (data on population), and estimation of water acquisitions.

Our analysis shows that in most of the target countries (particularly in Africa) water appropriation by EU based agribusiness investors accounts for a sizable share of the country-specific water use for crop production (including both food and feed) for domestic consumption. In some cases, such as Sierra Leone, the water appropriated through land deals is above the amount of water currently used for food and feed production (Table 4), while in Liberia it is close to that amount. This result is particularly relevant considering that most of the African countries targeted by investors from EU countries show high level of undernourishment[6] due to poor access to water and food. Zambia, Liberia and Mozambique rank among the top ten countries with the highest undernourishment rates in the world, with levels of undernourishment of 47.8%, 31.9% and 25.3% respectively (FAO, 2016) (Table 4). An increase of water appropriation for food, feed or energy production could therefore result in severe negative impacts on the already poor food security and economic water scarcity conditions of the population of these countries if land productions are exported to EU high-income countries or sold in international markets without sharing the benefits with local land users (Rulli et al., 2014). This is particularly true considering that according to the literature most of the LSLAs entail a conversion from subsistence farming to large commercial agriculture; such investments often take place without a proper consideration of the impacts on local natural resources, food security and resource access by the local populations, and therefore, they often result in negative impacts on local food self-sufficiency (ILC International Land Coalition, 2011; Hall et al., 2015). It has also been demonstrated that land deals are often associated with land evictions and poor local development, especially in developing countries (Vermeulen and Cotula 2010; Hall et al., 2015). A report on the impacts of land investments in Ethiopia has showed that resettled indigenous communities from land earmarked for commercial agricultural development usually become food insecure and fearful about their own survival because they lose access to land and water resources, while the proceeds from the sale or lease of the land are often not shared with the local population (The Oakland Institute, 2013; 2015).

[6] It expresses the probability that a randomly selected individual from the population consumes an amount of calories that is insufficient to cover her/his energy requirement for an active and healthy life. The indicator is calculated in three year averages, from 1990-92 to 2014-16. (FAO, 2016).

Table 4 Water acquisition with respect to the total renewable water resources used for crop production (food and feed) for domestic consumption (realised land acquisitions)

Target Countries	Water for food and feed production (million m^3)	Water acquisition /water for food and feed production (%) - realised land deals	Prevalence of Undernourishment 2014-2016 (%)
Benin	11,400	33	7.5
Burkina Faso	19,700	19	20.7
Guinea	16,800	43	16.4
Indonesia	304,000	2	7.6
Liberia	3,980	99	31.9
Mozambique	23,400	39	25.3
Philippines	112,000	3	13.5
Russian Fed.	332,000	2	0.0
Sierra Leone	5,590	134	22.3
Uruguay	12,400	31	<5.0
Zambia	7,230	25	47.8

Sources: Authors' elaboration based on Mekonnen and Hoekstra, 2011; Land Matrix, 2013, dataset as of 15 October 2013; FAO, 2016

4. Conclusions

This paper has used a land-water-energy-food nexus approach to the study of European large-scale land investments and their impact on resource scarcity in the target countries. This study has involved: (i) an estimation of the land and "virtual" water resources acquired by the investor countries, including an estimation of the green and blue water components using an innovative site-specific method based on georeferenced data; (ii) the analysis of the competition for freshwater usages among flexible, food, and energy crops; (ii) a quantitative assessment of the availability of water and land resources in the target countries; and (iii) an analysis of resource scarcity in the target countries with respect to land and water acquisitions.

This study shows that large-scale agricultural investments exhibit important water-energy-food trade-offs. The complexity of these trade-offs depends on a variety of aspects, including the market, governance arrangements, corruption and power imbalances and competition over authority, tenure systems, as well as environmental and social issues associated with agricultural investments choices (Schoneveld, 2017). Competing demands for water (i.e. local vs. international productions, business companies vs. local communities) can sharpen the trade-offs and opportunity costs of water use across forestry, food production, energy and industrial productions. By ignoring these features, researchers and policy makers fail to capture some of the key aspects of land investment decisions that help determine whether the realization of these investments achieves the objectives of improving agricultural production while promoting a sustainable development at the local, national and international levels. Combining information from global datasets on resource scarcity and use in the target countries with a site-specific estimation of water use by investors from EU countries for agriculture, we highlighted potential competition between the national and international markets for food and energy production. The analysis of the competition for freshwater usage among flexible crops, crops for food and crops for energy shows that most of the farmland acquisitions realized by investors from EU countries are expected to produce flexible crops, which can be used both for food and energy production (i.e. biofuel). Moreover, flexible crops, such as oil palm and sugarcane, or crops used for bioenergy or other industrial production (e.g., jatropha and rubber) requires a higher amount of green and blue water per hectare for their cultivation with respect to food crops (Table A3 in the Appendix). Therefore, in the target countries flexible and energy crops are responsible for a higher share of the water acquisition by investors from EU countries, than food crops. Tree cultivation is also contributing to a high share of the water acquired by investors from EU countries in absolute terms (Table A1 in the Appendix). However, the water requirement per unit area is smaller in food crops than for flexible and energy crops. Moreover, the amount of water used by investors from EU countries for agricultural production (mainly flexible and energy crops) represents an important share of the water already used for food crops and feed for domestic consumption, especially in African target countries, such as Guinea, Mozambique, Liberia, and Sierra Leone.

The above results shed light on the potential existence of competition over water for food and energy and between domestic and international markets. In countries prone to malnutrition and poverty due to socio-economic conditions such as lack of economic resources, inadequate infrastructures, and poor governance a strong competition is expected to exist between domestic and international uses (Giovannetti and Ticci, 2013).
Potential competition exists also over land use. Looking at the land suitable for cultivation, the study shows that two of the countries preferentially targeted by EU investments, namely the Philippines and Indonesia, exhibit land scarcity. Further land acquisitions in these countries are therefore likely to result in the exploitation of marginal and forest lands with negative impacts on the environment (e.g., Carlson et al., 2012; Davis et al., 2015a). Moreover, in countries where suitable land is already in use for commercial agriculture, responsible land investments could improve agricultural productivity and the livelihoods of local land users. Thus the overall outcome LSLAs could turn out to be favourable also to local communities, provided that land acquisitions do not entail forced land eviction and expropriation, and the benefits of these investments are equitably shared. However, there is a growing consensus among policy makers as well as in a number of studies performed at the local level and looking at the implications of land acquisitions on local populations, that these investments are generally detrimental to water and food security for the poor .
Turning land investments into deals that are beneficial to the rural poor requires more symmetrical power relations among the actors of LSLAs (investors, local communities, prior land users, and the governments) and the involvement of local land users during the negotiation process.

Even though in principle land investments cannot be labelled as “good” or “bad” based on global dataset without an in-depth analysis of each agreement from a case-specific type of evaluation, we argue that the use of information from global dataset combined with site-specific evaluation of water acquisitions is a fundamental initial requirement to inform nexus-related responses at the European level. For example, we suggest that in countries affected by malnutrition, economic water scarcity, or water limitations land investments should focus on food production for the national market. Investments should also support infrastructure development for local production, which could, in turn, improve food security and economic development of local land users. We also suggest that investments pursued by investors from EU countries should avoid targeting countries where there is a high risk of deforestation induced by the overexploitation of the land suitable for agriculture, as showed in this paper in the case of the Philippines and Indonesia.

While the European Union appears to be active in promoting the FAO Voluntary Guidelines on the Responsible Governance of Tenure (FAO, 2012a), there is the need for new guidelines providing some criteria to assess the impact of land acquisitions by investors from EU countries. These guidelines should include specific examples of "good" and "bad" practices, such as investments that have helped local development and environmental conservation, and are based on free prior informed consent (FPIC) by the local population. These positive examples should be contrasted with investments that have had a negative impact on the following aspects: biodiversity, the physical environment, local food security, human rights, poverty and local livelihoods, water and land access. Moreover, a recent study on five case studies of EU agricultural and forestry investments in the global South has shown that, even though European investors have decided to adhere to voluntary frameworks providing a "code of conduct" for land acquisitions, many investments still exhibit negative outcomes in terms of deforestation, loss of rural livelihoods, and violations of the rights of local communities (Fern, 2017). The persistence of such outcomes is due to the fact that the "code of conduct" was developed as a voluntary guideline and, as such, it cannot be actually enforced. Therefore, the EU needs to adopt enforceable policies that ensure that European corporations and other financial actors based in Europe operate overseas consistently with EU commitments to human rights, development and climate change.

Even though we are aware of the limitations of the data used in this study, which referring to global datasets cannot provide an analysis of localised specific circumstances of water and land scarcity in each country; however the analysis provides, based on empirical data, useful information on the different amount and types of resources that are appropriated by investors from EU countries and its potential consequences within the country-level specific conditions, and how they may differ from one to another.

Appendix A

Methods used for virtual water calculations and irrigation map

The estimation of water appropriations associated with land acquisitions generally requires information on the spatial extent, rainfall regime, irrigation rates and efficiency, soil properties, crop type, and cropping season of the acquired land (Rulli et al., 2013). By including information on the geographical location of the land deals, it is possible to take into

account specific climate and soil properties of the areas where the land deals are taking place, thereby obtaining a more precise estimation of the water appropriated through crop production. In our calculation we use land deals data as provided by Land matrix database (2013). When detailed data on location are not available, we assume that the location of the land deal coincides with the centroid of the agricultural area of the target country. When the Land Matrix database provides the approximate location of the land deal (e.g. province, region etc.), we associate the position of land deal in the centroid of that location.
Soil properties for land deal location are available through the Harmonized World Soil Database (FAO, 2008), while meteorological data are taken from the Global Climate Network of the National Oceanic and Atmospheric Administration (NOAA, 2013). In the case of countries (e.g. Liberia) in which the meteorological stations are not available, gridded data of rainfall and temperature from the Climate Research Unit of the University of East Anglia (New et al., 2000] are used. Data of wind speed, relative humidity and sunshine hours per day are taken from Climwat (FAO, 2009) by considering for each country the meteorological stations closer to the centroid of its agricultural area.
The CROPWAT 8.0 model (FAO, 2009c), obtained by coupling USDA Soil Conservation Service method (USDA, 1985) and the FAO Penman-Monteith equation (FAO, 2009c), is used to calculate the effective precipitation as a function of soil properties, soil type and land use and the crop specific and area specific rates of potential evapotranspiration. Rates of actual crop evapotranspiration are used to calculate the net amount of irrigation water actually used by plants (or "net irrigation").

Table A1 Water acquired by the EU at the global level and per type of crop

Crop	**Total (million m^3)**	**m^3/ha**
Fodder plant	14	5,012
Fruits	3,886	15,404
Jatropha	9,772	16,952
Maize	6,564	5,469
Oil Palm	5,219	15,053
Oil seed	148	4,072
Other cereals & Grain	52	3,966
Rapeseed	281	4,079
Rice	766	8,391
Rubber	795	14,727
Soybean	152	3,977
Sugarcane	866	15,065
Trees	6,153	8,713
Tubers	264	8,281
Wheat	2,300	6,544
Unknown	9,154	8,455

Source: authors' calculations

Table A2 Share (%) of green and blue water acquired by the EU at the global level per type of crop

	Green water	Blue water
Trees	100	0
Jatropha	41	59
Maize	78	22
Soybean	50	50
Oil Palm	91	9
Tubers	98	2
Rice	79	21
Oil seed	84	16
Sugarcane	56	44
Wheat	82	18
Rapeseed	67	33
Rubber	80	20
Fruits	93	7
Others & Grain	73	27
Fodder plant	100	0
Unknown	73	27

Source: authors' calculations

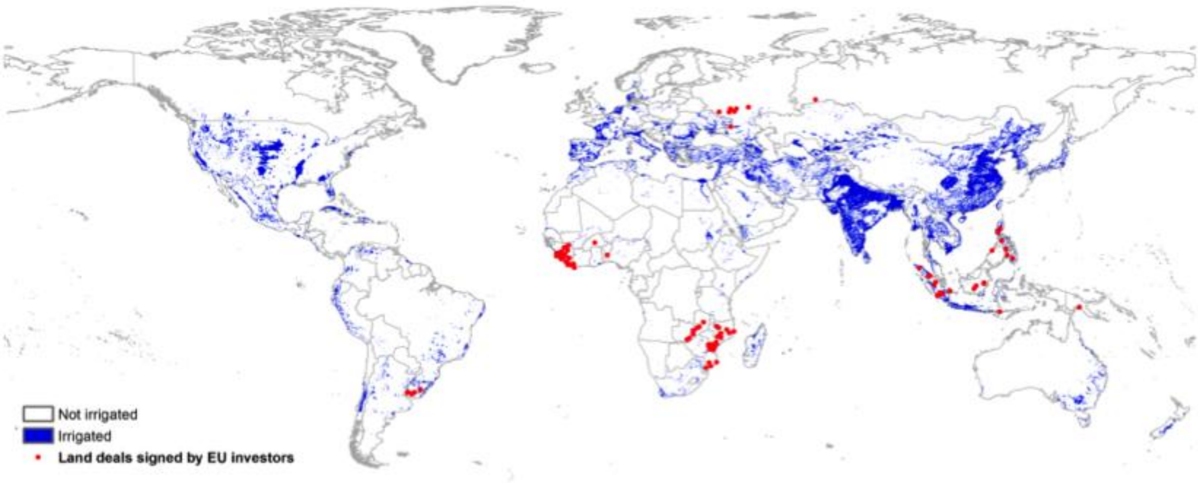
Table A3 Crop water requirement per country and per type of crop

	Crop Water Requirement (mm)										
	Benin	Burkina Faso	Guinea	Indonesia	Liberia	Mozambique	Philippines	Russia	Sierra Leone	Uruguay	Zambia
Banana						1626.9					
Barley										222.5	
Cassava						636.7	952		868.6		
Castor Oil Palm						1613					
Coconut						1449.4					
Food crops						738					
Jatropha	1857	1880.2				1388.8	1660.1				
Maize			665.1			437.4		503.8	358.0	559.6	586
Oil Seeds						515.3					
Palm Oil				1667.8	1372.9		1612.6		1354.3		
Pineapple						607.5			1105.4		
Potatoes						496.7					
Rapeseed								385.3			
Rice						890.8			916.5.5	440.9	
Rubber				1663	1441.2				1425.7		
Sesame						205.6			378.1		
Sorghum			350.0			257.2			314.6	248.5	
Soybean						368		445.3		306.3	500.2
Sugarbeet								465.4			
Sugarcane				1521.7		1451.1	1413.7		1266.3		
Sunflower						519.3		334.9			
Trees					1067.3	895.6			1064.3		
Wheat								601.2		222.8	520.1
Unknown						829.3		456.0	905.2	333.4	535.3

Source: authors' calculations

In our paper we also assumed that investors maximize crop production using irrigation. Therefore, we calculated the resulting water needs (precipitation and irrigation water) assuming that the areas targeted by land investors are equipped with irrigation systems. To verify if the acquired lands are already irrigated we overlapped the FAO's Global Map of Irrigated Area with the map of land deals signed by EU investors (Fig. A1) we found that the average distances between the centre of mass of land deals and the centre of mass of the closest 10’ irrigated grid cell is zero for the 13% of land deals and smaller than 5km, 10 km and 15km for the 20%, 25% and 30 % of land deals, respectively.

Fig. A1 Centre of mass of land deals (red dots) signed by EU investors reported over the global 10’ grid map resolution of irrigated areas (blue areas) provided by Siebert et al.2013



Source: authors’ elaboration.

Acknowledgments

This research has been conducted under the project ‘The role of Europe in land deals: understanding the food-energy-water security nexus’, funded by the Enel Foundation. PD was supported by the National Socio-Environmental Synthesis Center, NSF#DBI-1052875.

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