Utrecht University

GRAZED AREAS IN NORTH AMERICA FROM EUROPEAN COLONIZATION UNTIL PRESENT DAY

A research proposal

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Source of the figure on the front page: https://www.audubon.org/magazine/summer-2019/grazing-its-1799-how-ranchers-can-bring-back

Key information

Summary

Land use describes the alteration to a landscape done by humans. This has major impacts on the climate such as an increase in greenhouse gases (GHG). Deforestation is probably one of the best-known land use changes, but grazing is also a big part of the present, and historical, land use changes. Grazing means not just the process of an animal eating grass, enabling a certain area to be grazed upon is also part of the grazing concept. The latter can be done for example through deforestation. Grazing has increased in the last few years due to a strong population increase. Therefore, it is becoming more important to model future scenarios when considering grazing. However, this certainty of these scenarios is depending on the accuracy and amount of historical data. The lack of historical data related to grazing is a knowledge gap that gets in the way of modelling land use scenarios with high certainties. This project will focus on providing more data on the course of grazing areas and its intensity in North America from the European colonization till present day. Also, this project will try to expand to provide additional information about the course of grazing areas in North America during the Holocene. It is expected that the intensity of land use change increased drastically after the European colonization in the 18th century. However, the main limit to this research will be available data making it necessary to combine multiple data in order to draw conclusions.

Key concepts:

Grazing; History; North America; Climate change; Colonization

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Introduction

"Land use is the human employment of the land" (Meyer & Turner, 1996, p. 238). Meyer and Turner (1996) described land use as an exploitation of humans to meet their demands regarding resources. Land cover, *"the biophysical condition of the land: notably the kind and condition of the vegetation and other biota, the water, the soil, the artificial structures that cover its surface"* (Meyer & Turner, 1996, p. 238), can be affected through multiple ways by land-use. The first method is to change land cover completely, the second is to quantitatively change the land cover without complete alteration of the landscape and the third is by preserving a certain area from natural influences (Meyer & Turner, 1996). Land-use change is a human trait and has been present since there has been human kind. This has been increasing the carbon dioxide (CO_2) emissions into the atmosphere by mostly deforestation for cropland and grazing land (Klein Goldewijk, Beusen, van Drecht & de Vos, 2011), making this an important factor of ecosystem processes and climate change (Klein Goldewijk, 2012).

Research showed that land-use change can influence the climate system by exchanging greenhouse gases but through a changing albedo and/or heat fluxes it can also affect radiative forcing (Klein Goldewijk, 2012; Pielke et al., 2002). These findings increased research for the consequences of land-use change and many studies showed that land-use change is a large CO_2 source for (the increased) global emissions (Klein Goldewijk et al., 2011). Therefore, modelling the impact of land-use change has become more important. By modelling land-use change, feedbacks between different components, such as the climate-ecosystem-human interactions, can be examined (Gaillard et al., 2010). Also, it can be used to determine the impact of land-use change on atmospheric CO_2 concentrations (Klein Goldewijk & Verburg, 2013). Nowadays, many scenarios are modelled to assess different possible futures. These scenarios are partly based on historical information, because historic land-use and the dynamics that come with it show how ecosystems can evolve through time with the interference of humans.

To be able to study the long-term effects well, data from the Holocene, 10.000 BC – present-day AD, regarding land-use is preferred (Klein Goldewijk, 2012). Also, modelling future scenarios is not only based on data, it is also depending on the model itself, especially for global-scale scenarios (Klein Goldewijk & Verburg, 2013). However, only since a few decades have human kind written down their observations in a detailed manner. The records that are present lack, in most cases, detailed data due to undeveloped technology and knowledge about the concepts of ecosystems and land-use change. Another way to gather information about land-use change is through investigating population numbers and livestock sizes. In the years before the 19th and 20th century, not many records related to land use have been written down. If there are records, they are either lacking in detail as well or are already lost to us. This results in resulting in a data gap during Holocene of approximately 8000-9000 years that cannot be easily discovered. This makes it difficult to gather data from the Holocene. (Klein Goldewijk, 2012, Gaillard et al., 2010). Data from this era has been gathered mostly by interdisciplinary work from archeologists, geologists, biologists etc. Data that has been found should be considered with uncertainty regarding the accuracy (Klein Goldewijk & Verburg, 2013).

Managed grazing is an aspect of land-use, it consists of grazing done by herbivores that are part of a human livestock. There are a few different methods of managed grazing. The first distinction that be made is between deforesting an area to let livestock graze, or to let livestock graze in the original natural area such as grasslands, forests and savannas (Asner et al., 2004). Another distinction can be made between continuous and rotational grazing. Continuous grazing is a method in which livestock are not restricted in their movement, within their pasture.

A disadvantage of this method is that the size of the livestock needs to be well maintained so that it cannot go past the grasses' capacity to regrow. The rotational grazing is managed intensively by moving livestock from grazing area to grazing area in order to let some areas rest between the grazing periods. A disadvantage of this method is that it is time-consuming. The management of grazing areas, such as deforestation, weed control, fertilization etc., affect the amount of CO_2 emissions (Ogle et al., 2014).

Livestock has provided humans with wool, milk, beef and other products, making grazing an important factor of land-use for humans. This has had its consequence on the climate in the past and present and will also have influence on the climate in the future. This underlines the what about grazing on 'natural importance of being able to model the effects of grazing on future climate using historical data. With more accurate and detailed future scenarios, policy makers will be able to write better policies for sustainable grazing (Asner et al., 2004; Klein Goldewijk & Verburg, 2013).

The study area for this project is North America. This area has been chosen because of adequate data research for multiple regions, including the Great Plains. Also, North America has been colonized by European countries a few centuries ago. During this colonization, maps have been made that can indicate where colonists lived and thus where their livestock grazed (UGA, n.d.). Also, by focusing on the colonization, the impact of sudden land-use change can be determined and taken into account for future modelling.

Historical data around grazing is, as is mentioned before, difficult to gather. The lack of historical data creates a knowledge gap. Another problem about historical data is the uncertainty because a lot of data has been deduced from multiple different sources. This research will focus on the reducing the uncertainty around grazing from the start of the North American colonization to the present. The focus will be on trying to map different areas where grazing took place. If times allows, the project will be extended to map areas that has been grazed during the Holocene. There are two research questions for this project:

Research question 1: Which areas have been grazed by livestock in North America and how is this developed since the European colonization till the present?

Research question 2 With what intensity are these areas in North America grazed upon?

By answering these research questions, the course of managed grazing will be mapped and this can help future research in finding how much was grazed. Furthermore, the grazing intensity will be researched to give an indication about the effects of grazing after colonization. However, there is probability that the second research question will not be answered fully due to the time limit and available data.

Conceptual Research Design

North America

North America is part of the American continent and is known for its rich ecological diversity and is therefore sometimes compared to an ecological mosaic. This is because northern North America is located near the North Pole and the southern region is located near the equator. Also, it contains the Earth's lowest elevation and relatively tall mountains. Due to the diverse ecosystems, it is divided in multiple levels. When the level increases, smaller areas, within a certain ecological region, are described more detailed. Level I consist of 15 ecological regions (figure 1) and level II consists of 50 ecological regions (Commission for Environmental Cooperation (Montréal, Québec), & Secretariat, 1997; EPA, n.d.). Appendix 1 contains a table with the levels I and II of North America.

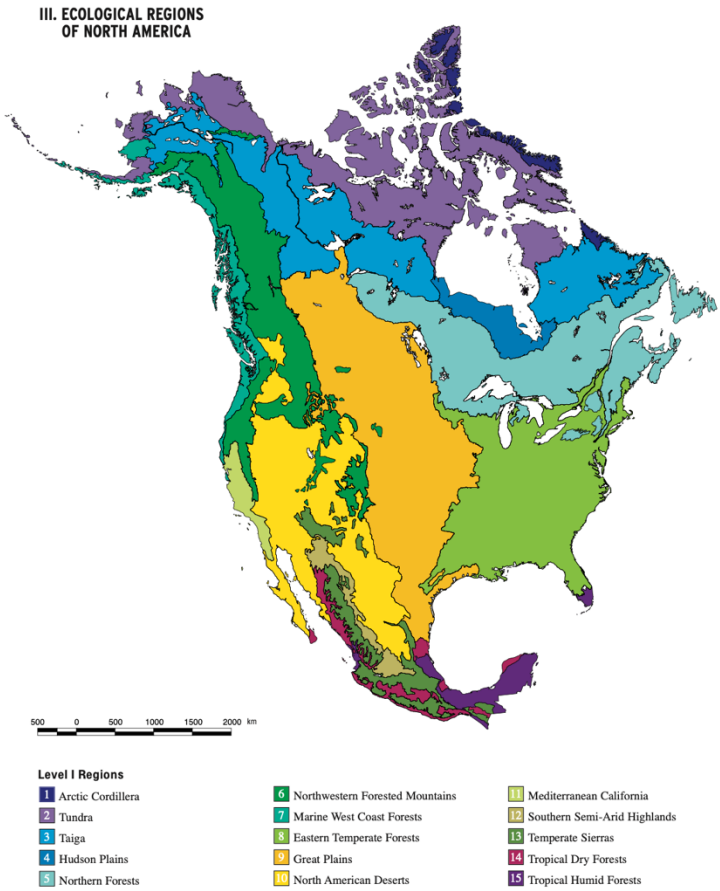

Figure 1. This figure shows the15 ecological regions in North America that are in level I. The orange region is the Great Plains. Source: Commision for Environmental Cooperation (Montréal, Québec) & Secretariat (1997).

The Great Plains is a big latitudinal ecological region in North America and consists of an area of approximately 3.5 million km^2. The most northern part in situated in Canada while the most southern part is located in Mexico. The width of the area covers from western Indiana to the Rocky Mountains in the east. In Canada and Mexico, the area is mostly flat while in the United States (US) the areas also consist of hills and tablelands. The climate of the prairie differs from a sub-humid to a semi-arid climate (Commission for Environmental Cooperation (Montréal, Québec)., & Secretariat, 1997). After the Civil War (1861-1865) the Great Plains were settled European settlers. The semi-arid climate spreads in the US from west, with a lot of cropping, to the east, containing pastures. Although land-use influence the environment, in the Great Plains there are two important climatic factors that influence the natural ecosystems and land-use. First, there is the increased precipitation from east to west, and second, there is an increased temperature from the north to the south. Nowadays, the Great Plains provide the largest areas regarding farming, around one-third of the agricultural area, and ranching, around two-third of the agricultural area, in the world (Commission for Environmental Cooperation (Montréal, Québec), & Secretariat, 1997; National research council, 2005).

Grazing

Grazing, or managed grazing, is part of the land-use concept. This is broad term that defines the multiple ways in which humans (can) alter land. This ranges from deforestation to farming and to grazing. Grazing is done by livestock, that is kept by humankind; and also includes land management done by humans in order to let livestock graze the land. The Great Plains is one

of the areas where grazing takes place in a high intensity, approximately half of all beef cattle in the United States (US) grazes in this area (Asner et al., 2004). However, it does not always mean that there are negative effects. In this case, prior to the colonization, bison grazed the Great Plains in large numbers and this made shortgrass areas resilient to the effects of grazing. So, when livestock replaced the bison population there were no big consequences for the environment. It does, however, still produce carbon emissions. Areas where bison did not naturally graze, managed grazing has had big effects on the ecosystem, resulting in endangered species of flora and fauna (Milchunas et al., 1998). Reeder and Schuman (2002) researched the effects of grazing on carbon concentration of two types of grasslands, short-grass steppe and mixed-grass prairie. These grasslands are both common in the Great Plains. When grazing is applied moderately in the semi-arid areas, there can be an increase in carbon sequestration. However, by increasing the grazing pressure in these areas, the carbon sequestration will decline leading to an increase in GHG (Reeder & Schuman, 2002).

Pre-colonization

Before North America was colonized, native Americans, otherwise known as Indians, lived in North as well as South America. They did not have the concept of fences and restricted areas for their livestock. This would allow their livestock to roam different areas in search for their preferred food and would suggest that their livestock consisted mostly of wildlife. There is some disagreement about the intensity of land use that Indians applied in North America (Denevan, 1992). However, Anderson (1990) argued that the current prairies in North America are only able to exist due to a (mild) fire regime. This suggests that Indians did indeed burn down areas for wildlife to graze upon those areas so they could be easier hunted down (Denevan, 1992)).

Colonization

European countries started to explore the world towards North America around the 15th century. The most known person for finding America is Columbus. This find changed a lot for the American continent. Spain, Portugal and England were known to battle for this region. Colonizing North America has changed the continent drastically, which also brought along several problems. The Europeans introduced fences, buildings and rules to the continent. Also, they hunted down large herbivores of which the bison would be the best known. brought several problems for the area (Denevan, 1992). Thirdly, although it is not connected directly to land use and grazing, the colonization introduced exotic diseased that were deadly for some human populations and animals. Lastly, the colonization was combined with land-use change in search for minerals such as gold (Pickett & Pickett, 2014).

Due to the European colonization in North America, population density increased drastically after the 18th century from 1 to 316 million in 2000 (Klein Goldewijk et al., 2010). This automatically results in an increase in food production and thus an increase in livestock and grazing areas. The development per 50 years is shown by Maizel (1998), who showed a strong increase in land use in North America from 1790 until 1990. The colonization of the United States (US) starts east US and expands towards the east.

Hypothesis

Based on the fact that managed grazing has increased since the European colonization in North America and that certain areas are not responding well to high grazing pressures; there are two different hypotheses for this project.

H1: The grazed areas in North America developed strongly after the European colonization and has been developing till now.

H2: The intensity of grazing increased in North America, especially in the Great Plains, after the European colonization till now.

Relevance

This research will contribute to the historical data available about grazing and development of grazed areas after the colonization of North America. By increasing historical data on grazing, the knowledge gap about the effects of grazing, and thus land use, can be reduced. This is important because accurate historical data is becoming more important in order to model future climate scenarios in relation to the effects of land use. When more accurate models can be produced, better data will be available for policy makers and stakeholders. This will result in more sustainable policies and a better future climate. Another aspect that this project can provide is additional data for the Historic Database of Global Environment (HYDE) 3.2. This is a data base that provides historical data about population development and land use/land cover along the Holocene (Klein Goldewijk et al, 2010). This data base is used by many researches in order to model future scenarios. However, since there is still uncertainty about the historical data, the results are certain as well and can influence policies (Klein Goldewijk & Verburg, 2013). When the results of these project have been analyzed, they can be compared with HYDE 3.2. If information can be added it means a decrease in the knowledge gap. If the results cannot be added in HYDE 3.2 it will mean that either it is already present, and thus the data is correct, or the results of this project are not accurate enough. Either way, it provides significant relevance that will help future modelling about future land use.

Another relevance of this project is regarding the farmers who keep livestock. When more is known about the effects of grazing, it can be executed in a more sustainable way. This will benefit the farmers, but also humans globally.

Technical Research Design

Research strategy

This results for this project are dependent on literature research. Multiple sources, like primary literature, maps and (travel) reports, will be used in order to find information about the course of grazing in North America. One of the methods that will be applied is by gathering information about human population development. By defining the location and size, as much as possible, of human populations, an estimated guess about livestock can be made. When this is compared to the different ecosystems surrounding a specific ecosystem, a specific managed grazing method can be defined. This will result is the possibility to translate it into land-use change and providing data for the results. Klein Goldewijk et al. (2010) estimated population numbers and densities for the Holocene. They based their estimates on previous results from

the following researches: World atlas of population history (McEvedy & Jones, 1987); A concise history of world population (Bacci, 2007); The world economy: a millennial perspective (Maddison, 2001); and, The pristine myth: the landscape of the Americas in 1492 (Denevan, 1992). They combined their estimates with population estimates from Populstat (Lahmeyer, 2004). Lahmeyer (2004) provides historical data that covers several periods and countries. Based on the theory that urban population densities form an asymmetrical bell-shaped curve, Klein Goldewijk et al. (2010) calculated this curve for every country for the Holocene period. Due to this curve, they were able to produce a rough estimate of population growth and decline during the Holocene. The results were put into the Historic Database of Global Environment (HYDE) (Klein Goldewijk et al., 2010). HYDE 3.2 is a database that provides urban and rural population figures for the time period Holocene. With these estimates, they calculated built-up areas by dividing total urban population and the time-dependent urban densities. Built-up areas are defined as areas that are artificially used by humans (Klein Goldewijk et al., 2010).

As mentioned before, the popularity of historical population has increased and this also applies for historical land use/land cover. The latter two can be derived from the population estimates. However, there is already an uncertainty with the population estimates and uncertainty for land use will therefore be present as well. There are two methods applies to determine historical land use and cover. The first is using the Dynamic Global Vegetation Models (DGVMs). These different models describe the interaction in an ecosystem between carbon and water exchange and the vegetation. The interactions show a time series of land cover. However, the different DGVMs are not consistent and the results vary greatly. This is partly due to the fact that human interaction with the land is not included in these models. The second method is based on statistics. Statistical information of the concerning countries regarding sub-national or national levels were put into historical data sets (Klein Goldewijk et al., 2011). Maizel (1998) provided statistical information about USA regarding the relationship between population settlement and farmland. They calculated the population and percent of land in farms for multiple years. The results showed a strong increase of urban settlement in USA after the European colonization. Also, they concluded that a combination of multiple historical databases is necessary in order to refine and decrease uncertainty of the effects of land use.

In order to decrease uncertainty around grazing after the European colonization, multiple historical sources will be used. Some of them are also used to produce HYDE 3.2. Also, other sources will be used in order to gather ‘new’ data that might provide different insights into this topic. It will be important to gather a lot of data about a certain region and in a specific period. Therefore, the results will be more accurate, as is necessary for this project. The strategy that will be used for this project will differ from the methods used in Klein Goldewijk et al (2011) and Maizel (1998). The main reason is that the timeframe will not allow for a lot of modelling, which would take a lot of time in order apply it to the historical data gathered. Thus, this project will be strictly literatures based and the results will be shown described in text format. Figures and tables will be used when it clarifies the written results.

Research Material

The research material will mostly consist of scientific literature and results from previous researches. Also, when possible, specific information about the course of colonization in North America will be gathered. They will be observed closely is order to create a specific time frame with as much data about grazing as possible. One way to describe the trend of colonization is by using the maps that they made during their travels. Although these are far from accurate,

they give an impression about how they observed the land and what they thought of as important areas for land use (UGA, n.d.). Scientific literature will be collected by viewing the references of certain articles as well as looking for those who cited these articles. This way, there will be as much data as possible collected.

Data collection and data processing

Data will be collected as much as possible within the time limit, but also as detailed as possible. This means that data on the countries, states and counties will also be gathered in order to produce the most accurate results. When the necessary data is collected, a time frame and map of the course of grazing areas over the years from the colonization till present-day can be made. Besides, the intensity of grazing will also be shown in the results as much as possible. The collected data will be compared to HYDE 3.2 in order to decide the certainty. The observations of these comparisons will be written down in the discussion. The figures that show the progress of grazing areas will either be from previous researches or will be drawn by hand.

In order to describe the intensity of grazing and course of grazing areas, it will be necessary to describe the change of ecosystems from the colonization till the present. For the present-day ecosystems, the ecological levels I and II (EPA, n.d.) will be used. Historical ecosystems will be derived and described from researches. As is mentioned above, the results will be compared to HYDE 3.2 in the discussion. By doing this, data from HYDE 3.2 will be looked at again and possible new data can be made available for the data set. This again will contribute to increased knowledge about the effects of historical grazing and thus historical land use.

Data will be collected through multiple search engines such as: www.scholar.google.com; www.google.com; www.scopus.com.

Discussion

Expected results

Due to the strong population increase after the colonization of North America, there is expected to be a clear distribution of grazing areas from then until present-day. Besides the expansion of grazing areas, the intensity is expected to increase as well. It should be noted that there is a possibility that technological development may have been able to decrease the intensity of grazing and if observed this will be shown in the results. Furthermore, there are certain areas in North America where it is expected that grazing has been developing steadily, such as the Great Plains. Nowadays, half of the beef cattle of the US grazes in this area and it is expected that the course towards this will be shown.

Contribution to the sustainability

By providing more historical data, the uncertainty around a certain period and region will decrease. This will help increase the certainty of modelling land use scenarios regarding future climate. Modelling future climates has been increasing in the last few decades due to the climate change that have been observed. The information on which these models is based is historical data, thus making it important to provide more historical data. This will contribute into making better and more sustainable policies in regard to grazing.

Applicability in societal practices

It will be difficult to apply the results directly into societal practices. This because this project will provide additional data in order to increase certainty of future climate models. It will depend on the accuracy and certainty of the results and the outcome of future models if it will be applicable for humans with livestock.

Limitations and risks of the research

The biggest limitation for this project is data availability. As is explained, there is not much historical data on grazing ready for the taking. This will lead to the need of combining multiple data sets in order to show a result with a descent certainty. It should be noted that the results are based on data that already have an uncertainty factor. by using the data for this project, the results will be uncertain and this should be taken into account regarding modelling future climate scenarios.

The risk for this project is not being able to find enough data due to the time limit. This will lead to results that are not complete and not accurate enough. By focusing mainly on the period after the colonization in North America, the chance of the time limit becoming a risk will be reduced.

Outline and planning of the Research Project

Outline

The research project is based on a literature research. Information will be gathered in order to answer the research questions:

- *Which areas have been grazed by livestock in North America and how is this developed since the European colonization till the present?*

- *With what intensity are these areas in North America grazed upon?*

In order to answer this question, the literature research will have this format:

- Title
- Table of contents
- Summary
- Chapter 1: Grazing
- Chapter 2: Timeline of human population from colonization of North America until present-day
- Chapter 3: Results
- Chapter 4: Discussion and conclusion
- References

Planning

Week	Activity	Deadline chapter
1	Writing literature background on grazing and its importance.	Chapter 1
2	Start finding information on the human population movement in North America.	–
3	Finish writing chapter 2.	Chapter 2
4	Start writing results. This includes making figures that will help answer the research question.	–
5	Continue with the results.	–
6	Continue with the results.	Chapter 3
7	Start writing the discussion and start on conclusion.	–
8	Finish writing the conclusions and make an overview of future research.	Chapter 4
9	Review the chapters and finish layout.	Final draft
10	Review all chapters, incorporate feedback and improve the layout.	Research Project

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Appendix

Appendix 1

Appendix 1 contains the level I & II of the ecological regions in North America (EPA, n.d.)

Table 1. This table contains the ecological regions of levels I & II in North America (EPA, n.d.).

LEVEL I	LEVEL II
1. ARCTIC CORDILLERA	1.1 Arctic Cordillera
2. TUNDRA	2.1 Northern Arctic 2.2 Alaska Tundra 2.3 Brooks Range Tundra 2.4 Southern Ar ctic
3. TAIGA	3.1 Alaska Boreal Interior 3.2 Taiga Cordillera 3.3 Taiga Plain 3.4 Taiga Shield
4. HUDSON PLAIN	4.1 Hudson Plain
5. NORTHERN FORESTS	5.1 Softwood Shield 5.2 Mixed Wood Shield 5.3 Atlantic Highlands 5.4 Boreal Plain

6. NORTHWESTERN FORESTED MOUNTAINS	6.1 Boreal Cordillera 6.2 Western Cordillera
7. MARINE WEST COAST FOREST	7.1 Marine West Coast Forest
8. EASTERN TEMPERATE FORESTS	8.1 Mixed Wood Plains 8.2 Central USA Plains 8.3 Southeastern USA Plains 8.4 Ozark, Ouachita-Appalachian Forests 8.5 Mississippi Alluvial and Southeast USA Coastal Plains
9. GREAT PLAINS	9.2 Temperate Prairies 9.3 West-Central Semi-Arid Prairies 9.4 South Central Semi-Arid Prairies 9.5 Texas-Louisiana Coastal Plain 9.6 Tamaulipas-Texas Semi-Arid Plain
10. NORTH AMERICAN DESERTS	10.1 Cold Deserts 10.2 Warm Deserts
11. MEDITERRANEAN CALIFORNIA	11.1 Mediterranean California
12. SOUTHERN SEMI-ARIS HIGHLANDS	12.1 Western Sierra Madre Piedmont 12.2 Mexican High Plateau
13. TEMPERATE SIERRRAS	13.1 Upper Gila Mountains 13.2 Western Sierra Madre

	13.3 Eastern Sierra Madre 13.4 Transversal Neo-Volcanic System 13.5 Southern Sierra Madre 13.6 Central American Sierra Madre and Chiapas Highlands
14. TROPICAL DRY FORESTS	14.1 Dry Gulf of Mexico Coastal Plains and Hills 14.2 Northwestern Plain of the Yucatan Peninsula 14.3 Western Pacific Coastal Plain, Hills and Canyons 14.4 Interior Depressions 14.5 Southern Pacific Coastal Plain and Hills 14.6 Sierra and Plains of El Cabo
15. TROPICAL WET FORESTS	15.1 Humid Gulf of Mexico Coastal Plains and Hills 15.2 Plain and Hills of the Yucatan Peninsula 15.3 Sierra Los Tuxtlas 15.4 Everglades 15.5 Western Pacific Plain and Hills 15.6 Coastal Plain and Hills of Soconusco