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Projet de Fin d'Etudes

Woody encroachment impacts on soil properties

L'impact des ligneux sur les propriétés du sol

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2017-2018

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AVERTISSEMENT

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Formation par la recherche, Projet de Fin d'Etudes en génie de l'aménagement et de l'environnement

La formation au génie de l'aménagement et de l'environnement, assurée par le département aménagement et environnement de l'Ecole Polytechnique de l'Université de Tours, associe dans le champ de l'urbanisme, de l'aménagement des espaces fortement à faiblement anthropisés, l'acquisition de connaissances fondamentales, l'acquisition de techniques et de savoir faire, la formation à la pratique professionnelle et la formation par la recherche. Cette dernière ne vise pas à former les seuls futurs élèves désireux de prolonger leur formation par les études doctorales, mais tout en ouvrant à cette voie, elle vise tout d'abord à favoriser la capacité des futurs ingénieurs à :

- Accroître leurs compétences en matière de pratique professionnelle par la mobilisation de connaissances et de techniques, dont les fondements et contenus ont été explorés le plus finement possible afin d'en assurer une bonne maîtrise intellectuelle et pratique,
- Accroître la capacité des ingénieurs en génie de l'aménagement et de l'environnement à innover tant en matière de méthodes que d'outils, mobilisables pour affronter et résoudre les problèmes complexes posés par l'organisation et la gestion des espaces.

La formation par la recherche inclut un exercice individuel de recherche, le projet de fin d'études (P.F.E.), situé en dernière année de formation des élèves ingénieurs. Cet exercice correspond à un stage d'une durée minimum de trois mois, en laboratoire de recherche, principalement au sein de l'équipe Ingénierie du Projet d'Aménagement, Paysage et Environnement de l'UMR 6173 CITERES à laquelle appartiennent les enseignants-chercheurs du département aménagement.

Le travail de recherche, dont l'objectif de base est d'acquérir une compétence méthodologique en matière de recherche, doit répondre à l'un des deux grands objectifs :

- Développer toute ou partie d'une méthode ou d'un outil nouveau permettant le traitement innovant d'un problème d'aménagement
- Approfondir les connaissances de base pour mieux affronter une question complexe en matière d'aménagement.

Afin de valoriser ce travail de recherche nous avons décidé de mettre en ligne sur la base du Système Universitaire de Documentation (SUDOC), les mémoires à partir de la mention bien.

REMERCIEMENTS

Nous tenons à remercier notre directrice de recherche, madame Séraphine Grellier, pour nous avoir encadré et conseillé durant toute cette période dans le projet de fin d’études et nous avoir permis de concrétiser notre travail. Merci également d’avoir pris le temps de nous corriger et expliquer de la rédaction du rapport.

SOMMAIRE

Introduction

Encroachment of endemic woody species and gully erosion in grasslands and savannas has increased worldwide over the past 100 years. Research shows that nearly 10% ~ 20% of the arid and semi-arid regions have experienced shrub or bush encroachment. It has been a global phenomenon widely reported in the United States, Africa, Australia, South America and Mediterranean Basin during the past decades (van Auken, 2000; D’Odorico et al., 2011; Eldridge et al., 2011). Such increases in woody plant abundance, with accompanying changes in the herbaceous cover and the composition of the natural vegetation in grassland and savanna regions, is termed bush or shrub encroachment (Archer etal. 1988, Brown and Archer 1999, O'Connor and Crow 2000, Hoffman and Ashwell 2001). During the process of the encroachment, the surface vegetation changed from herb to shrub, the coverage of herbaceous plants decreased, the bare land increased, and the temporal and spatial heterogeneity of soil moisture and nutrients increased. The structure and function of the original community ecosystem have a significant impact. Controlling mechanisms and the consequences of woody encroachment on ecosystems are at the heart of a scientific debate.

However, a number of factors contributed to the formation of this phenomenon. Including overgrazing, fire, increased greenhouse gases, drought caused by global warming, and changes in rainfall patterns. Through the analysis of the existing literature, we find that the most common influencing factors are overgrazing and grassland burning. As overgrazing and other disturbance will reduce the above-ground biomass of the herb, the cover of the herbaceous vegetation will be reduced. At the same time, the surface homogeneity will be destroyed, the surface bareness will increase, and the soil erosion will be intensified, resulting in the loss and redistribution of soil moisture and nutrients. Shrubs access to more available resources, especially water. Changes in resource balance are conducive to the germination and growth of shrubs, leading shrubs occupy a dominant position in the community in a short time. As for the fire, frequent fires reduce the richness of herbs with good palatability, and promote the development of plant with poor palatability, good fire-resistant, and rich lignin. Meanwhile, studies suggest that climate warming promotes shrub invasion because the majority of invasive shrub growth is limited by low temperatures. Global warming mitigates damage caused by frost damage, reducing the mortality of savannah-sensitive shrubs. There is also a close relationship between climate change and fire. Global warming will affect the frequency and intensity of fire, thus affecting the density of shrubs and herbs. Increasing CO_2 concentration can also promote shrub invasion. As shrubs and herbs have different physiological characteristics, CO_2 can affect vegetation growth by changing water use efficiency, photosynthetic rate and photosynthetic nutrient utilization. Most of the tropical and subtropical herbs are C4 plants, most of which are C3 plants. C4 plants have higher water use efficiency in arid and semi-arid environments, making the herbs more competitive. However, when the concentration of CO_2 in the atmosphere increases, the concentration of CO_2 between the shrubs cells, and in the atmosphere will also increase, thereby enhancing the water use efficiency of the shrubs and making the shrubs more competitive than the herbs. In short, the factors that affect the invasion of shrubs into the grassland are complex with the vegetation interactions.

As for the consequences, this phenomenon has led to complex effects. Woody encroachment is often closely linked to changes of functions and structure in ecosystem. At the community level, shrub invasion affects the biomass of vegetation and species richness of the ecosystem. In 13 North American prairie communities, the species richness decreased with the invasion of woody plants, on average 45%, and the species richness of the communities with higher precipitation decreased more. What's more, it makes the distribution of above-ground vegetation changed, affecting the distribution of root system and the distribution of nutrient elements and water, reducing soil nutrient. Shrub density increases occurred in the North American Chihuahuan Desert and Australia's arid and semi-arid grasslands. Prairie shrubs inhibited the growth of vegetation in the lower canopy, decreased the nutrient pool and changed the elemental distribution, which is considered as the main reason for the decline and accelerated degradation of ecosystem. Many studies suggest that woody encroachment is another way of expressing grassland degradation or desertification, because the increase of surface runoff caused by shrubification and soil erosion, as well as the reduction of soil moisture, are typical examples of desertification. From a conservation perspective, woody encroachment has been threatened the maintenance of grassland and savanna ecosystems and its endemic biodiversity. Other negative impacts on hydrology, climate and animal have also been expected by some experts. However, it can't be said completely that the positive impact doesn't exist. Therefore, this topic provides a good opportunity to study existing research results so that we can get clear on the causes, its different effects and think deeply how to prevent the damage and put its positive impacts to good use.

The objectives of our project are to review the consequences of woody encroachment, especially for soil properties. Various data including the geographical extent of woody encroachment, the types of woody plants, its causes, relative climates and soils types are collected. For a resume of the current stage, the most important is the analysis and the evaluation of data-base among the numerous ecological studies. Then, based on the database, we will find and analyze the influence of woody plant invasion on the soil from the perspective of various parameters. In addition, we have more thematic studies about soil properties later on. In follow parts, we will study the microclimate under trees for herbaceous vegetation and the biodiversity of pedofauna and food web interactions, for which we need pay attention to the impacts for soil fauna and flora by the woody plants. However, in our extensive reading of the first part, we did not get too much of the content of this topic, we need to find relevant articles based on the database for intensive reading. Meanwhile, the change of soil biogeochemical cycles by encroachment is the second topic we will figure out. For this one, articles about carbon, nitrogen and soil nutrients should be marked and detailed read. Finally, we will study encroachment and hydrology. Soil physical properties, water flows and resources and soil erosion are some of the topics that we deal with importantly. Therefore, we need to organize the database at the same time pay attention to the relevant information. All in all, it is our main task to concentrate on the impact of woody plant invasion on the soil. Everything that the database shows about the impact on soil content is the focus of our study. Sorting the database allows us to recognize the resources on hand. The results of the database will make our next job more organized. We can use the database to better select articles and deal with the following questions in a targeted manner.

Method

In our initial research stage, after a discussion with professors, we conducted a preliminary analysis on the impact of woody plant invasion on soils by its conditions and factors in the form of a database analysis. In order to clarify the true impact of woody plant invasion on soil, we conducted a lot of in-depth reading of the collected articles and summarized them in the following aspects.

Based on 182 existing studies, a database including name of first author, year of publication, title, journal, type of article, continent, country, genera of encroaching plant, leguminous or not, main topics, cause of encroachment, climate, rainfall, type of biome and soil type, has been built. Through this database, several facts could be find out. The name of first author give us the information about people who worked in this field for the research of soils; There might be a relation between the year of publication and the global climate changing; The journal also gives us the most researches concentrate on which journal of environment; And throughout the type of the article, it could be easy to find out three different types of articles. If the article is about some experimentation that designed by the team or the author, it could be considered as a topic-oriented article with a specific area been studied. In the other hand, if the article contents some research was been done by analyzing many experimentations by other researches, the type of the article would be meta-data. It also appears that some articles would resume the consequences or find out the raison of the encroachment as the type of reviews; The other indicator such as the continent and country would be a good method for further research in analysis of the climate and the soil type, and also give a clear view of the distribution of the encroachment around the world; We also can see the impact of the plants that is leguminous to the soil properties that by its characteristic of fixing the nitrogen into the soil, it might have an effect negative or positive for other plants; The sector of main topic shows the various topic concern on the effect of encroachment into soils. It is also important to clarify the cause of the encroachment mentioned in the article, which would more close to our studies that the proportion of the causes that related to the soils; The three points related which were climate, rainfall and type of biome concerns to the plants itself, the function of the encroachment could be more easy to find through the analysis of these three factors; The last indicator is also important for clarify the real reason of woody encroachment, the absorption of different elements like the carbon, nutrition and nitrogen were all have consequences to the type of soil, different type of soil could have different function of supports for its plants.

To press close to the main purpose, 157 articles with accessible consequence on soil properties have been selected and arranged. For each indicator, data respecting the original have been extracted and recorded by several important factors and some indicator have been linked to each other. However, for some articles where certain data are not specifically defined, related information, such as the type of climate and biome, respect Wikipedia and ArcGIS. Indicators with stronger pertinence to the research purpose have been counted and analyzed in the form of graphic.

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Analysis of data-base

- **Continent and country**

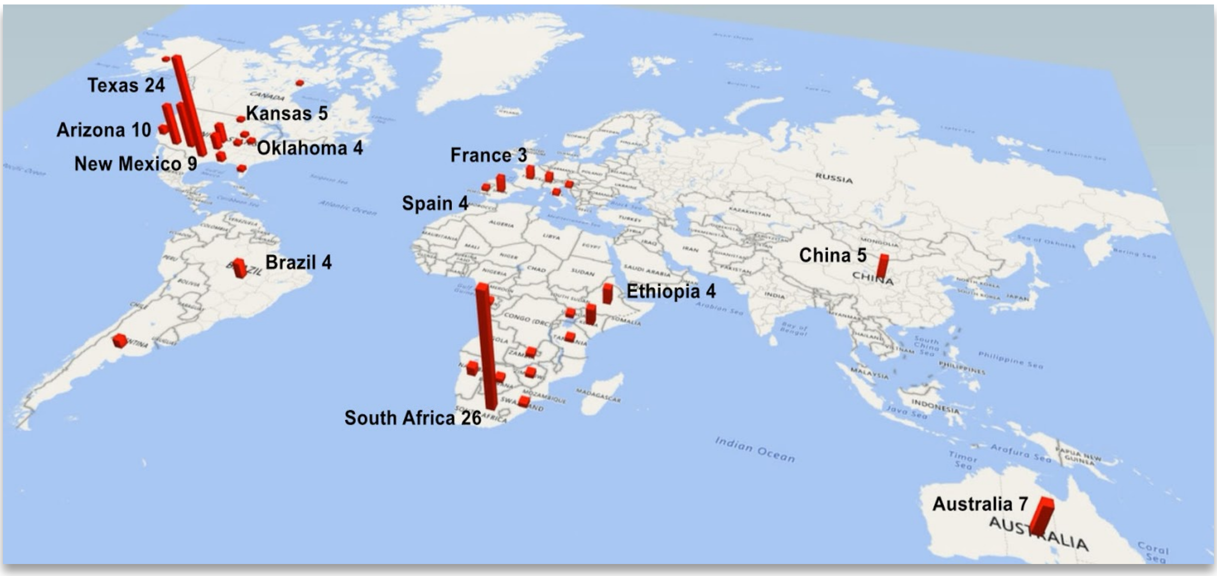

Figure 1 Distribution of different studies in the world

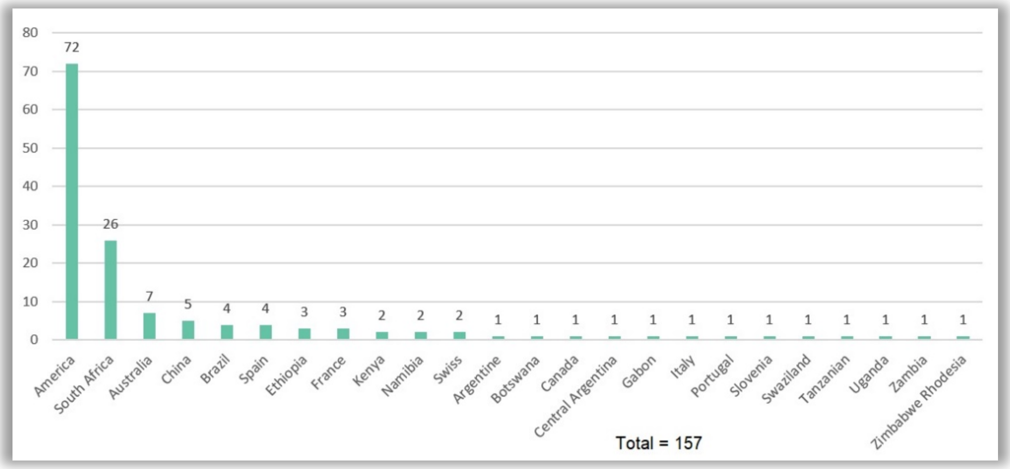

Figure 2 Distribution of different numbers of studies in the world

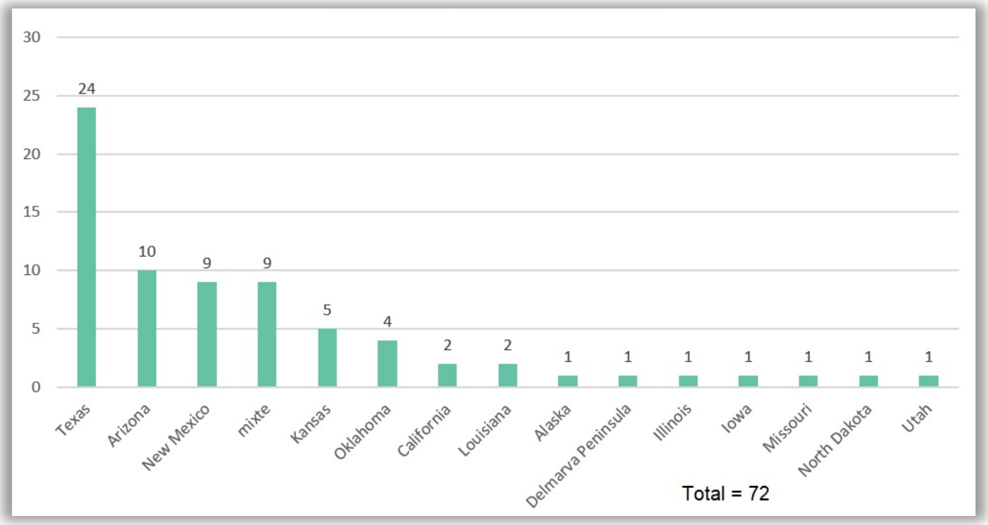

Figure 3 Distribution of different numbers of studies in America

Globally, arid and semi-arid regions account for about 41% of the total land area, of which 10% to 20% are shrubified. At present, the research on shrub lands is mainly concentrated in two regions: North America and southern Africa. In North America, shrubbery non-woodland area accounts for about 330 million hm2. For example, shrub plant density has dramatically increased in Chihuahuan savannah in North America's lower elevations, replacing the original semi-arid grasslands. In the Texas savannah area, the coverage of woody plants increased from 13% in 1941 to 36% in 1983. In South Africa, about 13 million hm2 of savannah shrubs have occurred. There is also a lot of coverage of shrubbery in China. Among them, the phenomenon of *Caragana microphylla* shrub in Inner Mongolia grassland is the most typical, about 5.1 million hm2 of grassland shrubs appear. As woody encroachment has a global influence, existing studies we have followed, cover cases around the world. Data were related to a wide range of study sites from 6 continents, 24 countries, which consist of North America, Southern Africa, Australia, China, Brazil, Spain, Ethiopia, France, Kenya, Namibia and Swiss and so on. Nonetheless, studies are unevenly distributed. Most studies are found in North America, and Texas, Arizona and New Mexico occupy the top three slots. At the same time, with 26 studies, South Africa becomes the second largest country where woody invasion has been observed. Due to different special circumstances, researchers have also great interest in cases of Australia, China, Brazil and Spain (Mediterranean basin). It can be inferred that there is a certain degree of similarity of climate, type of biome and soil types between popular study sites.

(a) (b) (c)

(d) (e) (f)

Figure 4 Distribution of different sites around the world
(Source: Baidu Image)

(a) Shrub-desert steppe in New Mexico, USA; (b) Shrub-weed steppes in Kansas, USA; (c) Shrub-alpine steppes in Lesotho, Africa; (d) Shrubs in the Portuguese savannah (e) Scenic of the Portuguese savanna after being clumped by *Cistus ladanifer*; (f) The shrub-grassland landscape of Inner Mongolia, China

- **Year of publication**

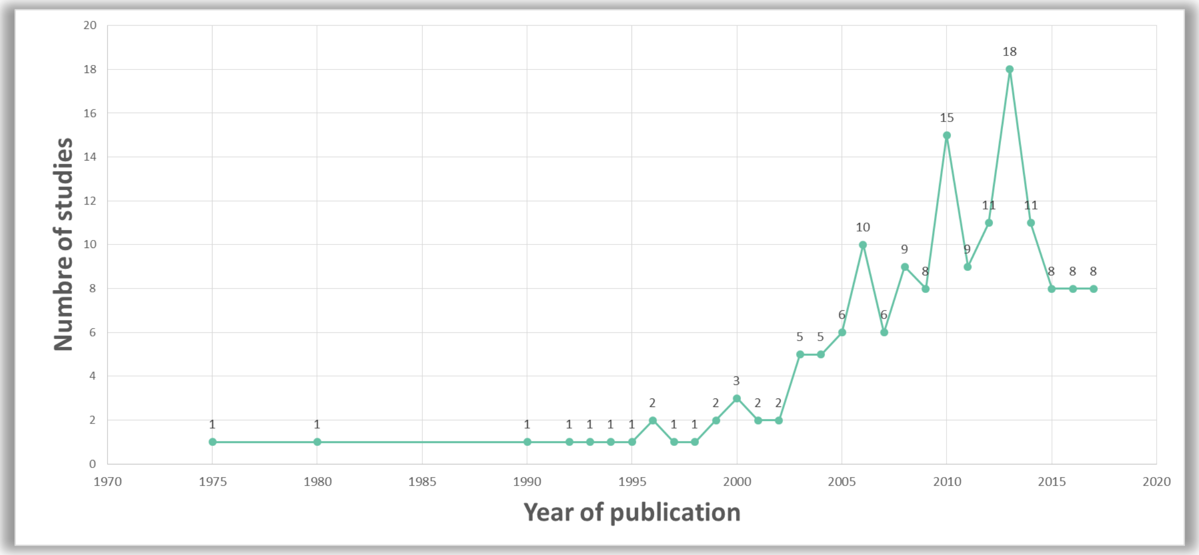

Figure 5 Distribution of different numbers of studies by its year of publication

Even though the woody plant has already encroached on grasslands and savannas since last century, studies after 2000 accounted for 90% of the total database. Particularly, a peak of research took place in the 10 years from 2005 to 2015. For a certainty, woody plant encroachment is an issue that is gaining increasing attention. More new discoveries will be revealed to the public.

- **Leguminous**

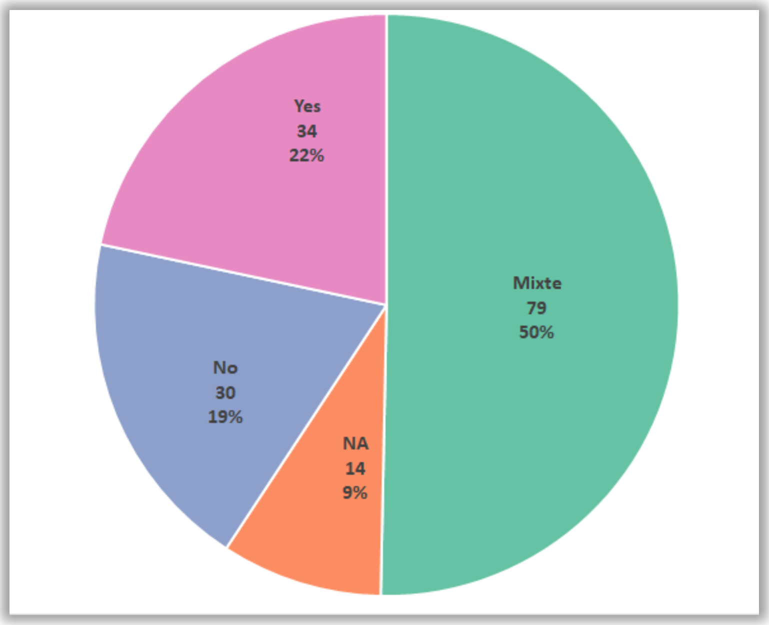

Figure 6 Different numbers of studies by whether it's leguminous

Leguminous plants belong to the family Leguminosae. There are notable for their ability to fix atmospheric nitrogen. This ability in them is due to a mutualistic symbiotic relationship with rhizobia found in root nodules of these plants. These plants are used in a crop rotation to replenish soil nitrogen. The proportion of data shows that fifth part articles studied the encroachment of leguminous species, and 50% of articles are involved in a mixture of leguminous plants and other plants. Most of the woody plants that causes woody invasion are legumes. Among North American semi-arid shrub lands, shrub species of the genus *Mezufolia*, such as *Prosopis glandulosa*, *P. velutina* and *P. juliflora*, are major woody plants. These leguminous shrubs can fix nitrogen in the atmosphere through rhizosphere symbiotic nitrogen fixing microorganisms and provide more nitrogen input to the ecosystem. Nitrogen fixed by legumes can be passed between legumes and non-legumes. Nitrogen transfer between legumes and neighboring herbs relies on the availability of subsurface nutrients to the herbaceous plants. By nitrogen fixation, which introduces more nitrogen to ecosystems, leguminous shrubs will profoundly alter the species composition of the native grassland communities. At the same time, it also shows that nitrogen is also a factor that cannot be ignored. Soil organic matter is an important source of various nutrients in soil, especially nitrogen and phosphorus. Generally speaking, soil organic matter content is an important indicator of soil fertility.

- **Main topics**

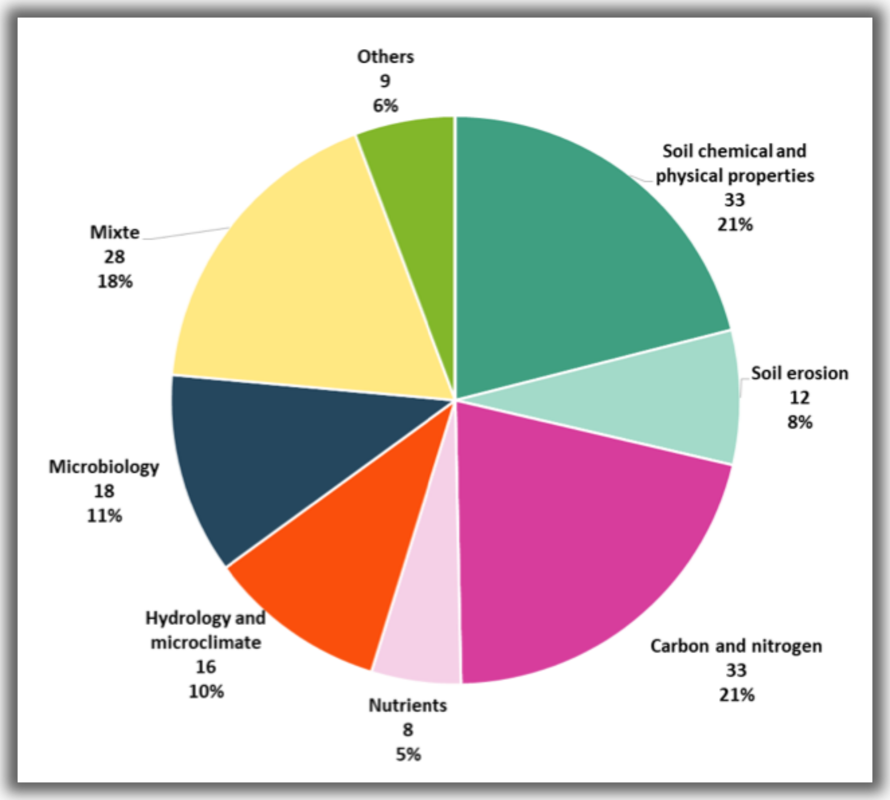

Figure 7 Different numbers of studies by main topic

Due to the wide geographical coverage of the article, and the research focuses on complex issues, 18 main topics and multi-theme have been mentioned. Among all studies, several topics occupy the majority of the total data. There are nearly 30% of article topics related to soil, including soil chemical and physical properties (21%), soil erosion (12%). Studies of multi-theme refer to the soil also with a high proportion, which provides a strong foundation for our thematic research. Meanwhile, Carbon and nitrogen (21%), microbiology (11%), hydrology and microclimate (10%) and nutrients

(5%), with a certain amount mentioned, become important topics. The part of others combined several studies of woody cover, woody thickening, topographic, economic implications, anthropogenic disturbance, diversity, litter decomposition. Because multi-theme (18%) also has a large proportion, the interaction between the topics and the complex role of them should be explored in depth. Since the causes of the invasion of woody plants are complex and the consequences of the phenomenon are diverse, the articles of multi-theme make up a large proportion. However, through the statistics of this factor, we can find that articles on topics such as soil physical properties, chemical properties, and soil erosion are likely to make more references to impact on soils. At the same time, these articles are focus of the fourth part to reanalyze. However, articles on carbon, nitrogen, and nutrients mentioned more about their interaction with shrubs and their impact on soils. For example, in grassland ecosystems, the homogeneity of the distribution of herbaceous plants makes the soil water and nutrients more uniform. The shrub invasion can change the spatial distribution pattern of soil resources and the flow direction of resources among shrubs, resulting in the uneven distribution of grassland resources. This heterogeneity is embodied in soil moisture, nutrients, soil biology, soil texture and other aspects, and will increase the self-holding capacity of shrubs. Human activities such as overgrazing can undermine the uniformity of grassland vegetation, leaving some of the surface bare. The exposed surface is subject to high temperatures and high evaporation, preventing or delaying the absorption, denitrification and ammonization of organic nitrogen, which leads to the loss of nutrients. Nutrient-rich soils and seeds carried by the wind and water can gather under shrub plant canopy to increase soil penetration and fertility. Therefore, functions, cyclings and feedbacks of many factors eventually led to the impact of woody plant invasion on the soil. Even reading an article on a single topic should focus on interaction with other factors.

- **Cause of encroachment**

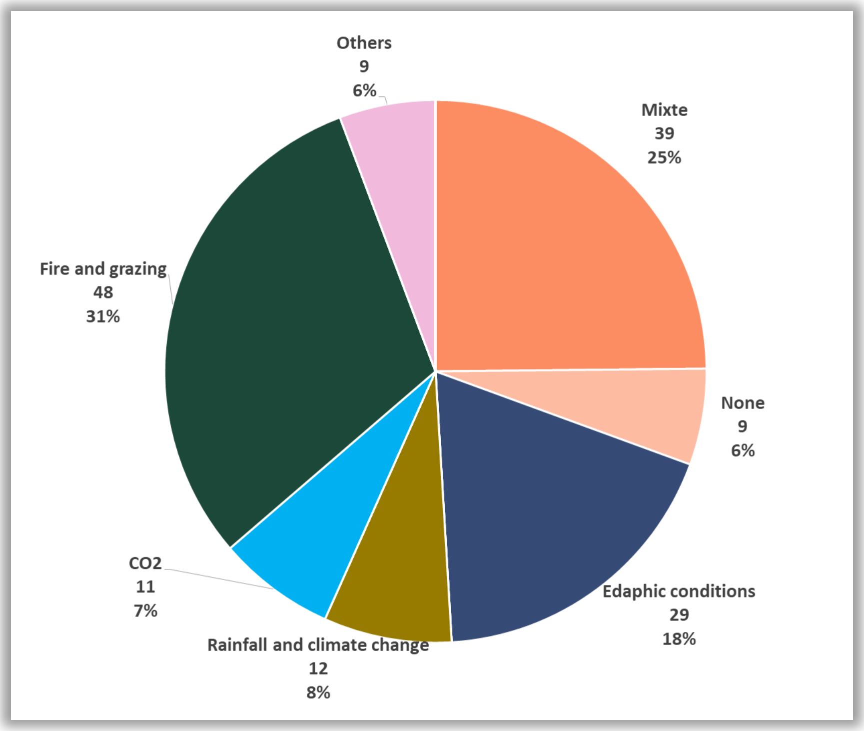

Figure 8 Different numbers of studies by cause of encroachment

Through the analysis of the different types of woody encroachment mentioned in the articles, by sorting out and integrate all these data and integrate, and finally it can be summarized into several causes: Soil, Climate, Carbon dioxide, Human activities, Synthetic causes and others. With this chart above, it is easy to find that the biggest single part is the synthetic causes (25%), the reason is that many studies have a combination of different types of encroachment due to the complex geological conditions and the impact of various environmental factors.

Through the analysis of the established database, it is easy to find that the woody encroachment influenced by edaphic conditions can be found all over the world, climate distribution and type of biome are also widely distributed. Through the analysis of the established database, it is easy to find that the woody encroachment influenced by edaphic conditions (18% of the causes) can be found all over the world which combined soil chemical properties of 2 studies and 1 study of edaphic conditions (sodium). Climate distribution and type of biome are also widely distributed. The two important indicator of edaphic conditions were SOC and TN, some studies through soil physical fractionation combined with isotopic data such as the analysis of 15N, try to determine the controls facilitating the accumulation of SOC following woody plant invasion into grasslands (Creamer, C, 2013). Some other studies find out how shrub impacts on soil organic carbon and TN pools change with time of woody plant site occupation on contrasting soil types (Wheeler, C, 2007). As the edaphic conditions are much more difficult than our imagination, many abiotic factors could be changed, such as mineral nutrients and soil water availability, that can determine the growth response of neighboring plants, but the sign and magnitude of these responses are species-specific (Rolo, V, 2012).

Human activities are also one of the major causes, including the effects of grazing and fire, the impact of human activities on the environment cannot be ignored. Through these studies, human activity like fire and grazing (31% of causes) is also very important for finding the real function of woody encroachment. Two important factors could not be modeled in analysis but likely played a role in land cover dynamics: management and fires. In most of the arid climate area, fire and herbivore disturbance regimes largely determine the balance between woody plants and grasses in global savannas. Management strategies that ignore this fact by altering these vital disturbance regimes eventually have undesirable ecological and economic consequences. (Hudak, A, 1999) The main causes for this encroachment of woody plants include less application of indigenous knowledge of the pastoral community, poor understanding of how pastoral system function and conversion of the pastoral land to non-pastoral activities such as the establishment of ranches and introduction of crop cultivation. Management of natural resources is necessarily a site- and objective-specific endeavor (McPherson, 2001).

Fire is another factor which influences the structure of savanna ecosystems (Gordijn and others 2013), and both fire intensity and frequency have changed since the arrival of settlers (Medina 2007). It is clear from the present study that with continued fire suppression in mesic grasslands, the displacement of woody species will substantially alter the dynamics of C and N pools. Although further investigation of belowground processes associated is warranted, including the dynamics of decomposition, N mineralization, root productivity, and soil C and N (Lett, M, 2004). With a range of worldwide, fire is the most relevant disturbance conditioning the existence of savannahs and grasslands, prescribed burning is among the strategies to maintain the hydrological regimes in watersheds occupied by savannahs and grasslands (Honda, 2016).

Another important factor is the rainfall and climate change (8%), which combined the rainfall of 7 studies (4%), climate change of 4 studies (3%) and rainfall with initial woody cover of 1 study (1%). Other factors that not mentioned is all combined into the part of others, with 5 studies of grassland, 2 studies of Land abandonment,1 study of fire suppression and land fragmentation, 1 study of grazing and land abandonment.

- **Climatic distribution summary**

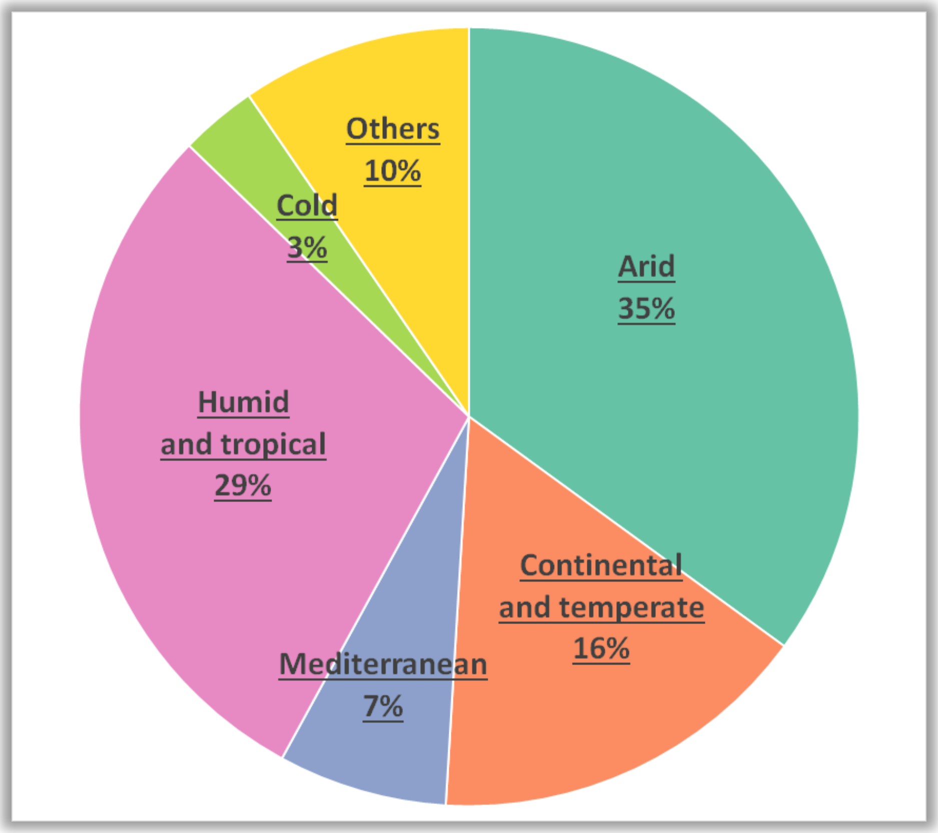

Figure 9 Different numbers of studies by type of climate

Based on a summary analysis of the countries and regions mentioned in the various articles and their corresponding climatic distributions, several major climatic distribution types and the proportion of sub-category contribution of each major climate were summarized. As a result, the distribution of the climate was resumed by several large sectors such as arid climate, continental and temperate climate, mediterranean climate, humid and tropical climate, cold climate and others. The arid climate (35%) combined with arid and semiarid, arid climates, semiarid Warm and semi-arid; Continental and temperate climate (16%) combines with Warm temperature climates, temperate, continental temperate semi-arid climate, continental, humid continental, temperate midcontinental; Humid and tropical (29%) combines with subtropical, semi-arid and subtropical, sub-humid subtropical, humid subtropical, subtropical with warm winters, hot summers, tropical humid, equatorial climates.

Most of the studies concentrate on the arid and humid and tropical climates, the reason is that most of the studies that we have summarized were in the south of America and Africa. These two types of climate are the most likely climates that can have the woody encroachment around the world due to climate, human activities as well as the geographical location or more important factor: type of vegetation. By comparing the type of climate with the countries and regions, it can be concluded that: Arid climate were mostly founded in some states in the south of America, Africa, and Australia; Continental climate was mostly in some states in the center of America, also China and South America; Humid and subtropical climate concentrate on Africa and some part of America; Some studies of Canada and Alaska shows that the encroachment was been found in the snow climate area.

As we live in a rapidly changing world with a global effect of climate change where human-induced range expansions, non-native invasions, and ecological regimes shifts are becoming increasingly common (Vitousek et al. 1996; Scheffer et al. 2001; Parmesan & Yohe 2003). Alterations in global or regional climate, increased atmospheric CO2 concentrations, N-deposition, and human land-use activities that could hasten, halt, or reverse forest encroachment should be considered in the development of new ecosystem models. (McKinley, 2008) Woody plant encroachment appears to be found all over the world, the climate change becomes a global effect that can't be ignored, some studies mentioned the SOC of soil is also an indicator for the encroachment related to global climate change. Some studies observed that the decrease in ambient plot soil carbon at study site will likely continue for a few more decades, reach a minimum, and then rise, though at a slow rate. The trends observed over the last decade in the ambient plots are consistent with broader scale observations throughout western North America that indicate a reduction in carbon uptake due to recent drought (Hidalgo et al., 2009; Pederson et al., 2011, 2013) As concluding, woody plant encroachment happened in all kinds of climate on the earth, human activities, soil types and vegetation types are inextricably linked.

- **Biomass distribution summary**

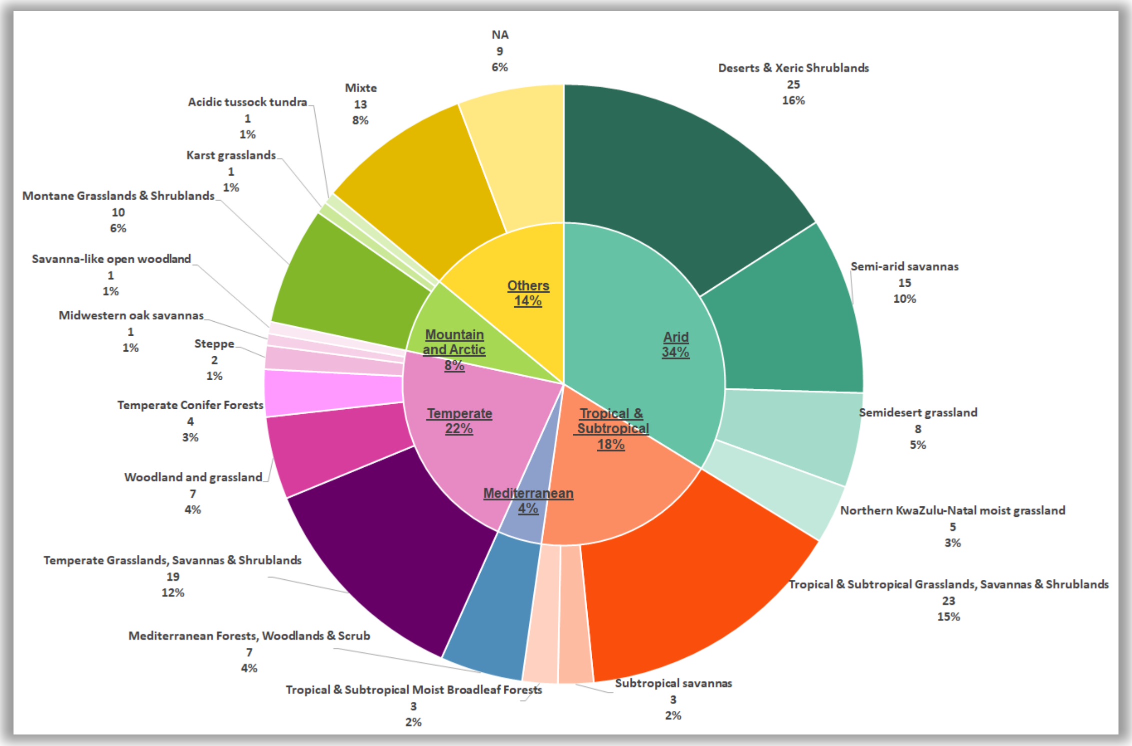

Figure 10 Different numbers of studies by type of biomass

Through the comparison of the countries and regions mentioned in the various articles and their corresponding biomass distributions, several major biomass distribution types and the same section for the climate that a sub-category contribution was made. Most of the studies concentrate on the arid, temperate, tropical and subtropical biomass, in the other hand all the types of biomass could have influenced by the woody plant encroachment, there wasn't a preference between the distribution of biomass and encroachment. Some studies were reviews, so there wasn't a type of biomass mentioned, and some other research were made that they combined different site of studies into one.

Due to the importance of soil processes to ecosystem stability, structure and function, there is a pressing need to better understand the effects of these vegetation shifts on above-ground-below-ground interactions (Vitousek & Walker 1989; Wardle et al. 2004; Bardgett & Wardle 2010). Some studies based on the research of biome of grassland show us the woody plant encroachment imparts substantial changes to the structure and function of grasslands and grassland-like ecosystems. The results of this study provide new information regarding the effects of mesquite on ecosystem structure, illustrate the linkages shared between above and belowground communities, and demonstrate that soil microbial community, and in particular soil fungi, may be altered by the process of woody plant encroachment(Hollister, E, 2010). Other studies found significant habitat-related shifts in soil microbial community structure along short transects spanning the prairie-to-forest continuum (Biederman, L, 2010).

There were other studies that focus on the nutrient of the soil that affected by vegetations between above and belowground communities, the most important is the effect of C and N pools. Luken [1990] hypothesized that woody encroachment into prairies is a perpetual process where nutrient enrichment by encroaching woody plants is followed by the invasion of selective plant species with high nutrient requirements(Bekele, A, 2006). Forest encroachment results in a shift in ecosystem C pools from being dominated by soil C in grasslands to woody vegetation in the forest (Pinno, 2011). And other studies expound the effect of leguminous shrubs on their neighboring grasses went beyond N subsides, and whether they can promote or suppress the neighboring plant growth were species-specific. This pattern suggests that the ultimate plant interaction should also depend on other factors, such as water and light availability, and microclimate (Zhang, H, 2016). Other studies found strong evidence that encroachment of an N2-fixing shrub in grasslands increased N cycling rates and N export in soil water (Baer, S, 2006).

We conclude that like many other biological invasions, the proliferation of woody plants into savanna rangelands can have ecosystem-wide effects. However, its impact is highly variable depending on the level of encroachment and the local species composition (Belay, T, 2013). While in many cases the desertification interpretation of shrub encroachment is well-founded, we caution against describing it as such as a universal phenomenon. Shrub encroachment could also lead to desertification reversal, or in the case of counterbalancing negative and positive impacts, could have no clear relationship to desertification (Maestre, F, 2009). As conclude, we can see that woody plant encroachment was happened in all kinds of biomass on the earth, with some important factors including human activities, soil types and are all linked to each other.

- **Soils proportion**

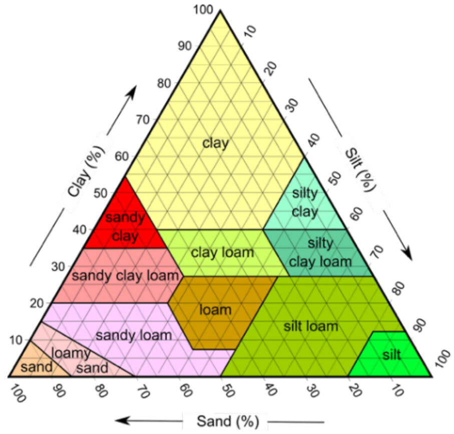

Figure 11 Soil classification by United States Department of Agriculture (Source: Wikipedia)

The chart above is a tool by USDA classification system based on grain size for analyzing the different types of soils, due to the reason of some articles didn't clarified that the proportion of sand, silt and clay of each studies sites they have mentioned, it could be difficult to find out the real soil proportion of the site, and some other studies have descripted the soil type of the site by its different subsoil layers. These two method of classification were all correct but in different ways. As woody plant encroachment can result in lower soil pH, higher soil carbon and nitrogen pools, higher potential nitrogen mineralization, and higher levels of exchangeable calcium (Eldridge et al. 2011), to clarify the function of different types of soil and its influence on different mineral composition is also important. In the future step of this study will have an in-depth research in the soils properties.

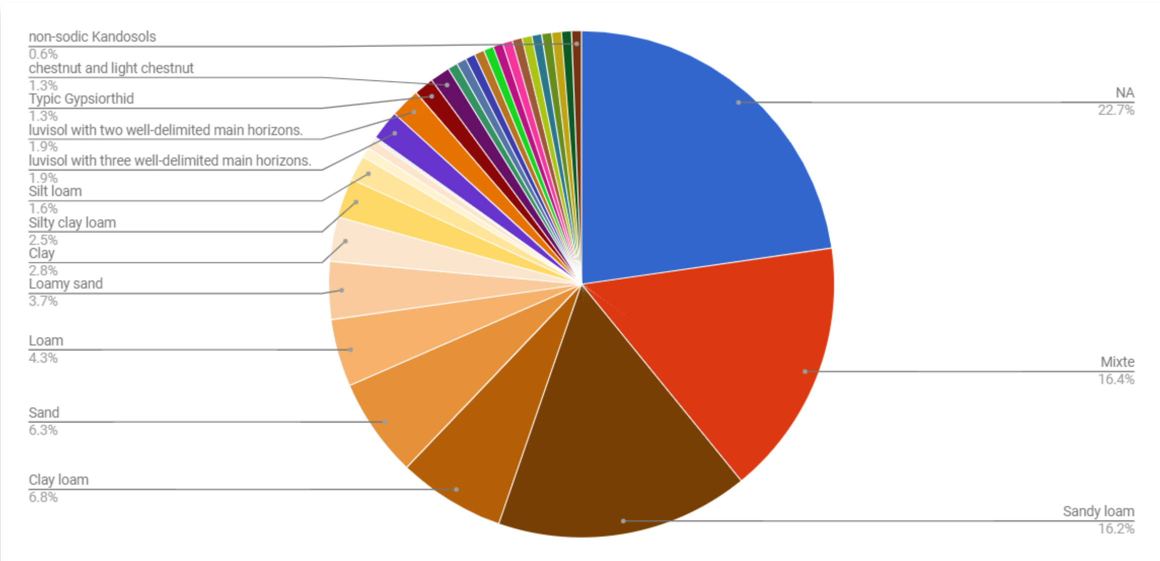

Figure 12 Different proportion of soils

Through this chart, it is hard to find a conclusion for the soils properties, first of all the not mentioned (22.7%) and the mixed (16.4%) parts of the chart were the biggest two parts. There always some part of the soils is not classified, further studies will be concerned in this chart in the future study.

- **Precipitation distribution summary**

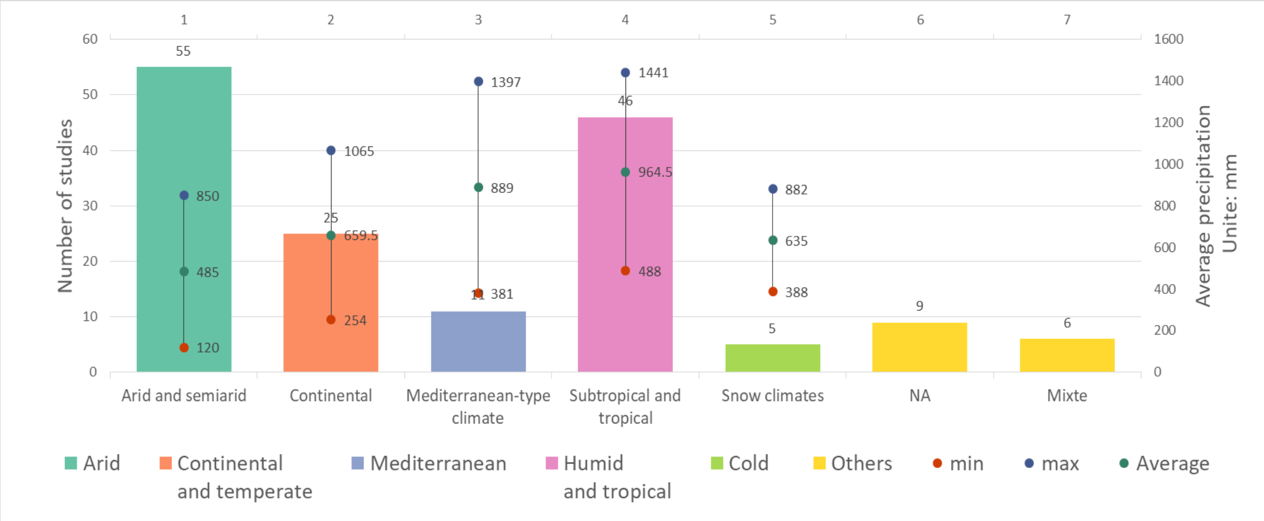

Figure 13 Different numbers of studies by precipitation distribution

With a different number of studies concern on the different climate, a chart of precipitation was made by calculating the average, minimum and maximum precipitation of different climate that mentioned. Through the graphic of precipitation and climate, it is easy to find out that difference between the climates was linked to the geographic conditions, so the same climate could be found with a various difference of precipitation. Through the articles, some evidence of the hydrological and the erosion of the soil were found which related the encroachment in the soil and the rainfall. Some studies show a higher probability of large precipitation events could favor woody encroachment in grasslands and savannas, thus possibly inducing a biome shift in the same direction already expected because of increased CO2 concentration levels (D'Onofrio, D, 2015). The runoff from encroached watersheds was mostly associated with high-intensity rainfall events through infiltration excess overland flow (Qiao, 2017). Other studies found that enhanced infiltration beneath canopies will promote more intense and longer pulses of nitrogen mineralization following rainfall (Cui and Caldwell 1997).

As for research of microclimate which examined spatial patterns of infiltration in grassland and shrub land, found that water infiltrates beneath the canopy will more likely be absorbed by plant roots. A synergistic interaction between soil moisture and nutrient cycling should exist beneath plant canopies (Bhark, E, 2003).

Trees facilitate understorey growth mainly if they ameliorate both water and nitrogen availabilities while allowing enough light to penetrate to the soil surface (Blaser, W, 2013). In general, the function of precipitation is more difficult than our imagination which combines the hydrologic, erosion of the soil and the mineralization of chemical elements, it needs further study to find the real function of precipitation into beneath canopy.

Conclusion

The current database aims to provide a clear perspective to support subsequent thematic studies. To summarize the main consequences of shrub encroachment on soils, it is necessary to clear up plenty of information from a large number of articles. Through the lecture of all the articles have the consequence into soils, it was clear to make these conclusions:

Woody plant encroachment is gaining increasing attention. However, it has a global influence, most of the studies were concentrate on America and Africa with arid, humid and tropical climate, and there is a strong relation between the climate of these areas and the causes of encroachment. Different important factors, such as shrub species (leguminous or non-leguminous), rainfall and soil properties, play the important roles and interact with each other in our study. Encroachment happened in all kinds of biomass and all kinds of climates on the earth. Meanwhile, the impact of human activities on the environment cannot be ignored. With the data well organized, it is revealed that woody plants impact soil chemical properties, soil physical properties, microbiology, hydrology and microclimate. Nevertheless, to enhance the understanding of woody encroachment on soil properties, we need to analyze and work on existing research in detail.

The balance between herbaceous plants and woody plants is influenced by climate (temperature, total amount of rainfall), soil (physico-chemical properties of soil, soil texture, depth of soil layer), disturbance (grazing, fire, herbivore preference), CO2 concentration, land use patterns and other factors combined effect. These factors also interact with each other in many time and space scales. However, the invasion of woody plants also has a complex impact on the soil. The most common is the "island effect" that significantly increases soil fertility and promote nitrogen mineralization. Meanwhile, this phenomenon can also lead to the typical performance of desertification such as the increase of surface runoff and soil erosion as well as the reduction of soil moisture. Fortunately, the following several sections of the thematic study precisely give us a clear direction to better explore the impact of the phenomenon on the soil.

Future parts

According to the requirements, there are 3 different incoming themes to get clear, which consist of the soil, as life support for soil fauna and flora, impacted by the woody plants; encroachment modifies soil biogeochemical cycles; encroachment and hydrology.

For each follow part, we have detailed focus to analyze, and the main topics we have counted will help us to access related researches. For the second part, a microclimate under trees for herbaceous vegetation, and biodiversity of *pedofauna* and food web interactions will be explored in detail. For the third part, carbon below ground stock changes, turnover of the ratio of carbon to nitrogen, and soil nutrients will be the focus of attention. For the fourth part, soil physical properties, water flows and resources, and soil erosion will be the keys to research. On the basis of the data-base, related articles and experiments will be further re-read. Specific studies will be analyzed and summarized.

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Woody encroachment impacts on soil properties
L'impact des ligneux sur les propriétés du sol

Résumé :

Au cours des 100 dernières décennies, l'envahit des ligneux dans les pâturages et savanes ont augmenté dans le monde entier. Comprendre l'ensemble de ces impacts positifs et négatifs sur le sol (propriétés biologique, physique et chimique) et trouver une manière de contrôle des ligneux est une nécessité.

Avec l'augmentation des populations humaines, la dégradation mondiale des pâturages s'intensifie, la fréquence des incendies est également intensifiée. Parallèlement, sur la base d'études approfondies, plusieurs facteurs tels que le changement climatique, notamment le taux de CO2 dans l'atmosphère, la proportion de précipitations, les conditions édaphiques ont également affecté ce phénomène. La plupart des études se concentrent davantage sur les effets sur les propriétés. Cette étude est en train de révéler que les conséquences sur les propriétés du sol dépendent de nombreux facteurs comme l'espèce du ligneux (espèce légumineuse ou non légumineuse), des conditions environnementales (climat dont la température et les précipitations, site de l'étude), le degré d'invasion, la compétition pour les ressources du sol et la densité du sol.

Les objectifs de notre projet sont d'examiner les conséquences pour la fonction de l'écosystème, en particulier pour les propriétés du sol. Les conditions géographiques de l'envahit ligneux, les types de plantes ligneuses, leurs causes de l'envahit, les climats relatifs et les types de sols sont recueillies et sont prises en compte. Le travail plus important est l'analyse et l'évaluation de la base de données parmi les nombreuses études.

Mots Clés : invasion, ligneux, prairies, savanes, propriétés du sol, arbustes.