The impacts of agricultural land-use change on climate regulating ecosystem services

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Master thesis in Environmental Sciences

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Environmental systems analysis

WAGENINGEN UNIVERSITY & RESEARCH

"Nature provides a free lunch, but only if we control our appetites"

William Ruckelshaus

Preface

This thesis is one of the fruits of my labor at Wageningen University & Research, in the environmental sciences programme. During the period of six months, this research focused on "The impacts of agricultural land use change on climate regulating ecosystem services". Much was learned through this research, but personally, I gained hands-on experience in digging literature to get all data that were needed to carry out this study. I gained a new perspective on data acquisition and methods of obtaining high-quality data. Honestly, my personal learning curve has reached a considerable level. It was a great joy to read more than a hundred papers and be aware of the well-known and current knowledge on the terrestrial ecosystems.

I am grateful to my supervisor, Rob Alkemade for his full help during the whole research period. He was always willing to help me when confronted with problems or when needed advice and comments. I wish to express thanks to all of those people that were involved in my study. I would like to thank my husband, parent, friends and fellow students for their moral support. In particular, I would like to thank the Netherlands Government for giving me the opportunity to take part in this master programme.

I hope you will enjoy reading this thesis

Wageningen, 2018

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Abstract

In developing countries, the native vegetation, such as forests and cerrado, has been converted to farmland. Such land-cover change affects water and energy budgets, but this is currently poorly understood. Therefore, several studies advocate to more comprehensively evaluate land-cover change effects on climate, by not considering only the radiative effects of greenhouse-gas emissions, but also non-radiative biophysical effects, such as changes in evapotranspiration and soil moisture. Consequently, I reviewed the existing scientific literature to investigate these land cover change impacts on climate regulation. Analyzing the variation in evapotranspiration and soil-water content helps to better understand how those changes affect precipitation and how this, in turn, alters local climates.

Twenty-five of the reviewed studies were analyzed but only, ten papers provided evapotranspiration values and seven papers provided soil-water content estimates of different land covers. The other eight qualitatively related evapotranspiration and soil-water content variation to the influential environmental factors. To compare the evapotranspiration and soil-water content values over different land covers, the average, percentage change and the significance of differences were calculated in MS-Excel. Both measured and modeled results agreed that the evapotranspiration from forests and crops significantly differed ($P<0.05$). The evapotranspiration in the original vegetation was much higher compared to that of crops or pastures. These results suggest that the conversion of native vegetation to farmland or pasture changes the hydrological cycle by shifting the balance between rainfall, evaporation and transpiration. In addition, the evapotranspiration change is not only controlled by the vegetation types but also other factors such as weather variables, crop characteristics, management activities and environmental conditions.

The measured results indicate that at a comparable soil depth, soil-water content varies spatially and temporally. Soil-water content interchanged between forest, crops and pastures, and no significant difference appeared between them ($P>0.05$). The results also show that the soil-water content variation does not only depend on the land-cover type but also soil texture, soil structure, soil density and soil depth, precipitation, vegetation characteristics and landscape-management activities. Overall, my results confirm that conversion of original vegetation to agricultural vegetation reduce evapotranspiration. As the agricultural production continues to intensify in the region, the impacts on evapotranspiration and soil-water content, and in turn, on the water cycle and local climate need to be addressed.

1. Introduction

1.1 Background

Natural ecosystems provide many benefits to people and therefore contribute to human well-being. These contributions are known as 'ecosystem services'(Fisher et al., 2009). Ecosystem services include provisioning services (e.g. food and water), regulating services (e.g. pollination and climate regulation), cultural services (e.g. recreation and spiritual services) and supporting or habitat services (e.g. nutrient cycling and habitat for species). Millenium Ecosystem Assessment, (2005) gives a broad overview of these services. Terrestrial ecosystems can regulate climate through biogeochemical (greenhouse gas regulation) and biophysical (water and energy regulation) processes (MA, 2005, Li et al., 2013, Smith et al., 2011).

The processes involved in climate regulation include: a) Absorption of atmospheric CO_2 through photosynthesis; b) Regulating cloud formation, precipitation and radiative properties of the atmosphere, by controlling the amount of water vapor entering the atmosphere through evapotranspiration of soil and plants; c) Change of albedo in different land surfaces which can have cooling or warming effects on the earth surface; d) vegetation scavenging of aerosols from soil erosion or vegetation that can reflect or trap solar radiation (cooling or warming effects) and affect cloud formation (Smith et al., 2011; Table 1). Several other factors can also affect the process of climate regulation. Factors that influence the climate regulation process by ecosystems, include land-cover change, such as the conversion to cropland and application of agricultural technologies to produce food, wood, timber and other materials (Li et al., 2013, Lead et al., 2005). For instance, the agricultural technology, such as conventional tillage which involves regular and deep plowing of the soil to loose soil structure, advance drainage and aeration, controlling weeds, can reduce soil organic matter, make soil less able to absorb and retain water and expose soil to erosion and run-off.

Several studies affirmed that land cover changes have a recognized effect on both biogeochemical and biophysical processes. For instance, land cover changes affects regional and global climate through changes in vegetation and soil carbon which lead to the modification of the net flux of greenhouse gases (biogeochemical effects) and biophysical variation of the surface energy budget mediated by albedo, evapotranspiration and surface roughness (Li et al., 2015, Alkama and Cescatti, 2016, Zhang et al., 2014, Perugini et al., 2017, Quesada et al., 2017).

Evapotranspiration is a process by which water vapor is released into the atmosphere due to soil evaporation and plant transpiration. It plays an important role in water balance as well as the energy balance of the land surface (Oki and Kanae, 2006). Vegetation absorbs water from the soil in liquid form via their roots and releases it as a vapor into the atmosphere, and then the released water vapor condenses to form clouds and rain. Evaporation and transpiration are important physical processes that contribute to the hydrologic cycle, they occur simultaneously and there is no easy way to distinguish the two processes. In an agricultural field, when a crop is small, the water is predominantly lost by soil evaporation, however, once the crop is well developed and completely covers the soil, the water is predominantly lost by transpiration. For instance, at the full crop covered soil more than 90% of evapotranspiration comes from transpiration, whereas when the crop just start growing after seeding almost 100% of evapotranspiration comes from evaporation (Allen et al., 1998, Moene and Van Dam, 2014). In addition, both evaporation and transpiration depend on the availability of soil water. However, climate and other environmental conditions also lead to spatially or temporally heterogeneous changes in evapotranspiration level.

Table 1. Biogeochemical and biophysical mechanisms through which ecosystems regulate climate. (Adapted from (Smith et al., 2011)

Biogeochemical effects	Sources or sinks of GHGs affect radiative forcing and leads to climate warming. Carbon is stored in vegetation and soils including peatlands. Growing vegetation and well-managed soils can remove carbon from the atmosphere and ecosystem management can regulate CO2 emissions to the atmosphere.
	Source of aerosols; vegetation and soil erosion produce the aerosol that can reflect or trap solar radiation (warming or cooling effect) and affect cloud formation.
Biophysical effects	Local regulation
	Regulation of humidity and precipitation and temperature, Provision of shade and shelter from heat, Ultraviolet light, wind and precipitation.
	Regional/Global regulation
	Surface roughness –affect winds
	Surface albedo; Darker surfaces reflect less of the sun's energy and trap warmth in the atmosphere. Planting more trees can reduce albedo, especially where there is often snow cover. Therefore, change in surface albedo can affect radiative forcing and temperature.
	Evapotranspiration –affect transfer of heat and moisture. The evapotranspiration from vegetation and soil control the amount of water vapor entering the atmosphere, regulating cloud formation and radiation transfer in the atmosphere.

Evapotranspiration is the sum of plant transpiration and soil evaporation. If the plant transpiration or soil evaporation decreases, so too does evapotranspiration. Therefore, evapotranspiration change is not only controlled by the vegetation types but also other factors. These factors are mainly weather conditions, crop factors and management and environmental conditions. Weather conditions control the amount of energy available for evaporation and therefore weather parameters such as solar radiation, wind speed, relative humidity and temperature play an important role in determining evapotranspiration rate. Crop height, plant density, variety and development stage are also the important factors that should be considered because differences in crop height, crop resistance to transpiration, crop roughness, etc. result in different evapotranspiration levels. Another factor to be considered is soil moisture since the evaporation cannot occur if there is no water available in the soil. When the plant's soil is lacking the moisture, the plant begins to transpire less as an effort to survive. This, in turn, decreases evapotranspiration (Briney, 2017). Therefore, understanding the spatial and temporal variations in evapotranspiration and its influential factors is very important.

1.2 Problem description

According to the United Nation's report (UN, 2013), the population in developing countries, especially in Africa, are still growing exponentially. The population increase over the last decades has increased the practice of agricultural land conversion to meet the high demand for food and economic development. This has degraded many ecosystem services. As human numbers further increase, more food and other resources are needed. So, increasing consumption rapidly increases the use of natural resources and this globally lead to changing ecosystems. A key issue for sustainable development is whether land resources will continue to match with the growing human populations, especially those in developing countries. Currently, more than 80% of world's population lives in developing countries (UN, 2017) and a many are highly dependent on natural resources and ecosystem services for their livelihoods (Baumann, 2002).

According to FAO (2011), the rate of deforestation in tropical regions remain high. In, for example, both Latin America and Africa, the average rate exceeds 0.5% per year and this is more than five times of the global rate (FAO, 2011). The deforestation and potential degradation of land and the conversion to croplands and pastures in developing countries are the main driver of changing climate regulation by ecosystems and therefore impact climate (Blackman, 2013, IPCC, 2007). The removal of forest and replacing them with crops or pastures will, therefore, have a large impact on the climate and hydrology of the deforested area. High deforestation rates and expansion of agricultural area drive widespread changes in vegetation, potentially leading to changes in evapotranspiration.

Contribution of evapotranspiration to climate regulation is expected to have changed as a result of deforestation and agricultural expansion (FAO, 2011). Evapotranspiration is a critical and an important component of the water cycle, in addition to precipitation and runoff, since it returns about 60% of annual land precipitation to the atmosphere (Pan et al., 2015) and it is responsible of 15% of atmosphere's water vapor. Without that inputs of water vapor cloud formation is reduced and consequently precipitation (HydroPoint, 2017).

Figure 1 shows the influence of vegetation on evapotranspiration (ET) and soil moisture. The arrows indicate the interactions between the characteristics that are described in the boxes. These interactions can be either negative or positive. Different vegetation types have their specific characteristics, and thus also different levels of evapotranspiration and soil moisture. Changes of vegetation cover, such as conversion from forest to cropland or harvesting and logging, will change the evapotranspiration level and soil moisture content. Soil texture determines the total water storage, available water-holding capacity and the water movement in the soil. Therefore, soil texture will affect directly the soil hydraulic conductivity, field capacity, wilting point and other soil parameters and indirectly affect soil moisture and surface runoff, which will further affect hydrology (e.g. evapotranspiration, total runoff) and soil thermodynamics (e.g. soil heat flux, soil temperature and land surface temperature). Due to its cooling effects, the evapotranspiration tends to have a negative impact on surface temperature (Xia et al., 2015).

Generally, the evapotranspiration in forests is higher than in croplands or pastures, as more energy is emitted from the ground as sensible heat instead of latent heat. After deforestation, the flux of water into the atmosphere will likely be reduced, and therefore water vapor in the air and consequently precipitation will be reduced (Sanderson et al., 2012).

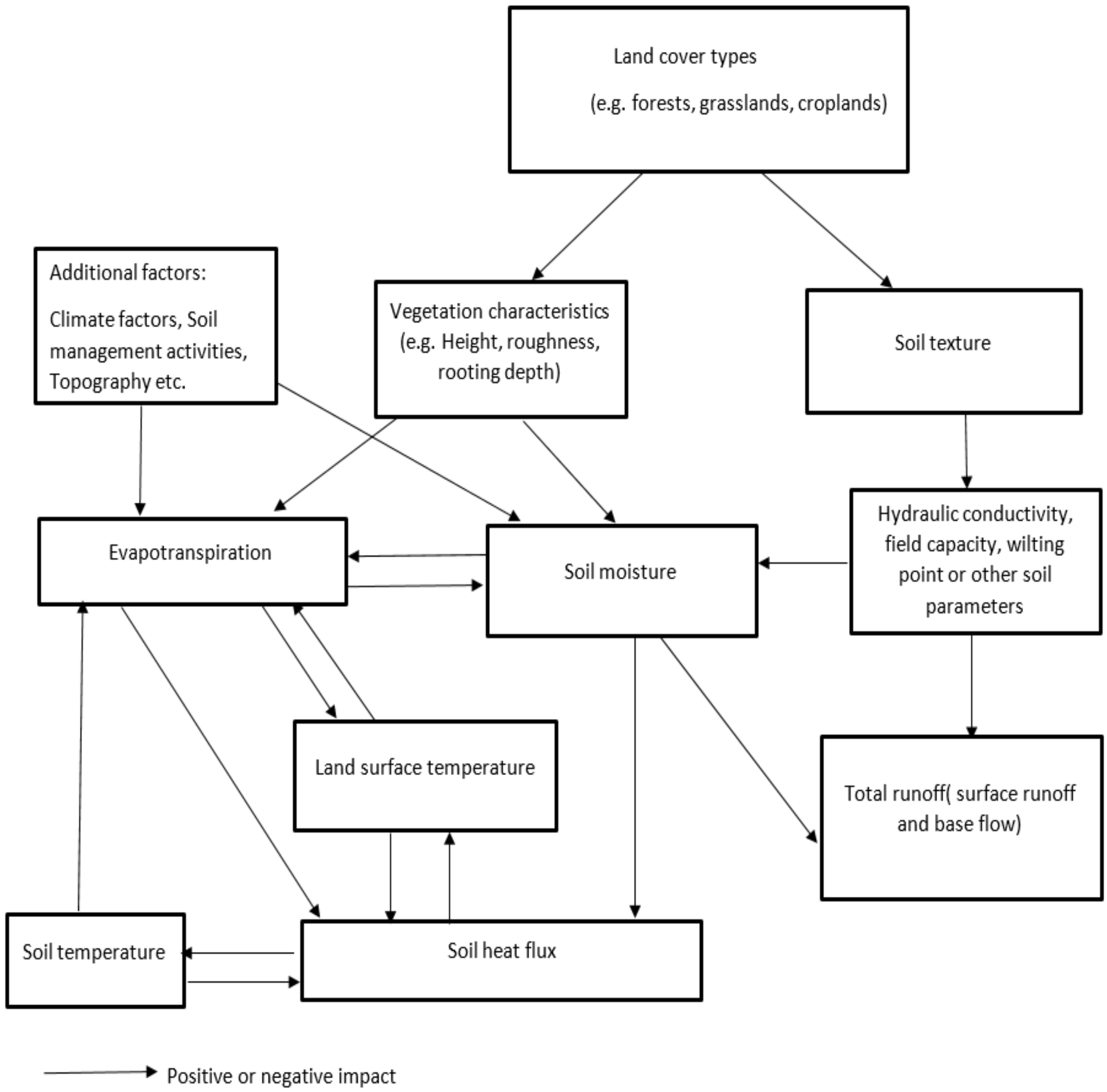

Figure 1. Schematic diagram of the impacts of vegetation type on evapotranspiration, soil moisture and soil temperature

Assessing the impacts and clarify the major drivers of the land-cover change with respect to climate regulating ecosystem services is necessary to implement appropriate land use and land management. Yet, several studies have already advocated for a more comprehensive evaluation of land cover change effects on climate, beyond the global warming potential, without providing a quantitative assessment on non-radiative biophysical effects (Perugini et al., 2017). Scale and uncertainty issues of linked radiative and non-radiative biophysical effects hamper this assessment.

This study focusses on the impact that land cover change has on some aspects of climate regulation by ecosystems, these aspects include evapotranspiration and soil moisture to a better understanding of how those changes affect precipitation, and how this, in turn, alter the local climate. The research aims to investigate the impacts of land-cover change, including the conversion from natural vegetation to croplands or pastures on local climate regulating ecosystem services. Specific objectives of my study are:

(a) To investigate the difference in evapotranspiration between natural ecosystems and agricultural ecosystems;

(b) to investigate how the conversion of the natural ecosystem to cropland, pasture or other agricultural activities alters the soil moisture content.

I specifically addressed three questions (RQs):

RQ1) Does the conversion of the natural vegetation to cropland or pasture influence evapotranspiration in the terrestrial ecosystem?

RQ2) Does the removal of vegetation cover and its alteration during the conversion of forested land to cropland influence the water content in the soil?

RQ3) What are the factors that influence the impacts of land cover changes on evapotranspiration and soil water content?

This thesis is composed of six sections: Section 1 introduces the research title and explain its importance. Section 2 describes the method that I used to collect data and analyze them in order to answer my research questions. Section 3 provides the review results. Section 4 describes results analysis. Section 5 discusses the major findings in the analysis. Finally, section 6 concludes with a summary of my work and implication of the research results.

2. Research Methodology

2.1. Study areas

According to FAO (2011) and IPCC (2007) the rate of deforestation in developing countries remains alarmingly high. The conversion of forests to croplands or pastures will lead to changes in climate regulation by ecosystems and therefore impact climate. This study focused on four developing countries; Brazil, Indonesia, China and Kenya. The first three countries were selected have large extents of forests and have high forest losses according to Global forest watch report (GFW, 2017). Kenya was selected because it represents another agro-ecological zone (see Figure 2). and because of data availability.

Brazil: Brazil covers much of the Amazon rainforest (60%) which is the largest world tropical rainforest. The recent numbers showed that 7,989 square kilometers of rainforest were destroyed between August 2015 and July 2016, and suggest that the annual rate of primary forest loss in the Brazilian Amazon has climbed to 75% over its 2012 level (which was the lowest level) (Butler, 2016). Cattle ranching is leading cause of deforestation in the Brazilian Amazon. 65-70% of deforestation in the Amazon results from cattle ranches while 20-25% results from small-scale subsistence agriculture, large-scale (commercial agriculture), 2-3% from logging (legal and illegal) and 1-2% from urbanization, mining, dams and fires (Butler (2014). The Global forest watch report placed Brazil on the first place of developing country with high rate of tree cover loss and the second place worldwide.

Indonesia: Southeast Asia is experiencing a rapid expansion of agricultural land area by rainforest conversion. According to forest resource assessment, in 1990, tropical forest covered 247.3 million ha which was reduced to 214.1 million ha in 2010. The deforestation rate in Southeast Asia from 1990-2010 was approximately 1.7 million ha/y, of which 1.2 million ha/y came from Indonesia (FRA, 2010).The spatial and temporal explicit quantification of Indonesian primary forest loss totaled over 6.02 Mha from 2000 to 2012 and increased on average by 47,600 ha per year. By 2012 Indonesia had higher annual primary forest loss than Brazil, which was 0.84 Mha and 0.46 Mha respectively (Margono et al., 2014). The Global forest watch report Indonesia as the fifth country with the higher rate of tree cover loss and the second from developing countries.

China: In 2012 around 14% of China was covered by forest and the illegal logging and slash and burn agriculture consumed up to 5.000 square kilometers of primary forest every year (Hays, 2012). The Global forest watch report China on the seventh place of the countries with high rate of tree cover loss and the third from the developing countries.

Kenya: In 1963, the forest cover in Kenya was 10 percent, but by 2006 it became 1.7 percent. The destruction of 400,000 ha of Mau Forest in the heart of Kenya's Rift Valley brought the issues of the deforestation, environmental degradation and its impact on climate (Sweeney et al., 2011). The Global forest watch report put Kenya on the sixty-eight place of the countries with high rate of tree cover loss.

Figure 2 Map of four countries included in the analysis: Brazil, Kenya, China and Indonesia.

2.2. Literature review

To better understand how evapotranspiration responds to changes in vegetation cover types, this study compared the difference in the average annual evapotranspiration between natural ecosystem and agricultural ecosystem (RQ1). An assessment of how soil moisture varies across different land cover types was also carried out by making a comparison between water content in natural land and agricultural land (RQ2). Factors that can influence the variation of both evapotranspiration and soil water content were only described based on the available literature (RQ3). To answer my research questions, the current update knowledge on evapotranspiration and soil water content from published papers were collected and analyzed using a structured method known as a systematic review. The systematic review aimed to find estimates of the differences in evapotranspiration and soil moisture between forests, or natural vegetation in general, and agricultural land uses. Systematic review refers to a review that uses a systematic and explicit method to survey the literature, select papers to include and analyze data from the studies that are included in the review. In other words, the similar results should be obtained if the procedure is repeated (Pickering and Byrne, 2014). This approach can be used to review both qualitative and quantitative literature, which make it suitable for interdisciplinary research topics. This review followed the guidelines outlined by (Pickering and Byrne, 2014).

The relevant articles to be reviewed were searched from the following databases: Web of Science and grey literature from Google Scholar, and institutional website in combination with Wageningen University Library Online Service to have access to all the articles available. The search terms had to be relevant to the agricultural land use and ecosystem services. The search terms used were: “agriculture* or *land* or *land use* or *land cover change* or *land properties* or *farm* AND *climate regulation* or *evapotranspiration* or *evaporation* or *transpiration*or *soil moisture*”. For the geographic search, the following terms were used; Developing countries, Tropical region, Africa, and specific countries such as China, Indonesia, Brazil, Kenya. And for google scholar, two or more of these terms were combined to search literature. For instance, the follow combination was used; the evapotranspiration or soil water content and developing countries, evapotranspiration or soil water content combined with specific country such as Brazil, China, Indonesia and Kenya.

Papers were selected based on the following criteria: a) Be published after January 2000 in English. b) Report the variation in evapotranspiration or soil moisture. c) Report annual or monthly average change values of evapotranspiration or soil moisture content. d) Report the effects at the local level of one of the developing countries. The selection of eligible literature was conducted following the methodology proposed by Preferred Reporting Items for Systematic review and Meta-Analyses (Prisma, 2015). To ensure that I included studies that are related to my topic, all the studies were first screened after reading the titles and abstracts, and then exclude those that are irrelevant. After that, the full text of all studies that passed the initial screening was assessed based on the eligibility criteria, mentioned above. The number of studies excluded and those retained is recorded for each of the screening stages according to PRISMA statement (Figure 3).

2.3. Data source

To evaluate the evapotranspiration and soil water content changes in different vegetation types, I used the data obtained from the selected papers. For the evapotranspiration, most of the papers used the improved algorithm that uses remote sensing inputs (e.g. MODIS satellite observation of land cover, lead area index, albedo, fraction of absorbed photosynthetically active radiation), daily meteorological or weather inputs (e.g. air pressure, air temperature, wind speed and direction, humidity and radiation and rainfall data) and agricultural production data to estimate evapotranspiration by using the penman-Monteith equation (Oliveira et al., 2014, Spera et al., 2016, Nóbrega et al., 2017, Lathuillière et al., 2014, Mo et al., 2015, Alemayehu et al., 2017). The other evapotranspiration data were extracted from the modeled results, where studies modeled the evapotranspiration by using Expert-N model, Water Flow and Balance Simulation Model WASIM-ETH and the Integrated Model of Land Surface Processes (INLAND) and the Dynamic Model of Agroecosystems (AgroIBIS) (Gerold, 2010, Kurniawan, 2016, Dias et al., 2015). However, these models used the measured or observed input data and their results were validated (e.g. with the measurement of eddy covariance, Evaporation pan, Bowen ratio and water balance). Some papers also used data from different field measurements and apply the satellite-based image-processing model to improve the estimation of evapotranspiration. For instance, the study of Nóbrega et al. (2017) used the combination of the Surface Energy Balance Algorithm for Land (SEBAL) and Mapping Evapotranspiration at high Resolution with Internalized Calibration (METRIC) models to improve the evapotranspiration estimated from the Weather data. For soil water content, data were extracted from the measured results by using the electronic tensiometers, where soil samples were extracted using subsoil probes, soil augers, and oven drying to determine soil moisture. The laboratory analyses were conducted and determined the loss in soil mass during oven drying to constant mass (see Table 2).

2. 4. Statistical Analyses

Statistical analysis was used to combine the data from reviewed studies in order to detect spatiotemporal evapotranspiration and soil moisture changes. Since the evapotranspiration and soil water content vary considerably in time and space depending on the latitude and climate, data were grouped into four countries from different climate zones (Figure 2). Data were further grouped according to the vegetation cover types such as forestland, cropland, cerrado and pastures. The data of the observed, measured and modeled papers were critically analyzed and interpreted separately since they are not directly comparable, mainly due to the differences in boundary conditions they consider, instruments and techniques they used. Basic statistics, such as the average and standard deviation were reported for each vegetation cover type. To compare the evapotranspiration and soil water content values over different land covers, multiple comparison was made by calculating the difference in values (percentage change), calculating the mean values (average) over areas classified as forests or cerrado and croplands or pastures, and by testing the significance of the difference between the values by calculating the probability value (P-value) from T-test. It was planned to conduct Meta-analysis, but the time did not allow to go further. All the analyses were performed using Excel 2016.

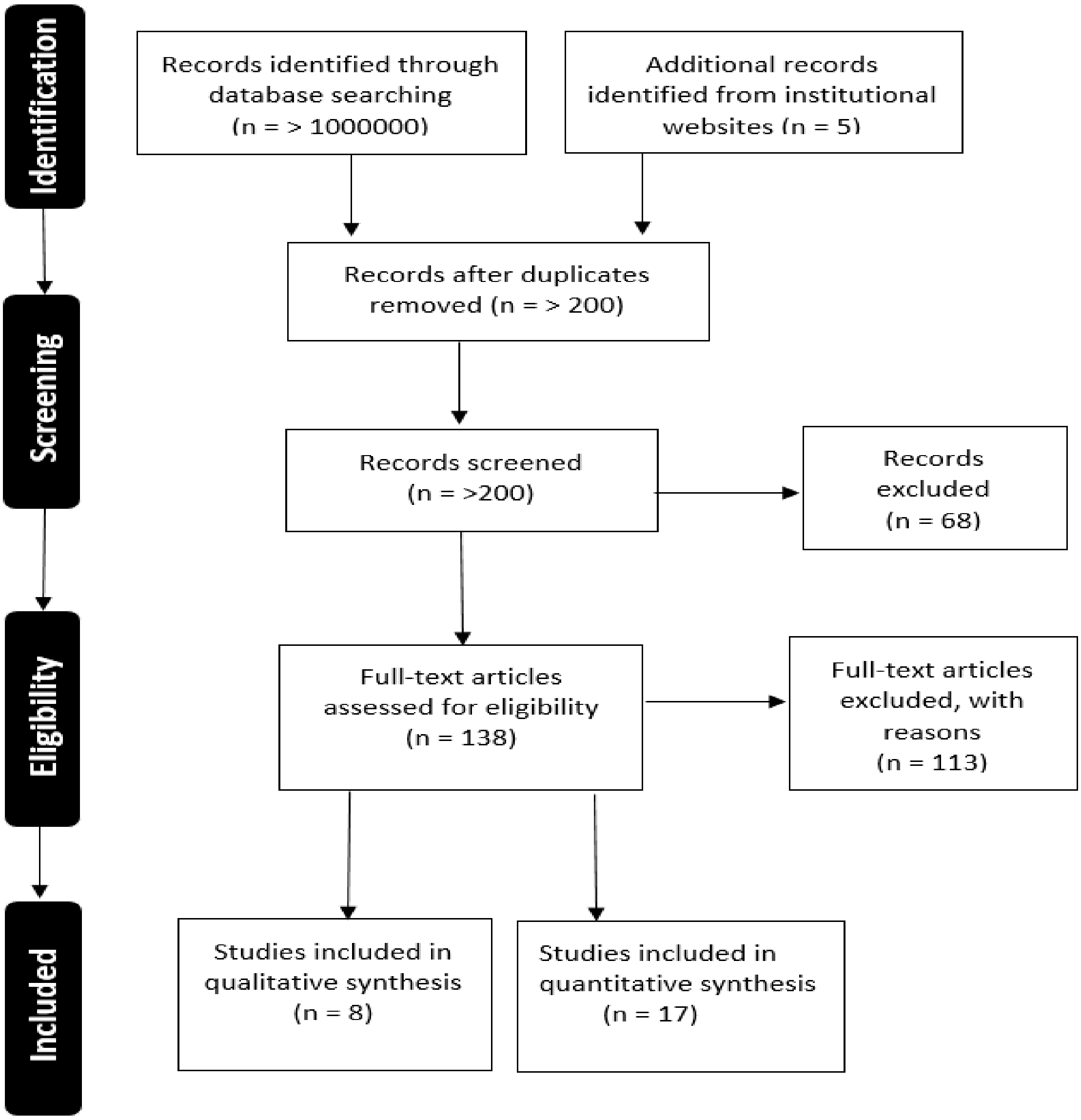

Figure 3. Flowchart describing the literature review process (Adapted from (Prisma, 2015).

3. Review results

The following section contains the main results from the reviewed studies. In total, the abstract of more than 200 articles have been scanned, 138 have been fully read and assessed based on the eligibility criteria. Out of 138 studies that were analyzed, 36 fulfilled the eligibility criteria, out of which 25 studies were included in the analysis and where seventeen studies used in the quantitative synthesis and eight studies used in qualitative synthesis. It was not possible to extract data from all the eligible studies because of a lack of time, not provide quantitative data, lack of supporting arguments, not focused on one of the developing countries and not reported in English. The comparative studies were not also included because they were only comparing the evapotranspiration simulate with different models, but they did not provide direct insights on evapotranspiration variation, and the studies provided the daily evapotranspiration rate were excluded because it was not reasonable to compare daily values with annual values. From the twenty-five studies selected, ten provide evapotranspiration values under different land cover types, and seven provide soil water content estimates of different land cover types, and the other eight provide a qualitative study on evapotranspiration and soil water content variation and their influential factors.

Table 2 Summarizes all studies included in the analysis and their main characteristics according to sources (e.g. observed, measured or modeled), climate zone (tropical, temperate) and vegetation type (forest, grassland, cropland, etc).

3.1. Evapotranspiration change under different vegetation types and climate zone

Ten studies reported data on changes in annual evapotranspiration values within different vegetation cover types (see Appendix 2). For each country selected I give a brief overview of the main findings.

I found five papers for Brazil. The study by Dias et al. (2015) assessed the influence of land cover changes on evapotranspiration in Mato Grosso state. They simulated evapotranspiration for the most four common land cover types found in the upper Xingu basin: tropical forest, cerrado, pasture and soybean cropland. This area is characterized by a generally flat topography and dominated by oxisols with a mean soil texture of 2% silt, 43% clay and 55% sand. The mean annual precipitation during the study period was 1301mm. Mean annual evapotranspiration in natural ecosystems was 1017mm, while for the agricultural ecosystems was 623mm. Total annual runoff was 694mm in agricultural ecosystems and 324mm in natural ecosystems. Therefore, simulated mean annual evapotranspiration was around 40% lower in agricultural ecosystems than in natural ecosystems, whereas the average of total runoff for agricultural ecosystem was twice that of the natural ecosystem.

The study by Oliveira et al. (2014) assessed water balance of Brazilian cerrado. The results showed that the evapotranspiration was highest in forest and Cerrado, and it is reduced in the other land cover types. This study also examined the annual evapotranspiration data in an area of the 45km^2 that was deforested in 2009. The consequence of deforestation was an evapotranspiration decrease of 36% (429mm) between 2008 and 2009. They affirmed that conversion of native vegetation to pasture or cropland led to a decrease of evapotranspiration.

The study by Spera et al. (2016) determined the impacts of agricultural conversion on regional evapotranspiration in Matopiba. During this study period, aggregated cropland area in Matopiba was almost doubled from 1.3 ha to 2.5 million ha, with an additional one million hectares had been converted and later left fallow or used for the other purposes. The result indicated that the averaged evapotranspiration over cerrado vegetation was higher than that in cropland. They noticed that during 2003 native vegetation transpired 800mm of water per unit area, while croplands transpired 510mm, which means 64% that of cerrado. Both single and double-cropping rotations showed a decrease in evapotranspiration during the dry season when compared to native vegetation. There was a significant different seasonal trend in evapotranspiration between natural vegetation and row-crop agriculture. They also found that changes in land use have decreased water recycled to the atmosphere via evapotranspiration each year (2001-2013) and that more water would have been recycled into the atmosphere if there had have been no land use changes. This was determined by comparing the evapotranspiration in land-use changes with the evapotranspiration estimated as if there had have been no land use changes.

Table 2. Papers included in the analysis

Paper	Method	Geographical area / Length of time series	Variable	Vegetation types
Silvério et al. (2015)	Regression analysis (Remotely-sensed data & weather input data)	upper Xingu basin, Brazil (2000-2010)	ET/LST	Forest, cropland and pasture
Zheng et al. (2015)	ECH2O EC-TM soil-moisture sensor	Saihanwula, China (2013)	SWC/ST	Forest, grassland
Dias et al. (2015)	INLAND/AgroIBIS models	Mato Grosso state, Brazil (2008-2010)	ET	Forest, cropland pasture and cerrado
Oliveira et al. (2014)	Penman-Monteith equation (MOD16/GRACE/TRMM data)	Cerrado biome, Brazil, (2002)	ET	Forest, cropland pasture, cerrado grassland
Spera et al. (2016)	Penman-Monteith (MODIS MOD16A2 data)	Matopiba, Brazil (2001-2013)	ET	Cropland and cerrado
Nóbrega et al. (2017)	SEBAL & METRIC models (weather data)	Mato Grosso, Brazil (2012-2014)	ET	Pasture and cerrado
Lathuillière et al. (2014)	Penman-Monteith (MODIS MOD16 data)	Mato Grosso, Brazil (2000-2009)	ET	Forest, cropland and pasture
Mo et al. (2015)	Remote sensing ET model (NDIV &Terra-MODIS)	Tibetan palteau, China (2000-2010)	ET	Forest, grassland cropland and shrubs
Kurniawan (2016)	Expert-N model	Sumatra, Indonesia (2013)	ET	Forest and cropland
Gerold (2010)	WASIM-ETH model	Sulawesi, Indonesia (2002-2007)	ET	Forest and cropland
Alemayehu et al. (2017)	MODIS- MOD16 & GLDAS	Mara basin, Kenya (2002-2010)	ET	Forest, cropland grassland and shrubs
Kiptala et al. (2013)	SEBAL model (MODIS data)	Upper Pangani basin Kenya (2008-2010)	ET	Forest, cropland shrubs and grassland
Feltrin et al. (2013)	Subsoil probe & oven drying	Santa Maria, Brazil (2010-2011)	SWC	Forest and pasture
Wang et al. (2009)	Subsoil probe/ Oven drying	Shaanxi Province, China (2001-1006	SWC	Forest, cropland grassland and shrubs
Wang et al. (2013)	Soil auger/ Oven drying	Loess Plateau, China	SWC	Forest, cropland grassland and shrubs
Yang et al. (2012)	soil drill & oven drying	Loess Plateau, China (2009-2010)	SWC	Forest, pasture cropland, grassland shrubs
Wang et al. (2014)	Subsoil probe/ Oven drying	Loess Plateau, China (2001-2008)	SWC	Forest, cropland grassland and shrubs
Handayani (2004)	Pressure plate apparatus method	Sumatra, Indonesia	SWC	Forest, cropland and grassland
Otieno et al. (2011)	Soil cambers/ Oven drying	Nyanza province, Kenya (2008-2009)	SWC	Forest, cropland and pasture
Mganga et al. (2011)	Gravimetric method	Kibwezi district, Kenya (2008)	SWC	Pasture, cropland and shrubs
Wei et al. (2017)	DHSVM model	Huangnizhuang watershed China (2001-2009)	SWC	Forest, grassland and shrubs
Almusaed (2010)	N.D	Any location	ET	Any type
Zhang and Chen (2017)	MOD16 & Meteorological data	Pearl River Basin, China (2002-2014)	ET/RH/T	N. D
Fang et al. (2016)	Soil drill/ oven drying	Ansai watershed, China	SWC	Grassland, cropland shrubs, pasture, forest
Wang and Wang (2017)	Penman-Monteith equation (weather data)	Shaanxi Province, China (2012-2014)	ET	Cropland

ET−evapotranspiration, SWC−soil water content, RH−relative humidity, ST−soil temperature, T−temperature, LST−land surface temperature, N. D−not determined

The fourth is the study of Nóbrega et al. (2017) which investigated the impacts of conversion the native Cerrado vegetation to pasture on soil hydro-physical properties, evapotranspiration in Das Mortes river basin. The results show that evapotranspiration is smaller in the pasture (639±31% mm/y) than in the cerrado catchment (1004±24% mm/y), and that that there is a significant difference in soil hydro-physical properties between the cerrado and pasture, with greater bulk density and streamflow, and smaller total porosity in the pasture catchment. Therefore, they confirmed that conversion of native cerrado to pasture causes soil hydro-physical properties degradation, reduction in evapotranspiration and increase streamflow.

The study by Lathuillière et al. (2014) assessed hydrologic changes in Mato Grosso. This study presented changes to evapotranspiration contributions from terrestrial ecosystems over the 2000-2009 period, a decade of important deforestation and agricultural expansion activities in the area. The monthly mean forest evapotranspiration was 103mm and 76.4mm, respectively for wet and dry season. Annual forest evapotranspiration contributions to the total evapotranspiration dropped over the decade from 50% in 2000 to 40% in 2009. The evapotranspiration in the pasture was higher than those in crops. However, the annual ET_P went from being ten times the value of ET_C in 2000 to only four times ET_C in 2009, mainly due to the replacement of pasture by cropland, particularly soybeans, in Mato Grosso. The results showed that the monthly evapotranspiration was higher in forestland and varied with precipitation, with the highest values during the wet season and the lowest in the dry season. These results strengthened the importance of forests in recycling precipitation by returning a large amount of soil moisture to the atmosphere.

Only one paper was found for China. The study by Mo et al. (2015) investigated the spatiotemporal variability of evapotranspiration over terrestrial China. This study declared that the largest annual evapotranspiration was from paddy rice (844mm) and evergreen broadleaf forest (783mm), and the lowest was from grassland (377mm) and open shrubs (275mm). The predicted annual evapotranspiration (ETa) showed a large spatial variability across the country, decreasing gradually from south-eastern to northwestern areas. Therefore, in the irrigated cropland the annual evapotranspiration values were larger than in the local precipitation where water availability was limited. The actual evapotranspiration pattern was consistent with that of annual precipitation and indicating that the annual evapotranspiration (ETa) was regulated by precipitation. However, they affirmed that the spatial pattern of actual evapotranspiration was regulated not only with precipitation but also by other factors, such as vegetation characteristics and potential evapotranspiration, etc. This study also found out that the annual evapotranspiration was highly diversified, and its pattern was closely associated with vegetation conditions in the study area, whereas the annual evapotranspiration is low, corresponding with scarce rainfall events and the amount of hardly-vegetated areas.

For Indonesia, I found two papers. The study by Kurniawan (2016) presented the impact of forest conversion to rubber and oil palm plantations on nutrient leaching losses in two landscapes of highly weathered soils that are different in texture, located in Sumatra. The simulated results showed that the annual evapotranspiration in the forest was 1384mm, 1622mm in loam and clay acrisol soils, respectively. Annual evapotranspiration in oil palm plantation was 1027mm, 1071mm, in rubber plantation was 1077mm, 1114mm, in loam and clay acrisol landscapes, respectively. The simulated water balance showed that evapotranspiration and runoff were higher in the clay than loam soils and the evapotranspiration was lower in rubber and oil palm plantations. Transpiration was the largest component of total evapotranspiration in both landscapes (74%, 67% of total evapotranspiration, respectively, for forest and rubber). The study by Gerold (2010) investigated the impact of forest conversion on the water balance, nutrients losses and soil erosion in a small mountainous catchment located in Sulawesi. The water balance components including evapotranspiration were measured in both natural forest and converted forest (cacao plantation) from 2002 to 2007. Natural forest had the largest annual evapotranspiration (1792mm) and precipitation (2725mm) than the deforested area (1220mm and 2590mm respectively). Gerold approved that land use practice with cacao plantations is less critical and can maintain water resources better than annual crops.

I found two papers for Kenya. The study by Alemayehu et al. (2017) mapped the evapotranspiration of different land cover classes in the Mara basin. The results showed that evapotranspiration was highly variable spatially and intra-annually. On average, dense evergreen forest and wetland were the highest water consumers with the evapotranspiration of 1228±59 mm/y and 1286±44 mm/y respectively, whereas the herbaceous cover and rainfed cereals were the lowest with the evapotranspiration of 698±46 mm/y and 706±69 mm/y respectively. The study by Kiptala et al. (2013) analyzed the evapotranspiration trends in 16 land use types, in Upper Pangani River basin. On average, dense evergreen forest (1228±59 mm/y) and wetlands (1286±44 mm/y) were the largest water consumers, whereas the rainfed cereals (706±69 mm/y) and herbaceous cover (698±46 mm/y) were the lowest consumers. Therefore, the highest annual evapotranspiration has been observed for the water bodies and the forested areas. The lowest potential evapotranspiration was estimated for the mountainous areas experiencing afro-alpine climate conditions. The results showed that for the whole basin, the evapotranspiration accounted for 94% of the total precipitation.

In general, all these studies acknowledged that the annual evapotranspiration varies spatially for different types of land use and that the land use, land cover classes and changes have a significant influence on evapotranspiration and further, on the hydrological cycle. Both measured and modeled results agree that the evapotranspiration in natural vegetation was much higher compared to that of agricultural crops. Therefore, replacement of natural vegetation by agriculture like; converting native vegetation such as forest to farmland, pasture or grassland disturbs the hydrological cycle by altering the balance between rainfall, evaporation and transpiration. They also affirmed that the variation of evapotranspiration is not only controlled by the vegetation types but also other different factors such as climate conditions, the vegetation characteristics, soil types, water availability, etc. (These factors will be more described in section 3.3).

3.2. Soil water content under different vegetation types and climate zone

The seven papers that provide estimates of soil water content within different vegetation cover types are summarized in this section. For each country selected I give a brief overview of the main findings.

Only one eligible paper was found for Brazil. The study by Feltrin et al. (2013) monitored the behavior and spatial variability of soil water content under forest vegetation and native pasture in southern Brazil. The electronic tensiometers with pressure transducers were installed at 0.1, 0.3 and 0.7m below the soil surface in order to obtain soil water content from October 2010 to

May 2011. The obtained results showed the greatest variations of soil water content and soil water storage at the depth of 0.1 and 0.3m and less variation at the depth of 0.7m, especially for pasture. At the soil depth of 0.7m, soil water content was 24%, 16% respectively in the forest and native pasture. Furthermore, Soil water content varied not only by the soil depth but also by season. The forest soil had greater water holding capacity and available soil water content than the pasture soil.

For China, I found four papers. The study by Wang et al. (2009) examined the effect of main vegetation types on soil moisture and its inter-annual change. The soil sample was extracted by using subsoil probe and dried in the oven to determine soil moisture of six vegetation; crop, grass, planted shrubs of caragana, planted forests of arborvitae, pine and the mixture of pine and arborvitae. A common characteristic in soil moisture measured under all vegetation types was that there was a great difference among 2001, 2005 and 2006 in the upper part of the soil. In 0-2m, soil moisture was significantly greater in cropland than those of all other vegetation types. The soil moisture of caragana shrubs was considerably lower than those in forests in the 2-10m soil profile, but the confirmed difference was very small. In addition, this study concluded that soil moisture under those six vegetation types depended on the annual precipitation in the study area. The study by Yang et al. (2012) studied the impacts of re-vegetation on soil moisture dynamics and evapotranspiration under five land cover types in loess plateau. This study aimed to reveal the response of soil moisture dynamic to different land use and afforestation approaches. Thus, the dynamic of soil moisture was quantified in order to evaluate the effects of land use change on soil water content during the period of 2009 and 2010. At a comparable soil depths, especially in the depth below 1m, the soil moisture content was lower in pasture grassland, forestland and shrubland compared with traditional farmland and native grassland. The values at 0-1m layer were higher than that in the 1-2m layer probably due to the rainfall. The results indicated that available soil moisture decreased more than 35% when converted to shrubland, pasture grassland, forestland as compared with traditional farmland. Furthermore, among other four types, subshrubs and grassland showed the highest temperatures, corresponding to greater moisture losses. This study confirmed that changes in land cover may alter the soil moisture budget and soil temperature as well.

The study by Wang et al. (2014) evaluated the soil moisture content status and variation in late 2001, 2005-2008 under deep and shallow-rooted vegetation in the semiarid area of the Loess Plateau. The results showed that the soil water content in caragana brush was particularly lower than those under other deep-rooted forests, and this may be due to the higher transpiration and bigger endurance in the drought of caragana. Soil water content was also lower in forestland that that in cropland. The study by Wang et al., 2013 determined the soil water content and related soil (soil particle composition, soil organic carbon) and plant properties such as root depth and root mass to a depth of 21m at the 11 sites across Loess Plateau. Soil water storage and the available soil water storage also were calculated for each 1m thick soil layer. The mean soil water content decreased with depth, from 12% in the surface layer to 8% at the depth of 2.5m, then increased to10% at the depth of 5m. The highest soil water content value was 15% at the depth of 19m. The mean soil water content among 11 sites varied from 4.9% to 18.1%, this difference was influenced by climate factors, soil properties, topography, land use and deduced vegetation characteristics and related hydrological processes such as rainwater infiltration, overland flow and soil erosion. In the root zone, the vertical distribution and quantity of soil water were significantly influenced by land use and plant characteristics, while below the root zone, soil texture became an important factor.an important factor.

I found one eligible paper for Indonesia. The study by Handayani (2004) evaluated the impact of forest clearance on soil quality properties in Bengkulu province, Sumatra. Soil samples were collected from natural secondary forest, bare land, cultivated land and grassland. The results showed that clearing, cultivation and burning of tropical secondary forest lands resulted in degradation of soil quality by changing physical, chemical and biological soil properties. The lowest saturated hydraulic conductivity was found in bare soils and the highest occurred in natural forest. Handayani indicated that land-use change following forest clearance in the study area decreased saturated hydraulic conductivity by 85% and soil water content at field capacity by 34%.

For Kenya, I found two eligible papers. The study by Otieno et al. (2011) examined the spatial heterogeneity in the different ecosystems in Nyanza province. They hypothesized that; the livestock grazing and shifting cultivation modify soil characteristics by lowering soil water holding capacity or promote rapid soil water loss, and that the acacia tree and termitaria facilitate soil moisture infiltration and improve soil moisture availability. The results showed a significant soil water content variation. Soil water content was higher in acacia trees compared to the abandoned farmland. But in contrary, soil temperature was higher in abandoned farmland than in forestland, where soil temperature was 26.4±1.6 and 28.7±1.6 degree Celsius, respectively in acacia and abandoned farmland. This study affirmed that acacia and termitaria improved soil resource availability and significantly contributed to ecosystem carbon dioxide exchange and productivity in the drought period. The study by Mganga et al. (2011) studied how different land use types influence soil properties in tropical semi-arid rangelands. The disturbed and undisturbed soil sample from cultivated, grazed and fallow land were collected and analyzed. Soil moisture content was 7.4±1.69 %, 6.9±0.88 %, 2.5±0.82 % in grazing land, cultivated land and fallow land, respectively. Grazed and cultivated land have higher soil water content due to the sandy clay soil textures with a higher percentage of clay content compared to sandy clay loam soils in the fallow land. It may be also due to the high rate of hydraulic conductivity in fallow land which facilitated the free movement of water in the study area

The reviewed studies indicated that soil water content varies spatially and temporally. Soil water content was affected and characterized by land cover and land uses in the different region. The results showed that the land use types influenced soil physical and chemical properties. In addition, soil water content variations depend on soil texture, structure, density and depth, vegetation characteristics, precipitation etc. and landscape management activities such as tillage, farmland fallow, etc. can affect soil moisture (These factors will be more described in the following section).

3.3. Evapotranspiration and soil water content factors

In this section, I give a brief overview of the main findings from four papers found. The study by Zhang and Chen (2017) analyzed the dynamic spatiotemporal changes in evapotranspiration and its associated factors in the Pearl River Basin from 2000 to 2014, by using the monthly MOD16 evapotranspiration dataset and daily meteorological data. The results of the study showed that over space and time, annual evapotranspiration showed a small increasing trend during the study period, with an average value of approximately 946.56mm. The evapotranspiration significantly varied at the monthly and seasonal scales. July was the highest month with higher evapotranspiration of approximately 119.57mm and this was 36.37% of the annual evapotranspiration. In this study, six factors such as temperature (maximum, minimum and averaged), relative humidity, wind and sunshine hours, were selected to discuss the effects of meteorological factors on evapotranspiration. They found out that in different months, these meteorological factors had different change trends and influences on evapotranspiration changes. Dynamic changes in annual evapotranspiration were mainly associated with temperature and relative humidity. However, these factors vary in different regions and at different times. The spatial variations in evapotranspiration and its correlated factors were affected by the complex effects of climatic conditions that differ at different latitudes and elevations and under different topographic conditions.

The study by Almusaed (2010) described the factors that control the evapotranspiration in the chapter 13 of this study. Almusaed affirmed that the rate of evapotranspiration at any location on the Earth's surface is controlled by the following factors: humidity and temperature, wind, source and availability of water, solar radiation, plant type, stomata resistance, physical attribute of the vegetation, soil property and texture, geographic pattern and energy convenience. The third one is the study of Wei et al. (2017) which investigated factors that controlling temporal stability of surface soil moisture in Huangnizhuang watershed by using long-term simulated high-resolution surface soil moisture data. To examine whether a watershed area can be identified from causative factors, the spatial pattern of soil moisture temporal stability related to the possible control of vegetation cover, soil type and topographic wetness index were analyzed. The results showed that areas with vegetation cover and a low topographic wetness index can provide a reasonable mean soil moisture estimates. Without considering the vegetation and topography, the temporal stability method results in lower accuracy in the estimation of soil moisture.

The study by Fang et al. (2016) analyzed the variation and factors that influence the deep soil moisture in Ansai watershed. At the comparable soil depth, this study affirmed that the variation of deep soil moisture under native vegetation was much lower than in human-managed vegetation. The deep soil moisture and its variation in farmland were higher than those in native grassland, this indicates that human agricultural measures can greatly increase deep soil moisture and its variation. To completely investigate the influencing factors of deep soil moisture, this study examined topographic factors, surface soil properties, vegetation traits and climatic factors. Those factors were presented by 23 different variables: average annual rainfall, altitude, slope position, slope aspect, slope gradient, clay, sand, silt, organic matter, capillary porosity, soil bulk density, vegetation coverage, grass biomass, grass height, planting density, plant height, diameter at breast height, crown width, basal diameter, litter maximum water holding, litter biomass and clear bole height. In general, vegetation cover was a dominant factor, however, the variation in deep soil moisture in the study area were the combined results of the climate, topography, soil and human management measures and vegetation.

4. Results analysis

4.1. Analysis of the effects of land cover changes on evapotranspiration

Based on the reviewed studies, I analysed the spatio-temporal changes in evapotranspiration. The review showed that a widespread agricultural expansion including the conversion of natural vegetation (e.g forest and cerrado) to crops and pastures has a significant influence on the evapotranspiration rate and its variation. In Section 3.1, all reviewed papers showed a noticeable variation in the evapotranspiration rate under different vegetation types, and they affirmed that the conversion of native vegetation such as forest and cerrado, to pasture and cropland, led to a decrease of evapotranspiration (see table 3). Evapotranspiration between forestland and cropland decreases ranges from 12% in the study by Mo et al. (2015), in China to 56% in the study by Lathuillière et al. (2014), in Brazil. Evapotranspiration between forestland and pasture decreases ranges from 17% in the study by Lathuillière et al. (2014) to 45% in the study by Dias et al. (2015) in Brazil. In addition, the evapotranspiration between the Brazilian cerrado and crops show a decrease ranges from 27% in the study by Spera et al. (2016) to 42% in the study by Oliveira et al. (2014). Furthermore, the evapotranspiration decreases range from 36% in the study of Nóbrega et al. (2017) to 44% in the study by Dias et al. (2015) between Brazilian cerrado and pasture.

Table 3. Change in annual evapotranspiration (mm) under native forest and cropland

Source	ET_F	ET_{CE}	ET_P	ET_{Cr}	ETc (F-Cr)	ETc (F-P)	ETc (CE-Cr)	ETc (CE-P)
Dias et al. (2015)	1025	1010	567	679	-34%	-45%	-33%	-44%
Oliveira et al. (2014)	1272	1269	721	731	-43%	-43%	-42%	-43%
Mo et al. (2015)	783	–	–	687	-12%	–	–	–
Kurniawan (2016)	1622	–	–	1071	-34%	–	–	–
Lathuillière et al. (2014)	1076	–	889	476	-56%	-17%	–	–
Gerold (2010)	1792	–	–	1220	-32%	–	–	–
Alemayehu et al. (2017)	1228	–		706	-43%	–	–	–
Kiptala et al. (2013)	1571	–	–	789	-50%	–	–	–
Spera et al. (2016)	–	904	–	661	–	–	-27%	–
Nóbrega et al. (2017)	–	1004	639		–	–	–	-36%
Average	1296	1047	704	780	-40%	-44%	-26%	-33%
Standard Deviation	342	156	138	227				

ET−evapotranspiration, ET_F−evapotranspiration in forest, ET_{CE}−evapotranspiration in cerrado, ET_P−evapotranspiration in pasture, ET_{Cr}−evapotranspiration in cropland, ETc−evapotranspiration change, F−forest, Cr−crop, CE−cerrado, P−pasture

Based on the results presented in table 3, the average annual evapotranspiration is 1296±342 mm in the forest and 780±227 mm in crops, 1047±156 mm in cerrado and 704±138 mm in the pasture. If the forest is replaced by crops and pasture, the evapotranspiration will be respectively 40% and 44% lower than that it could be in forestland. Crops have greater evapotranspiration rate than that in pastures. Therefore, the transition of forest to crop causes a lower decrease in evapotranspiration compared to the forest to pasture transition. In addition, the transition of Brazilian cerrado to cropland and pasture also reduces the evapotranspiration for 26% and 33% respectively. Then, conversion of cerrado to pasture leads to a more decrease of evapotranspiration than converting cerrado areas to cropland.

The evapotranspiration differences between cropland, pastures and forest and cerrado were not evenly distributed throughout the year. The highest evapotranspiration was in natural forestland

and cerrado, while the lowest was in cropland and pasture (see Figure 4). The average annual evapotranspiration was lower in the agricultural ecosystem (cropland and pasture) than in natural ecosystem (forest and Cerrado) (Table 3).

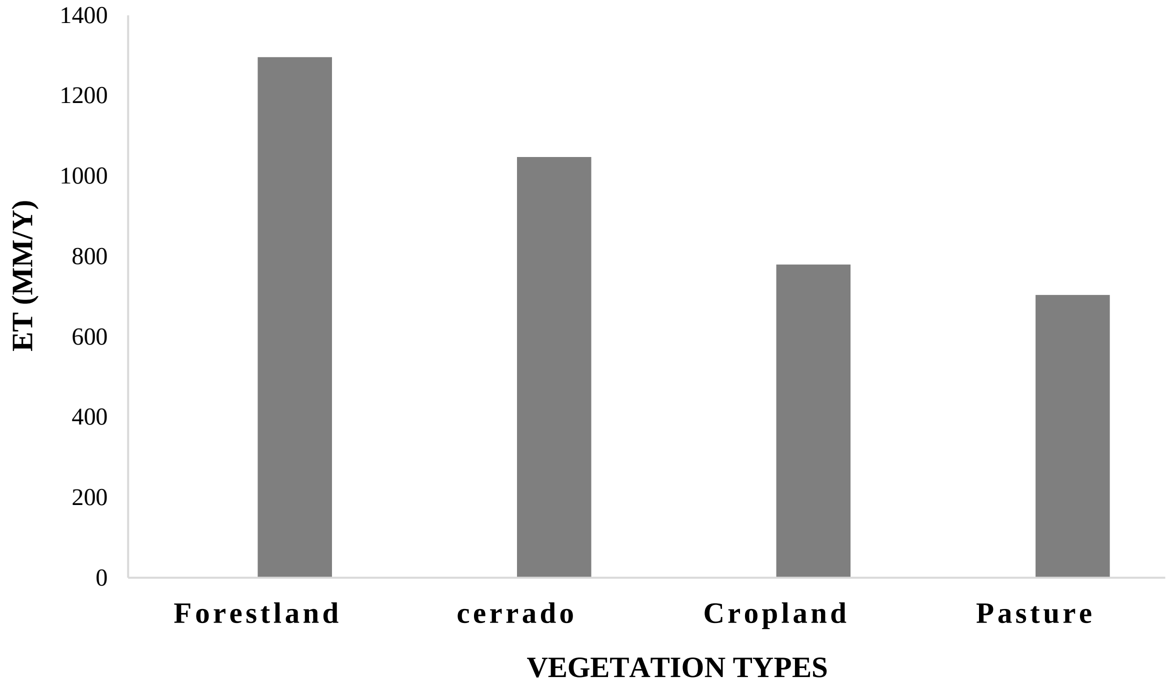

Figure 4. Evapotranspiration rate under natural vegetation (forest and cerrado) and agricultural land (crops and pastures.

Figure 5 shows a noticeable dissemblance of evapotranspiration in forestland and cropland between four countries. Most of the evapotranspiration occurred in subtropical countries such as Brazil and Kenya than that in China. Figure 6 shows the difference in evapotranspiration among Brazilian Cerrado, crops and pasture. The Brazilian Cerrado has greater evapotranspiration than that in crops and pastures. The probability (*P*) of that there is no difference between the evapotranspiration values in forest and crops is 0.004 and 0.72 between soil water content values from forest and pasture. The statistical analysis shows a significant difference ($P<0.05$) among the evapotranspiration values in forests and pasture and crops. This indicates that the forestland, pasture and cropland have dissimilar effects on evapotranspiration. The blue plots represent the evapotranspiration in forestland, the orange ones represent the evapotranspiration rate in cropland and the blue ones represent the evapotranspiration rate in the pasture.

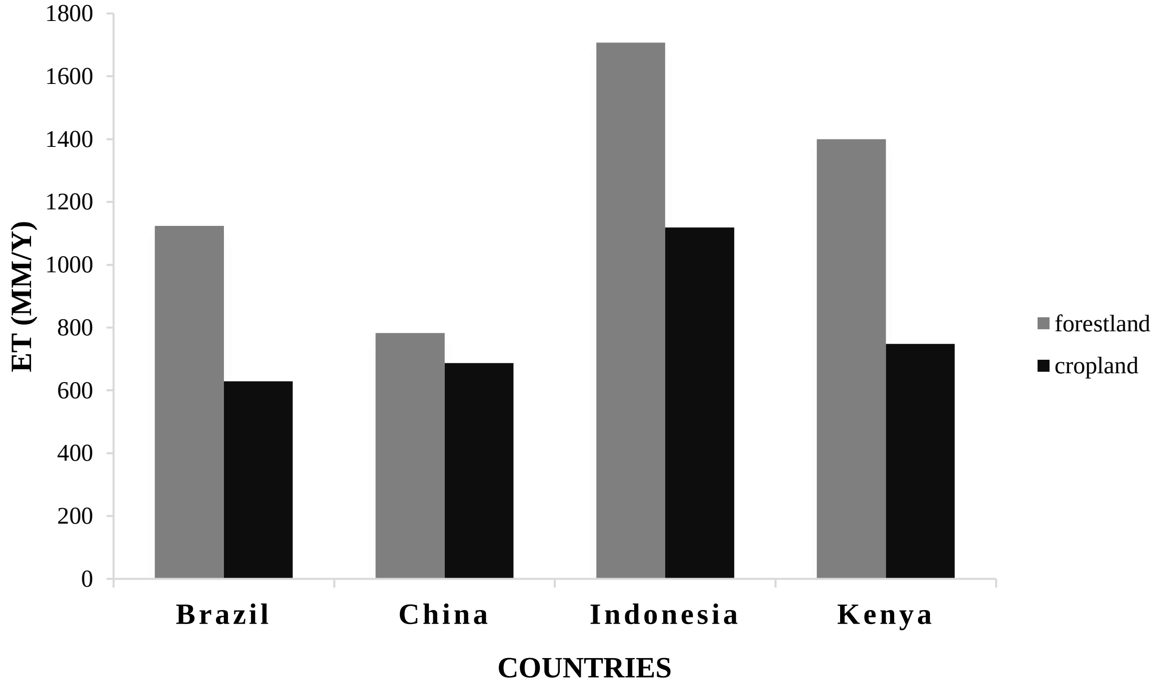

Figure 5. Evapotranspiration rate under forestland and cropland. Where the average of annual evapotranspiration is 1296±342 mm in forest and 780±227 mm in crops.

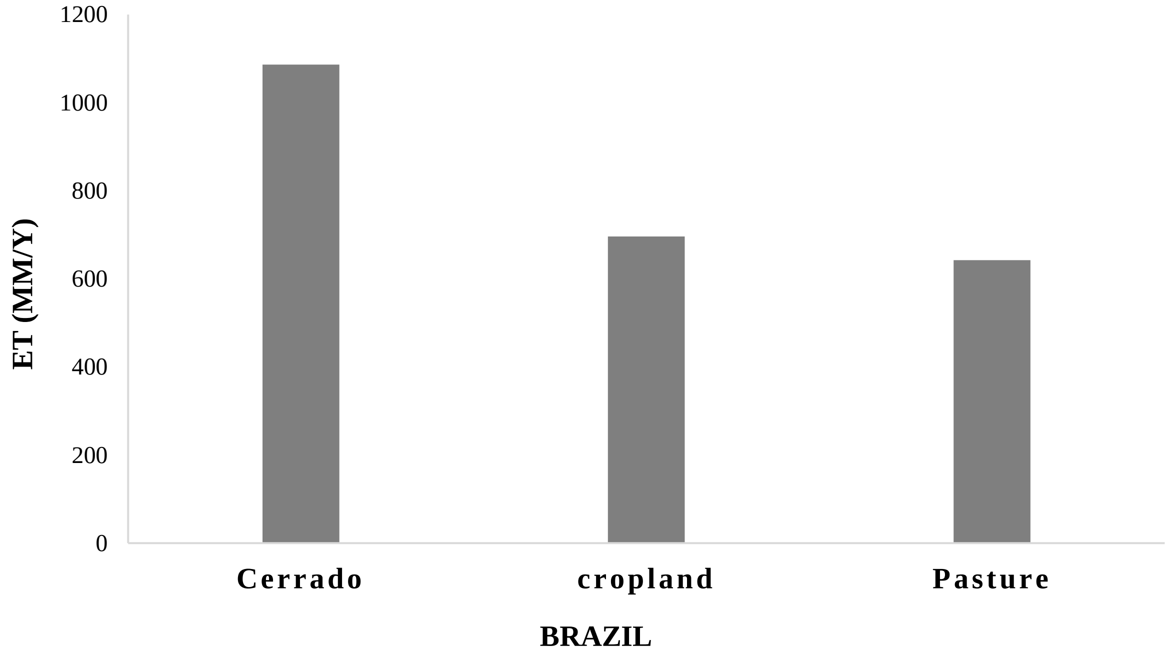

Figure 6. Evapotranspiration rate under cerrado and cropland in Brazil. Where the average of annual evapotranspiration is 1087±258 mm in cerrado, 696±49 mm in cropland and 642±77 mm in pasture.

4.2. Analysis of the effects of land cover changes on soil water content

Soil moisture variations under different vegetation types are shown in Table 4. The difference in soil water content between cropland, pasture and forestland was calculated to compare the differences among different vegetation cover. Soil moisture changes are not consistent between studies. The four studies from China, three of them show higher soil water content in cropland compared to forests and the other one shows an equal soil moisture content in cropland compared to forests, whereas other studies show similar of lower water contents in cropland.

Comparing the values of soil water content in the forest, crop and pasture, it is notable that the greatest values of soil water content were found in crops than in forest and pasture in China. Therefore, if the forestland is replaced by cropland, the soil water content will stay increase between 38% and 67% in China. However, it can also stay the same based on the study by Yang et al. (2012). In Kenya and Indonesia, the soil water content was greater in the forest than in crop and its decreases vary between 4% and 23% between forest and crops. Soil water between forestland and pasture decreases by 33% in Brazil and for the other countries, but no significant difference was observed since the soil water content values were nearly the same.

Table 4. Calculated change in soil water content under native forest, cerrado, pasture and cropland

Source	**SWC in forest (%)**	**SWC in crop (%)**	**SWC in pasture (%)**	**SWC change(F&Cr)**	**SWC change(F&P)**
Feltrin et al., 2013	24	−	16	−	-33%
Wang et al., 2009	7	11	−	57%	−
Wang et al., 2013	9	15	−	67%	−
Yang et al., 2012	8	8	8	0%	0%
Wang et al., 2014	8	11	−	38%	−
Handayani 2004	30	23	−	-23%	−
Otieno et al., 2011	24	23	24	-4%	0%
Average	16	15	16	-6%	0%
Standard Deviation	10	6	8		

SWC−soil water content, F−forest, C−crops, P−pasture

Based on the results presented Table 4, the average annual soil water content is 16±10 % in the forest and 15±6 % in crops and 16% in the pasture. So, if the forest is converted to crops or pastures, there will be no significant effect on soil water content. Figure 7 and Figure 8 show a summary of soil water content variation for different land cover types. In Indonesia and Kenya, the soil water content is higher in the forest than in crops, while in China it is the inverse. This is due to the other key control factors of soil water content such as the amount of rainfall and the soil type which are different within these countries.

The probability (P) of that there is no difference between soil water content values in forest and crops is 0.86 and 0.72 between soil water content values from forest and pasture. Therefore, the statistical analysis shows that there are no significant differences ($P>0.05$) among the soil water content values in forests and pasture and crops. This indicates that the forestland, pasture and cropland have similar effects on soil water content. The blue plots represent the soil water content in forestland and the orange ones represent the soil water content in cropland.

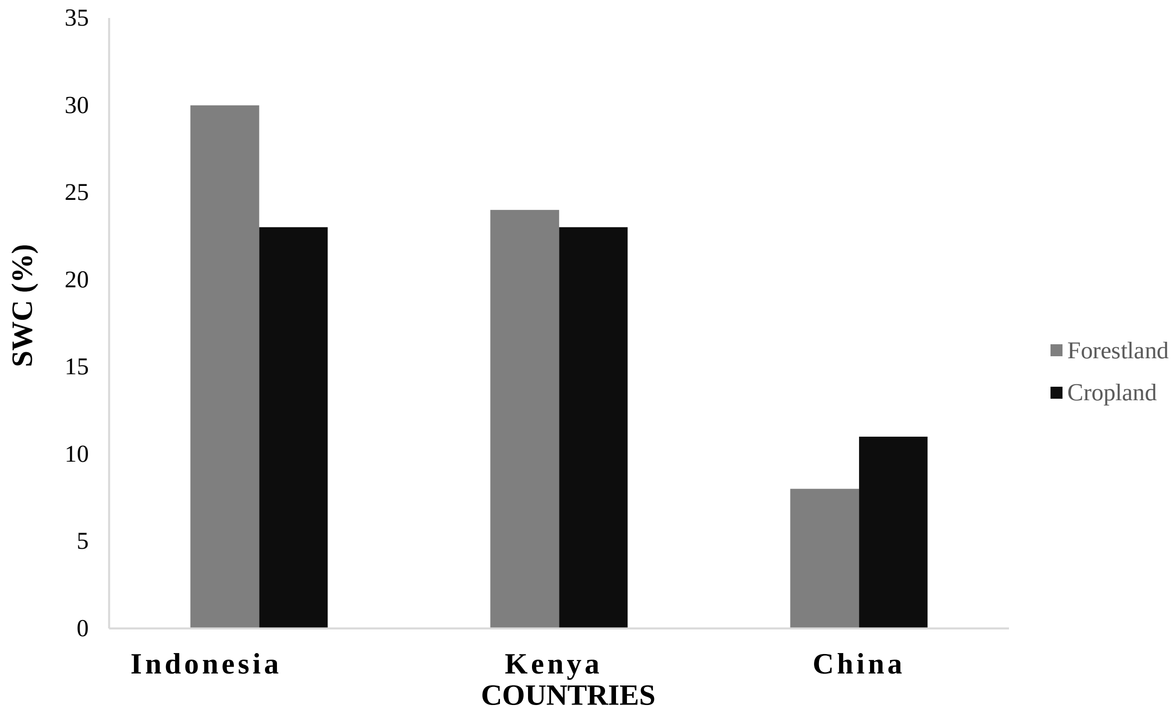

Figure 7. Soil water content under forestland and cropland. Where the average of evapotranspiration is 14±10 % in forestland and 15±6 % in cropland.

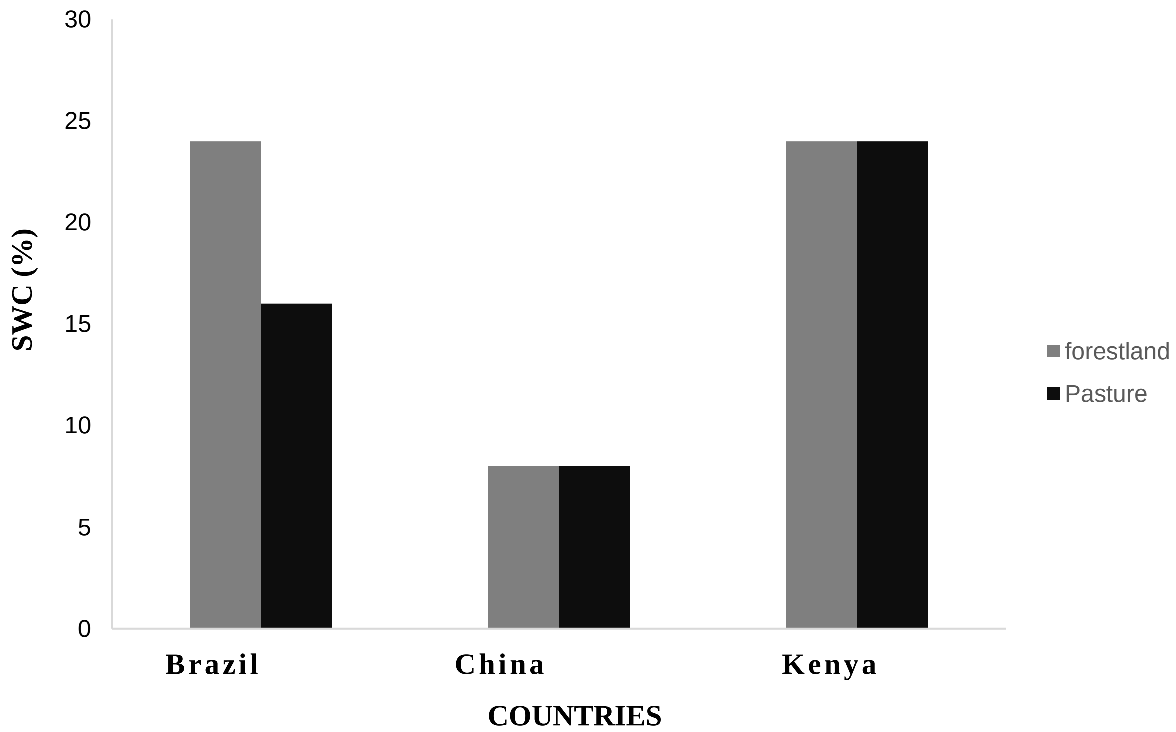

Figure 8. Soil water content under forestland and pasture. Where the average of evapotranspiration is 19±9 % in forestland and 16±8 % in pasture.

5. Discussion

This study characterized the spatio-temporal variations in evapotranspiration and soil water content over the developing countries' vegetation. In my study, I retrieved the evapotranspiration values from the reviewed studies and compared those values based on vegetation type. The results showed a good agreement between all studies and between countries. From the literature review, a consistent and significantly different seasonal trend in evapotranspiration between forest and cropland became apparent. As expected, the annual evapotranspiration in agricultural ecosystems was lower than those in the natural ecosystems. The higher evapotranspiration in the forestland was mostly caused by their root system and leaves that facilitated evapotranspiration. As I mentioned above, evapotranspiration is the sum of plant transpiration and soil evaporation, when plant transpiration or soil evaporation decreases, the evapotranspiration also decreases. Because the water transpired through leaves comes from the root, plant with more leaves and deep roots will transpire more. A big leaf will provide more leaf stomata, therefore more pores for transpiration. Forests also have big leaves with more surface area which transpire faster than that of crops and pasture that consist of less surface. Furthermore, forests have deep reaching roots which can permit continued deep-water access and constant water transpiration throughout dry season (Bareja, 2016). In another word, because the forests can access deep soil water reserves, they are able to transpire more in very dry years. The study by Spera et al. (2016) confirmed this, where they discovered that croplands showed a higher decrease in evapotranspiration during the dry season compared to that in native vegetation. They affirmed that the Brazilian Cerrado were resistant to water stress and their evapotranspiration rate were stable even during the normal dry season, while pastures with a shallow root system suffered from water stress more severely than cerrado and exhibit more variable evapotranspiration dynamics in the dry season. These explain the larger difference in evapotranspiration between forest and crops or pasture.

Most of the evapotranspiration occurred in Subtropical countries. The main reason of obtaining higher evapotranspiration rate in subtropical countries such as Indonesia, Brazil and Kenya than in China was probably due to different climate factors. For instance, Indonesia has a greater availability of solar radiation that provide the energy required to convert liquid to gas. Therefore, the more energy available, the greater rate of evapotranspiration. On the other hand, China had lower evapotranspiration because the study area was in the Tibetan Plateau which has low precipitation rate, and that make the soil too dry, and therefore, less water are available for transpiration (Wan et al., 2017). Furthermore, evapotranspiration variation depends on climate conditions, soil and vegetation conditions. For instance, Mo et al. (2015) acknowledged that the annual evapotranspiration was highly diversified, and its pattern was closely associated with vegetation conditions, whereas the annual evapotranspiration was low, corresponding with scarce rainfall events and the amount of hardly-vegetated areas.

In addition, the evapotranspiration rate was different within the same vegetation type. This is maybe due to the plant morphologies (Briney, 2017). Wang and Wang (2017) confirmed this, where their results showed that the evapotranspiration and daily transpiration were always higher for the 17- than the 7-year-old apple trees on the same scale. This indicates that the same crops or trees can have different evapotranspiration rate due the plant development stage. The evapotranspiration rate was also different between crops and pasture. Therefore, if the forestland is converted to cropland or pastureland, the impact on evapotranspiration will be different. The results showed that evapotranspiration in crops was greater than that in the pasture (Appendix 3; Table 3). So, conversion of forest to crops will lead to a smaller decrease in evapotranspiration than the conversion of forest to pasture. Silvério et al. (2015) also affirmed that forest to crop and forest to pasture transitions affected evapotranspiration differently in the Xingu area. However, this study showed the opposite, where the forest-to-pasture transitions caused a smaller decrease in evapotranspiration than forest-to-crop transitions. This is reasonably due to that crops have lower soil water content in the upper soil layers and shorter growing period compare to the undisturbed grassland (Silvério et al., 2015).

Almost all reviewed studies used the penman-Monteith equation to estimate the evapotranspiration, which was good for the comparison of the results, but this could result in the duplication of the calculation errors. However, these studies used the remote sensing inputs and the results were consistent with the other studies that used different method, thus, gives confidence in my analysis. Significantly, the natural vegetation and agricultural vegetation types resulted in different evapotranspiration levels. As anticipated, the conversion of the natural vegetation to cropland or pasture decrease the contribution of evapotranspiration to climate regulation because of a decreased evapotranspiration. This means that less evapotranspiration will reduce the rainfall amount and warm the land surface temperature. The results from the study by Silvério et al. (2015) support and arguments my findings by showing that forest to crops and pastures transition in the Amazon reduced the evapotranspiration and warmed the land surface temperature by 0.3 ^{0}C. The regional changes in energy budget also have substantial implications for the climate regulation ecosystem services provided by the natural ecosystems. Furthermore, if the trend of Reductions in evapotranspiration, such as those observed in this study persist, it has the potential to affect future crop productivity because those area that today are dominated by rainfed agriculture might no longer have a sufficiently long rain season or experience the delay in the beginning of rain season.

Water for evapotranspiration is mainly supplied by soil. The role of soil moisture within the soil land-plant-atmosphere system depends on soil moisture reservoir size and the availability of water in that reservoir, which in turn, depends on soil texture and structure and the characteristic of the root system (Lu et al., 2011). Interestingly, the reviews showed that the soil water content changes were not consistent between studies. In China, the soil water content was higher in crops than in forest whereas the other countries, the soil water content was higher in the forest than in crops. In general, the comparison of three land use types showed that the cropland had the lowest soil water content and the pasture and forestland had the highest value, with the average annual soil water content of 16±10 % in the forest and 15±6 % in crops and 16±8 % in pasture (see Table 4). Therefore, there was no significant soil moisture difference between forests, crops and pastures. Based on the analysed data, soil water content at the upper part was greater in the forest than that in crops whereas below a certain depth, the soil water content was lower in the forest than that in crops. This may be due to the shallowed root of crops that cannot access water in the deeper soil layers, which lead to the increases in soil water content with increasing soil depth. For instance, the study by Zheng et al. (2015) investigated the temporal dynamics of soil moisture under three types of vegetation at the depth of 40cm. Their results showed that soil moisture decreased with depth in the forested area, whereas it increased within the upper 30cm and then decrease below 30cm in the grassland. This means that more water was consumed from the deep soil by deep-rooted trees, while shallow-rooted grass consumed more water from the surface soil. High soil water content in the forest was mainly due to; On one hand, a greater field capacity, permanent wilting point, infiltration and water storage or available water content in the soil of forest compared with the soil of cropland. The difference in soil water storage between the native forest and pasture was mainly due to the formation of the internal microclimate in the forest due to the prevention of solar radiation of tree canopy (Feltrin et al., 2013). These lower inputs of solar radiation in the forest tend to reduce soil water evaporative rate. Contrarily, in the pasture, grasses completely cover the soil surface and the solar radiation fall directly on the surface. Consequently, the higher input of energy leads to the higher rate of soil water evaporation which causes the decrease of soil water. On the other hand, canopy shades the soil which in turn prevents direct radiation absorption and resulting in lower surface temperature and soil evaporation rates, and higher soil water content (Chen et al., 2009).

The average soil water content in crops was low, perhaps from the decrease in soil total porosity following the agricultural activities such as furrowing activities. Similarly, grazing may cause the compaction of the soil of surface soil and decrease soil water content (Lu et al., 2011). In addition, the soil structure in cultivated soils is physically less protected than that of forest soils because of the agricultural activities. For instance, tillage activities break down the normal structure and loosen the structure of the topsoil, which in turn alter the infiltration and runoff characteristics of the land surface, thus, affect groundwater recharge and soil water content. I unexpectedly found that the soil water content in natural vegetation and agricultural vegetation is not significantly different. My findings show that changes in vegetation type will have little effect on soil water content. This is probably due to the agricultural activities, such as irrigation, that provided enough soil water to support crops. However, from the reviewed papers, almost no study considered the effect of soil management practices on soil water content, while this is the most important influential factor in agricultural land. The main soil moisture influencing factors for different vegetation are more complex, apart from the soil texture and physical characteristics, topographical factors and the vegetation traits (Fang et al., 2016).

The main limitation encountered in this study was lack of sufficiency time. Due to a short thesis period, I had limited number of data from the selected papers. Although, these data showed a clear trend which shows a clear difference in evapotranspiration and soil water content among different vegetation types, therefore, I trust my results. Furthermore, if I would have more time to get more papers, I could have included more studies from different countries, do proper statistical analysis and made even a better assessment because with more papers there would have been more reliable sources. I wanted to do meta-analysis, but I did not have enough data, but I believe that all the assessments would have shown similar results since the data I got from the papers provided a clear trend. This review provided an understanding of the existing knowledge on the terrestrial ecosystems, especially on evapotranspiration and soil water content variation, however, more research was still needed but that was outside scope of my thesis work.

6. Conclusion

This study aimed to investigate the impacts of land-cover change, including the conversion from natural vegetation to cropland or pastures on local climate regulating ecosystem services. The methodology used in this study enabled the percentage changes estimation in annual evapotranspiration and soil water content among different vegetation types. The average annual evapotranspiration and soil water content values from natural vegetation were compared with those from agricultural vegetation. The additional factors that can influence the variation of evapotranspiration rate and soil water content were also described. By comparing the results, the agricultural vegetation had lower annual evapotranspiration rate than natural vegetation, while, the soil water content was not significantly different across countries. Therefore, my findings revealed that the conversion of forests to crops and pastures significantly decreased the evapotranspiration and in turn increase land surface temperature. A decreased evapotranspiration, decrease the amount of water vapor in the atmosphere, thus reduce humidity, cloud formation potential, rainfall and warm the surface land temperature, which is a reverse for the increased evapotranspiration. My findings also revealed that, the conversion of natural vegetation to agricultural vegetation will have a little effect on soil water content depending on the climate zone. Therefore, additional factors, such as climate factors, topography, soil type and soil management activities seemed to have a big influence on evapotranspiration and soil water content variation.

I conclude that: i) The land-cover change, that include forest to crops and pasture transition or widespread agricultural expansion alter the local climate as a result of changed evapotranspiration; ii) The evapotranspiration rates likely depend upon plant biophysical conditions such as the leaf area index, plant roots system and above ground biomass; iii) Soil moisture should not be assessed by considering only the vegetation type, but also other controlling environmental factors; and iv) Land-use change and land-cover change strongly affect the evolution of soil water content and hydraulic properties due to the modification of soil pore spaces and structure and land surface energy.

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Appendices

Appendix 1. The summary characteristics of papers included in the analysis

Paper	**Method/data source / Instrument used**	**Geographical area/ Length of time series**	**Summary**

Silvério et al., 2015	Regression analysis (Remotely-sensed data & weather input data) MODS16/MOD11A2/ MOD43A3/MOD08E3	Brazil 2000-2010	By using a combination of satellite data and maps of land cover, Silvério et al., 2015 quantified how transitions among widespread land uses (Forest to pasture, forest to cropland and pasture to cropland) altered the water and energy balance of the upper Xingu basin, which is the key area of agriculture expansion and production in the South-eastern Amazon. This study revealed that forest to crop and forest to pasture transitions decreased the net surface radiation by 18% and 12%, latent heat flux by 32% and 24%, respectively, while the sensible heat flux increased by 6% and 9%. This study affirmed also that the land use transitions during the 2000s reduced the evapotranspiration in the Xingu area by 35km^2 and significantly warmed the land surface temperature by 0.3 degree Celsius.
Zheng et al., 2015	Sensors; ECH2O EC-TM	China 2013	For a better understanding of the relationship between vegetation type and soil moisture conditions, Zheng et al., 2015 investigated the temporal dynamics of soil moisture under three types of vegetation at the depth of 40 cm. The results showed that soil moisture decreased with depth in forested area, whereas it increased within the upper 30cm and then decrease below 30cm in the grassland. This means that more water was consumed from the deep soil by deep-rooted trees, while shallow rooted grass consumed more water from the surface soil. This study also found that the soil temperature and soil moisture were positively correlated in the deeper soil, and that many soil properties such as temperature, PH, soil organic matter content and soil bulk density had effects on soil moisture content.
Dias et al., 2015	INLAND/AgroIBIS models	Brazil 2008-2010	Dias et al., 2015 assessed the influence of land cover changes on ET in Mato Grosso state. By using models, this study simulated ET for the most four common land cover types found in the upper Xingu: tropical forest, cerrado, pasture and soybean cropland. Simulated mean annual ET was around 40% lower in agricultural ecosystems than in natural ecosystems, whereas average of total discharge was 100% higher in agricultural ecosystem than in natural ecosystem.
Oliveira et al., 2014	Penman-Monteith equation (MOD16/GRACE/TRMM data)	Brazil 2002	Oliveira et al., 2014 assessed water balance of Brazilian cerrado. In order to get the accurate evapotranspiration estimates, they used an improved algorithm that uses remote sensing inputs (MODIS satellite observation of land

			cover, lead area index, albedo, fraction of absorbed photosynthetically active radiation) and daily meteorological inputs (air pressure, air temperature, humidity and radiation) to estimate evapotranspiration using the penman-Monteith equation. The averaged and Standard Deviation of annual Evapotranspiration in the Cerrado Biome in 2002 were 1272(±363.7) in the forest, 938.6(±323.2) in grassland, 731(±239.4) in cropland, 720.7(±202.6) in pasture and 1268.5(±313) in cerrado. The results showed that the evapotranspiration was higher in the forest, Cerrado than in cropland and that there has been a significant increase in annual evapotranspiration over the entire cerrado of 51(±15) mm/y, and the runoff decrease of 72(±11) mm/y. This study also examined the annual evapotranspiration data in an area of the 45 km^2 that was deforested in 2009. As the figure 4 showed the consequence of deforestation was an evapotranspiration decrease of 36% (429mm) between 2008 and 2009. They affirmed that conversion of native vegetation to pasture or cropland led to a decrease of evapotranspiration. Therefore, land cover change promoted changes in the evapotranspiration and climate variation.
Nóbrega et al., 2017	SEBAL & METRIC models (weather data)	Brazil 2012-2014	Nóbrega et al., 2017 investigated the impacts of conversion the native cerrado vegetation to pasture on soil hydro-physical properties, ET. They used data from field measurements (2012-2014) and applied the satellite-based image-processing model to improve ET estimation in Das Mortes river basin, Mato Grosso state. The results show that ET is smaller in the pasture (639 ±31% mm/y) than in the cerrado catchment (1004 ±24% mm/y), and that that there is a significant difference in soil hydro-physical properties between the cerrado and pasture, with greater bulk density and streamflow, and smaller total porosity in the pasture catchment. Therefore, they confirmed that conversion of native cerrado to pasture causes soil hydro-physical properties deterioration, reduction in ET and increase streamflow
Spera et al., 2016	Penman-Monteith (MODIS MOD16A2 data)	Brazil 2001-2013	Spera et al., 2016 determined the impacts of agricultural conversion on regional evapotranspiration in Matopiba. They used remote sensing techniques to map land use change across cerrado from 2003 to 2013. During this study period, aggregated cropland area in Matopiba was almost doubled from 1.3

			ha to 2.5 million ha, with an additional one million hectares had been converted and later left fallow or used for the other purposes. The result indicated that the averaged evapotranspiration over cerrado vegetation was 904mm/y, while over single-cropping the average was 661 mm/y, and over double-cropping rotations, the average was 805 mm/y. They noticed that during 2003 native vegetation transpired 800mm of water per unit area, while croplands transpired 510 mm, which means 64% that of cerrado. Both single and double- cropping rotations showed a decrease in evapotranspiration during the dry season when compared to native vegetation. There was a significant different seasonal trend in evapotranspiration between natural vegetation and row-crop agriculture. They also found that changes in land use have decreased water recycled to the atmosphere via evapotranspiration each year (2001-2013) and that more water would have been recycled into the atmosphere if there had have been no land use changes.
Lathuillière, M. J., et al, 2012	Penman-Monteith (MODIS MOD16 data)	Brazil 2000-2009	Lathuillière, M. J., et al, 2012 assessed hydrologic changes, they used remote sensing, meteorological and agricultural production data to determine the rainforest, crop and pasture components of total evapotranspiration in Mato Grosso. This study presented changes to ET contributions from terrestrial ecosystems over the 2000-2009 period, a decade of important deforestation and agricultural expansion activities in the area. The results showed that the monthly ET varied with precipitation, with the highest values during the wet season and the lowest in dry season. The monthly mean forest evapotranspiration was 103mm and 76.4mm, respectively for wet and dry season. Annual forest evapotranspiration contributions to the total evapotranspiration dropped over decade from 50% in 2000 to 40% in 2009. This study also modeled the agricultural evapotranspiration (ET_A) as the sum of crops (ET_C) and pasture (ET_P) evapotranspiration. The maximum values of ET_C calculated between 2000 and 2009 were 540(±26) mm/y, 292(±40) mm/y, 312(±20) mm/y in soybeans, cotton and maize, respectively. ET_C was dominated by soybeans which represented between 77% and 84% of ET_C. The evapotranspiration in the pasture was higher 889(±77) mm/y than those in crops.

			However, the annual ET_P went from being ten times the value of ET_C in 2000 to only four times ET_C in 2009, mainly due to the replacement of pasture by cropland, particularly soybeans, in Mato Grosso. The results strengthened the importance of forests in recycling precipitation by returning large amount of soil moisture to the atmosphere.
Mo et al., 2015	Remote sensing ET model (NDIV &Terra-MODIS)	China 2000-2010	Mo et al., 2015 investigated the spatio-temporal variability of ET over terrestrial China from 1981 to 2010. By using satellite observations together with climatic data in a physical ET model, this study declared that the largest annual ET was from paddy rice (844 mm/y) and evergreen broadleaf forest (783 mm/y), and the lowest was from grassland (377 mm/y) and open shrubs (275). This study also found out that the annual ET was highly diversified, and its pattern is closely associated with vegetation conditions in the study area, whereas the annual ET is low, corresponding with scarce rainfall events and the amount of hardly-vegetated areas.
Wang et al., 2017	Penman-Monteith equation (weather data)	China 2012-2014	Wang et al., 2017 compared the effects of apple trees of different ages by partitioning evapotranspiration into canopy interception in the semiarid region from May to September in 2012, 2013 and 2014. The experiment results showed that the evapotranspiration and its partitioning for the apple tree were mostly controlled by tree age. In 2012, 2013 and 2014, the evapotranspiration was 339.1, 341.4 and 312.4 mm/y and 361.1, 367.2, and 336.3 mm/y for the 7 and 17 years old trees, respectively. Therefore, the evapotranspiration and daily transpiration were high for the 17- than the 7-year-old trees.
Kurniawan 2016	Expert-N model	Indonesia 1year- 2013	This thesis study of Kurniawan presented the impact of forest conversion to rubber and oil palm plantations on nutrient leaching losses in two landscapes of highly weathered soils that are different in texture, located in Sumatra. The simulated water balance showed that ET and runoff were higher in the clay than loam soils, transpiration was the largest component of total ET in both landscapes and the ET was lower in rubber and oil palm plantations.
Gerold 2010	WASIM-ETH model	Indonesia 2002-2007	Gerold,2010 investigated the impact of forest conversion on the water balance, nutrients losses and soil erosion in a small mountainous catchment located in Sulawesi. The water balance components including ET were

			measured in both natural forest and converted forest (cacao plantation). Gerold,2010 approved that land use practice with cacao plantations is less critical and can maintain water resources better than annual crops.
Alemayehu et al., 2017	MODIS- MOD16 & GLDAS	Kenya 2002-2010	Alemayehu et al., 2017 mapped the ET of different land cover classes in the Mara basin. Their results showed that ET was highly variable spatially and intra-annually. On average, dense evergreen forest and wetland were the highest water consumers with the ET of 1228 (±59) mm/y and 1286 (±44) mm/y respectively, whereas the herbaceous cover and rainfed cereals are the lowest with the ET of 698 (±46) mm/y and 706 (±69) mm/y respectively.
Kiptala et al., 2013	SEBAL model (MODIS data)	Kenya 2008-2010	Kiptala et al., 2013 used MODIS and SEBAL models to analyze the ET trends in 16 land use types, in Upper Pangani River basin for the period 2008-2010.The results showed that for the whole basin, the ET accounted for 94% of the total precipitation. The highest annual ET has been observed for the water bodies and the forested areas. The lowest potential ET were estimated for the mountainous areas experiencing afro-alpine climate conditions.
Feltrin et al., 2013	Tensiometers; Subsoil probe & oven drying	Brazil 2010-2011	Feltrin et al., 2013 monitored the behavior and spatial variability of soil water content (SMC) under forest vegetation and native pasture in the southern Brazil. The electronic tensiometers with pressure transducers were installed at 0.1, 0.3 and 0.7 m below the soil surface in order to obtain SMC. The obtained results showed the greatest variations of SMC and soil water storage at the depth of 0.1 and 0.3 m and less variation at the depth of 0.7 especially for pasture. The forest soil had greater water holding capacity and available SMC than the pasture soil.
Wang et al., 2009	Subsoil probe/ Oven drying	China 2001-1006	Wang et al., 2009 examined the effect of main vegetation types on soil moisture and its inter-annual change. Soil sample were extracted by using subsoil probe and dried in oven to determine soil moisture of six vegetatition; crop, grass, planted shrubs of caragana, planted forests of arborvitae, pine and the mixture of pine and arbovitae. A common characteristic in soil moisture measured under all vegetation types was that there was great difference among 2001, 2005 and 2006 in the upper part of soil. AT the depth of 0-2 m the soil moisture were 7(±2.96) %, 11.1(± 1.96) %,

			8(±1.57) % and 7(±3.18) %, respectively in the mixture of pine and arbovitae, crop, grass and planted shrubs of caragana. In 0-2 m, soil moisture was significantly greater in cropland than those of all other vegetation types. The soil moisture of caragana shrubs were considerably lower than those in forests in 2-10m soil profile, but the confirmed difference was very small. In addition, thsi study concluded that soil moisture under those six vegeattion types depended on the annual precipitation in the study area.
Yang et al., 2012	Gravimetric approach; soil drill & oven drying	China 2009-2010	Yang et al., 2012 studied the impacts of re-vegetation on soil moisture dynamics and ET under five land cover types in loess plateau. This study monitored the variation of temperature during the growing season of 2011. The soil moisture was higher in corn crop than in shrubs and forest area. Among other four types, subshrubs and grass showed the highest temperatures, corresponding to greater moisture losses. This study confirmed that changes in land cover may alter the soil moisture budget and soil temperature as well.
Wang et al., 2014	Subsoil probe/ Oven drying	China 2001-2008	The purpose of this study was to evaluate soil moisture content status and variation in late 2001, 2005-2008 under deep and shallow-rooted vegetation in the semiarid area of the loess plateau. The results showed that the SWC in caragana brush was particularly lower than those under planted forest. And this may be due to the higher transpiration and bigger endurance in drought of caragana.
Wang et al., 2013	Soil auger/ Oven drying	China	This study determined the soil water content and related soil (soil particle composition, soil organic carbon) and plant properties such as root depth and root mass to a depth of 21 m at the 11 sites across Loess Plateau of China. Soil water storage and the available soil water storage also were calculated for each 1 m thick soil layer. At the depth of 0-21 m, SWC was 8.5%, 14%, 10.8% and 6.6% in forest, cropland, grassland and shrubs, respectively. The mean SWC decreased with depth, from 12% in the surface layer to 8% at the depth of 2.5 m, then increased to10% at the depth of 5 m. The highest SWC value was 15% at the depth of 19 m. The mean SWC among 11 sites varied from 4.9% to 18.1%, this difference was influenced by climate factors (e.g precipitation, evaporation, solar radiation, wind speed), soil properties(such as soil

			texture, soil bulk density, hydraulic conductivity, soil water holding ability), topography (e.g. altitude, slop) land use and deduced vegetation characteristics (e.g. vegetation types, coverage and growing age) and related hydrological process such as rainwater infiltration, overland flow and soil erosion. In the root zone, the vertical distribution and quantity of soil water were significantly influenced by land use and plant characteristics, while below the root zone, soil texture became an important factor.
Handayani, 2004	Pressure plate apparatus method	Indonesia	Handayani, 2004 evaluated the impact of forest clearance on soil quality properties in Bengkulu province, Sumatra. Soil samples were collected from natural secondary forest, bare land, cultivated land and grassland. The results showed that clearing, cultivation and burning of tropical secondary forest lands resulted in degradation of soil quality by changing physical, chemical and biological soil properties. The lowest saturated hydraulic conductivity was found in bare soils and the highest occurred in natural forest.
Otieno et al., 2011	Chambers/Oven drying	Kenya 2008-2009	This study examined the spatial heterogeneity in the different ecosystems in Nyanza province, Kenya. Otieno et al., 2011 hypothesized that; the livestock grazing and shifting cultivation modify soil characteristics by lowering soil water holding capacity or promote rapid soil water loss, and that the acacia tree and termitaria facilitate soil moisture infiltration and improve soil moisture availability. The field measurements were conducted during March 2008 and the results showed a significant soil water content variation. The acacia trees and termitaria improved soil resource availability and significantly contributed to ecosystem carbon dioxide exchange and productivity in the drought period. The results showed also that the C_3 vegetation in the abandoned plot was less productive than the native C_4 grasses and the SWC was higher in acacia trees.
Mganga et al., 2011	Gravimetric method	Kenya 1year- 2008	Mganga et al., 2011 studied how different land use types influence soil properties in tropical semi-arid rangelands, Kibwezi district. Disturbed and undisturbed soil sample from cultivated, grazed and fallow land were collected and analyzed using standard laboratories for soil physical properties. Soil moisture content was 7.4(±1.69) %, 6.9(±0.88)

			%, 2.5(±0.82) % in grazing land, cultivated land and fallow land(shrubs), respectively. Grazed and cultivated land have higher soil water content due to the sandy clay soil textures with a higher percentage of clay content compared to sandy clay loam soils in the fallow land. It may be also due to the high rate of hydraulic conductivity in fallow land which facilitated the free movement of water in the study area.
Wei et al., 2017	DHSVM model	China 2001-2009	This study investigated factors that controlling temporal stability of surface soil moisture in Huangnizhuang watershed by using modeled high-resolution surface soil moisture data. The results showed that vegetation cover and topography dominate the watershed-scale soil moisture stability and that without considering them, the temporal stability method result in lower accuracy in the estimation of soil moisture.
Almusaed 2011	n.d	Any location	Almusaed 2011 described on chapter 13 of his study, the factors that controlling the ET. Some of the factors are: humidity and temperature, wind, water availability, vegetation type, stomata resistence, soil property and texture, Geographic pattern and energy convenience.
Zhang & Chen 2017	MOD16 & Meteorological data	China 2002-2014	The study of Zhang & Chen 2017, analyzed the dynamic spatiotemporal changes in evapotranspiration and its associated factors in the Pearl River Basin from 2000 to 2014, by using the monthly MOD16 evapotranspiration dataset and daily meteorological data. The results of the study showed that over space and time, annual evapotranspiration showed a small increasing trend during the study period, with an average value of approximately 946.56 mm/a. The evapotranspiration significantly varied at the monthly and seasonal scales, and July was the highest months with higher evapotranspiration of approximately 119.57 mm, which was 36.37 % of the annual evapotranspiration. In this study, six factors such as temperature (maximum, minimum and averaged), relative humidity, wind and sunshine hours, were selected to discuss the effects of meteorological factors on evapotranspiration. They found out that in different months, these meteorological factors have different change trends and different influences on evapotranspiration changes. Dynamic changes in annual evapotranspiration were mainly associated with temperature and

			relative humidity. However, these factors vary in different regions and at different times. The spatial variations in evapotranspiration and its correlated factors were affected by the complex effects of climatic conditions that differ at different latitudes and elevations and under different topographic conditions.
Fang et al., 2016	Soil drill/ oven drying	China	Fang et al., 2016 analyzed the variation and factors that influence the deep soil moisture of Ansai watershed. At the comparable depth, this study affirmed that the variation of deep soil moisture under native vegetation was much lower than in human-managed vegetation. The main local controls of deep soil moisture variations were: Soil particles composition, rainfall, human agricultural management measures, vegetation type and planting zone.

ET; evapotranspiration, SWC; soil water content, RH; relative humidity, ST; soil temperature, T; temperature, LST; land surface temperature, N.D; not determined.

Appendix 2. Summary characteristics of the papers included in the quantitative analysis: source/location, method and evapotranspiration values (mm/y) under different land cover types. The number in parentheses are standard deviations.

Source	Method	Location/Temporal scale	Evapotranspiration (mm/year)					
			Forest	Grasses	Crop	Pasture	cerrado	Shrubs
Dias et al. (2015)	Modeled	Brazil 2008-2010	1025	n.d	679	567	1010	n.d
Oliveira et al. (2014)	Measured	Brazil 2002	1272	939	731	721	1269	n.d
Mo et al. (2015)	Observed/Modeled	China 2000-2010	783	377	687	n.d	n.d	275
Spera et al. (2016)	Measured	Brazil 2001-2013	n.d	n.d	661	n.d	904	n.d
Nóbrega et al. (2017)	Measured	Brazil 2012-2014	n.d	n.d	n.d	639	1004	n.d
Kurniawan (2016)	Modeled	Indonesia 2013	1622	n.d	1071	n.d	n.d	n.d
Lathuillière et al. (2014)	Measured	Brazil 2000-2009	1076	n.d	476	856	n.d	n.d
Gerold (2010)	Modeled	Indonesia 2002-2007	1792	n.d	1220	n.d	n.d	n.d
Alemayehu et al. (2017)	Modeled	Kenya 2002-2010	1228	798	706	n.d	n.d	742
Kiptala et al. (2013)	Modeled	Kenya 2008-2010	1517	630	789	n.d	n.d	756

n.d–not determined

Appendix 3. Summary characteristics of the papers included in the quantitative analysis: source/location, method, temporal scale, and soil water content (%) under different land cover types and soil depth. Values in parentheses are the standard deviations

Source	Method	Location/Temporal scale	Soil depth	Soil water content (%)				
				Forest	Pasture	Cropland	Grassland	Shrubs
Feltrin et al. (2013)	Measured	Brazil 2010-2011	0-0.7 m	24	16	n.d	n.d	n.d
Wang et al. (2009)	Measured	China 2001-2006	0-2 m	7	n.d	11.1	8	7
Wang et al. (2013)	Measured	China	0-21 m	9	n.d	14	11	7
Yang et al. (2012)	Measured	China 2009-2010	0-1 m	8	8	8	7	7
Wang et al. (2014)	Measured	China 2001-2008	0-3 m	8	n.d	11	8	8
Handayani (2004	Measured	Indonesia	0-0.15m	30	n.d	23	15	n.d
Otieno et al. (2011)	Measured	Kenya 2008-2009	0-0.3 m	24	24	23	n.d	n.d

n.d–not determined

Appendix 4. The summary characteristics of papers (138 papers) included and excluded in the analysis.

Source	Quantitative study	Qualitative study	Included
Silvério et al., 2015	√	√	√
Marshall 2012	√	–	–
Mutama et al., 2012	√	–	–
Zheng et al., 2015	√	√	√
Mutiga et al., 2010	√	–	–
Mwangi et al., 2016	√	–	–
Wang et al., 2016	√	–	–
Bagley, J. E., et al, 2014	√	–	–
Dias et al., 2015	√	–	√
Oliveira et al., 2014	√	–	√
Marhaento et al.,2017	√	–	–
Meijide et al., 2017	√	–	–
Merten et al., 2016	√	–	–
Panday et al., 2015	√	–	–
Santos et al., 2017	√	–	–
Carvalho et al., 2013	√	√	–
Meirelles et al., 2010	√	–	–
Nóbrega et al., 2017	√	–	√
Niu et al., 2015	√	–	–
Peng et al., 2013	√	–	–
Qiu et al., 2011	√	–	–
Wang et al., 2016	√	–	–
Spera et al., 2016	√	–	√
Comte et al., 2015	√	–	–

Han et al., 2017	√	–	–
Herman 2017	√	–	–
Hiranoet al., 2005	√	–	–
Lathuillière, M. J., et al, 2012	√	–	√
Olchev et al., 2008	√	–	–
Roll 2015	√	–	–
Sabajo et al., 2017	√	–	–
Sujalu et al., 2014	√	–	–
Mo et al., 2015	√	–	√
Yan et al., 2017	√	–	–
Zhao et al., 2016	√	–	–
Mashado et al., 2016	√	–	–
Zhang et al., 2016	√	–	–
Wang X et al 2014	√	–	–
Khand, K., et al. 2017	√	–	–
Wang et al., 2017	√	–	√
Alemayehu et al., 2017(a)	√	–	–
Djaman et al., 2016	√	–	–
Maeda et al., 2011	√	–	–
Kurniawan 2016	√	–	√
Olchev et al., 2015	√	–	–
Hirano et al., 2015	√	–	–
Gerold 2010	√	–	√
Vogelmann et al., 2017	√	–	–
Wang et al., 2013	√	–	–
Wang et al 2014	√	–	–
Xiao et al., 2014	√	–	–
Yang et al., 2012	√	–	–
Alemayehu et al., 2017	√	–	√
Kiptala et al., 2013	√	–	√
Odongo et al., 2016	√	–	–
Wang et al., 2009	√	–	–
Wang et al., 2012	√	–	–
Yu et al., 2015	√	–	–
Yao et al., 2016	√	–	–
Feltrin et al., 2013	√	–	√
Sun et al., 2017	√	–	–
Yang et al., 2012	√	–	–
Sato et al.,2017	√	–	–
Wang et al., 2009	√	–	√
Yang et al., 2014	√	–	–
Jin et al., 2017	√	–	–
Yang et al., 2012	√	–	√
Li et al., 2015	√	–	–

Tao et al.,2016	√	–	–
Tonks et al., 2016	√	–	–
Bohme et al., 2013	√	–	–
Wang et al., 2014	√	–	√
Yang et al., 2017	–	√	–
Li et al., 2017	√	–	–
Koech et al., 2015	√	–	–
Otuto et al.,2014	√	–	–
Uwuor et al., 2018	√	–	–
Gisheru et al., 2005	√	–	–
Guto et al., 2011	√	–	–
Lian & Huang 2015	√	–	–
Liu et al., 2008	√	–	–
Wang et al., 2013	√	–	√
Arsa et al., 2016	√	–	–
Astiani et al., 2017	√	–	–
Bana et al., 2103	√	–	–
Hassler et al., 2017	√	–	–
Vernimmen et al., 2013	√	–	–
Li et al., 2017	√	–	–
Fu et al., 2016	√	–	–
Handayani 2004	√	–	–
Moser et al., 2010	√	–	–
Paudel et al., 2014	√	–	–
Seki et al., 2015	√	–	–
Siryanto et al., 2017	√	–	–
Suteyo et al., 2016	√	–	–
Wang et al., 2016	√	–	–
Handayani, 2004	√	–	√
Liu et al., 2016	√	–	–
Liu et al., 2017	√	–	–
Otieno et al., 2011	√	–	√
Vilas et al., 2012	√	–	–
Wang et al., 2016	√	–	–
Mganga et al., 2011	√	√	–
Zhang et al., 2016	√	–	–
Hardie, et al., 2017	√	–	–
Zhang et al., 2017	√	–	–
Ahmad 2017	√	–	–
Wei et al., 2017	√	√	√
Lu et al., 2011	√	–	–
Ma et al., 2015	√	–	–
Zhang et al., 2016	√	–	–
Mashado et al., 2016	√	–	–
Niu et al., 2015	√	–	–
Chen et al., 2009	√	–	√
Zhang et al., 2015	√	–	–

Wang et al., 2016	√	−	−
Gao et al., 2013	√	−	−
Jia et al., 2017	√	−	−
Zhang_et_al-2017	√	−	−
Mello et al., 2011	√	−	−
Peña-Peña & Irmler, 2016	√	−	−
Pezopanne et al., 2014	√	−	−
Almusaed 2011	−	√	√
Briney 2017	−	√	−
Gao et al., 2014	√	−	−
Li et al., 2017	√	−	−
Liao et al., 2017	√	−	−
Zhang & Chen 2017	√	√	√
Silva et al.,2014	√	−	−
Speratti et al., 2017	√	−	−
Zhang et al., 2014	√	√	−
Fang et al., 2016	−	√	√
Silva et al., 2015	√	−	−
Von Randow et al., 2013	√	−	−
Vourlitis et al., 2015	√	−	−
Danelichen et al., 2016	√	−	−
De Souza 2011	√	−	−
Dias & Marenco 2016	√	−	−