Centre for Geo-Information

Thesis Report GIRS-2003-09

The influence of accessibility on crop choice and poverty in the Guatemalan highlands

March 2003

Nicolas Dosselaere

WAGENINGEN UNIVERSITY

WAGENINGEN UR

The influence of accessibility on crop choice and poverty in the Guatemalan highlands.

Nicolas Dosselaere

Thesis submitted in partial fulfilment of the degree of Master of Science at Wageningen University and Research Centre, The Netherlands.

Board of Examiners:

Prof. Dr. Ir. A.K. Bregt
Dr. Ir. R.J.A. van Lammeren
Ing. W.T. ten Haaf

Supervisors:

Prof. Dr. Ir. A.K. Bregt
Ir. J. van Etten

March 2003
Wageningen, The Netherlands

Wageningen University and Research Centre
Laboratory of Geo-Information Science and Remote Sensing
Thesis report 2003-09

Acknowledgement

Muchas gracias,

A la gente de Chimaltenango y Sacatepéquez, por su hospitalidad y su franqueza, lo cual hicieron mi estancia en Guatemala muy agradable

A Dr. Edwin Castellanos de la Universidad del Valle de Guatemala y el Ministerio de Agricultura de Guatemala, por los datos necesarios

Professor Arnold Bregt, voor je suggesties, correcties en verfrissende visie op dit werk

Jacob, voor je nuttige ideeën, verbeteringen en begeleiding tijdens het veldwerk

John Stuiver, Harm Bartholomeus, Henk Schok, Jan Hein Loedeman en Jan Clevers, voor jullie vriendelijke hulp bij allerhande kleine probleempjes

The GIS-group, for making it a pleasure to go to Alterra every morning

Inge, voor de verbeteringen en de toffe tijd in Guatemala

Pa en ma, voor jullie onvoorwaardelijke steun en geloof in mij

dank je wel!

Abstract

Poverty is in the beginning of the third millennium a true anachronism. Also in the Guatemalan highlands the poverty figures are alarming. Inequality is current, also on a spatial domain. Development economist, however, usually ignore spatial variability and are more concerned with general production inputs and outputs. This research tries to counteract this reasoning by underlining the importance of the spatial dimensions in the development problem. Especially the role of accessibility as a spatial constraining factor, its efficiency as a poverty trap and its ability to reduce crop choice were investigated. The importance of accessibility in the Guatemalan highlands was already earlier mentioned, but a detailed study that related accessibility with crop choice and poverty in a contextual manner had never been performed.

Different combinations of crop type and accessibility were considered. For the small farmers, transport on foot to the village, followed by motorised means to the market, was the most crucial accessibility type. Throughout this work, this accessibility type was strongly correlated with the small farmer's choice between agriculture for subsistence and for monetary reasons. Although the constraining effect of accessibility was general applicable, its role became especially distinctive under the form of strong spatial unequal distribution of the different crops, when the impact of other influencing factors (e.g. financial means) started to reduce. For big farmers, access to good all year-round passable roads was more determinative than the overall access to the market.

Also poverty and accessibility were strongly intertwined. Because development aid by means of accessibility improvement reaches better the target group than e.g. the traditional economical support, the former can be assigned as an excellent development strategy. However, aid should not be focused solely on a global access to the urban centres. As the local road network proved to be crucial in the small farmer's crop choice, the accessibility problem will never be solved without attention for the latter. Moreover, it should be accompanied by other related investments.

Keywords: Guatemalan highlands, accessibility, crop choice, poverty, spatial relation and GIS.

Samenvatting

Armoede is in het begin van het derde millennium een anachronisme pursang. Ook in de hooglanden van Guatemala zijn de armoedecijfers alarmerend. Ongelijkheid is algemeen geldend, ook op een ruimtelijk domein. Desondanks negeren ontwikkelingseconomisten al te vaak de ruimtelijke variatie en zijn meer begaan met de algemene productie input en output cijfers. Dit onderzoek probeert deze tendens tegen te gaan door het belang van de ruimtelijke dimensie in het ontwikkelingsproces te onderstrepen. Vooral de rol van bereikbaarheid als een ruimtelijk belemmerende factor, zijn efficiëntie als een 'armoede val' en zijn potentie om de gewaskeuze te reduceren, werd hier bestudeerd. Het belang van bereikbaarheid in de Guatemalteekse hooglanden werd al eerder vastgesteld, maar een gedetailleerde studie die bereikbaarheid relateert met gewaskeuze en armoede op een contextuele manier was nog niet eerder uitgevoerd.

Verschillende combinaties van gewaskeuze en bereikbaarheid werden behandeld. Voor de 'kleine' landbouwers was transport te voet naar het dorp, gevolgd door gemotoriseerd vervoer tot de markt, het meest belangrijke type van bereikbaarheid. Doorheen heel dit werk was deze bereikbaarheid sterk gecorreleerd met de 'kleine' landbouwers keuze tussen landbouw voor onderhoud en voor financiële redenen. Niettegenstaande de algemene geldigheid van de belemmerende impact van bereikbaarheid, werd zijn invloed vooral merkbaar onder de vorm van een ruimtelijke ongelijke verdeling van de verschillende gewassen, wanneer de invloed van andere beïnvloedende factoren (zoals financiële armkracht) begon af te nemen. Voor 'grote' landbouwers was de bereikbaarheid tot goede, steeds berijdbare wegen, meer doorslaggevend dan de algemene bereikbaarheid tot de markt.
Ook armoede en bereikbaarheid waren sterk gecorreleerd. Daar ontwikkelingshulp door middel van bereikbaarheidsverbeteringen beter de doelgroep bereikt dan bijvoorbeeld de traditionele economische steun, kan de eerstgenoemde als een uitmuntende ontwikkelingsstrategie worden aangeduid. Desalniettemin mag steun niet enkel een verbetering van de algemene bereikbaarheid in de bebouwde gebieden tot doel hebben. Omdat het plaatselijke wegennet cruciaal was in de kleine landbouwers' gewaskeuze, zal het bereikbaarheidsprobleem nooit opgelost worden zonder aandacht voor dit lokaal netwerk. Daarbij moet het vergezelt gaan met andere gerelateerde investeringen.

Kernwoorden: Guatemalteekse hooglanden, bereikbaarheid, gewaskeuze, armoede, ruimtelijke relatie en GIS.

Resumen

La pobreza es en el principio del tercer milenio un verdadero anacronismo. También en los altiplanos de Guatemala, las cifras de pobreza son alarmantes. Desigualdad es general, también en un contexto espacial. A pesar de ello, los economistas de desarrollo ignoran a menudo la variación espacial y se centran más en las cifras generales de producción de input y output. Este estudio intenta parar esta tendencia haciendo énfasis a la importancia del dominio espacial en el proceso de desarrollo. Especialmente el papel de la accesibilidad como un factor de obstrucción espacial, su efecto como "una trampa de pobreza" y su potencial para limitar la elección de cultivos ha sido analizado en este trabajo. La importancia de la accesibilidad en los altiplanos de Guatemala ya ha sido estudiada anteriormente, pero un estudio detallado que relaciona la accesibilidad con la elección de cultivos y la pobreza en un modo contextual nunca había sido realizado.

Diferentes combinaciones de elección de cultivos y accesibilidad fueron tratados. Para los 'pequeños' agricultores, el transporte a pie hasta el pueblo, seguido de transporte motorizado hasta el mercado, fue el más importante tipo de accesibilidad. En este trabajo, la accesibilidad tuvo una fuerte correlación con la elección de los 'pequeños' agricultores entre agricultura de subsistencia y agricultura con fines comerciales. No obstante la validez general del impacto obstruyente de accesibilidad, su influencia se convierte visible especialmente en forma de una distribución desigual espacial de los diferentes cultivos, cuando el influjo de otros factores influyentes (como recursos financieros) empiezan a disminuir. Para agricultores 'grandes', la accesibilidad a caminos buenos y transitables todo el año fue más decisiva que la accesibilidad general al mercado.
Se encontró también una fuerte correlación entre pobreza y accesibilidad. Ya que la ayuda al desarrollo a través de mejoras de accesibilidad consigue mejor resultados que por ejemplo el apoyo tradicional económico, la aquella puede estar indicada como excelente estrategia al desarrollo. A pesar de ello, el apoyo no puede tener solamente como objetivo una mejora de la accesibilidad general. Teniendo en cuenta que la red de carreteras local fue crucial en la elección de cultivos por parte de los 'pequeños' agricultores, el problema de accesibilidad nunca estará solucionado sin atención a la red local. Además, tiene que ir acompañado de otras inversiones relacionadas.

Palabras principales: altiplanos de Guatemala, accesibilidad, elección de cultivos, pobreza, relación espacial y SIG.

LIST OF CONTENT

ACKNOWLEDGEMENT .... **I**

ABSTRACT .... **II**

SAMENVATTING .... **III**

RESUMEN .... **IV**

LIST OF CONTENT .... **V**

LIST OF ACRONYMS .... **VII**

LIST OF FIGURES .... **VIII**

LIST OF TABLES .... **X**

CONTENT OF APPENDIX .... **X**

LIST OF FIGURES IN APPENDIX .... **X**

1) INTRODUCTION **1**

2) OBJECTIVES **3**

3) BACKGROUND **5**

3.1 THE STUDY AREA 5

3.1.1 Guatemala *5*

3.1.1.1 The primary sector of Guatemala 8

3.1.1.2 The road network and transport in Guatemala 11

3.1.1.3 The poverty problem in Guatemala 11

3.1.2 The departments of Chimaltenango and Sacatepéquez *14*

3.1.2.1 Agriculture in the study area 17

3.1.2.2 The road network in the study area 22

3.1.2.3 Poverty in the study area 23

3.2 ACCESSIBILITY AND ITS RELATION WITH CROP CHOICE AND POVERTY 23

3.2.1 The spatial distribution of poverty and its relation with accessibility *26*

3.2.2 The influence of accessibility on crop choice *27*

3.2.3 The relation between crop choice and poverty *32*

4) MATERIAL AND METHODS **33**

4.1 INTERVIEWS 37
4.2 LAND-USE DATA 39
4.2.1 Land-use data for the case study areas *39*
4.2.2 Land-use data for the departments of Chimaltenango and Sacatepéquez *40*
4.2.2.1 Pre-processing 41
4.2.2.2 The land-use classification 42
4.2.2.3 Classification accuracy assessment 43
4.3 ACCESSIBILITY MAPS 45
4.3.1 Input data *45*
4.3.1.1 Road quality data 45
4.3.1.2 Information about market and transport functioning 46
4.3.1.3 Height data 46
4.3.2 Creation of the accessibility maps *49*
4.4 POVERTY DATA 52
4.5 METHODOLOGY TO INVESTIGATE THE RELATION BETWEEN ACCESSIBILITY, CROP CHOICE AND POVERTY. 53
4.5.1 The influence of accessibility on crop choice. *53*
4.5.2 The relation between accessibility and poverty. *56*
4.5.3 The relation between crop choice and poverty. *57*

5) RESULTS AND DISCUSSION **59**

5.1 THE CASE STUDIES 59
5.1.1 The case study of Santiago Sacatepéquez *59*
5.1.1.1 Roads and transport in Santiago Sac. 60
5.1.1.2 Land-use and market situation in Santiago Sacatepéquez 67
5.1.1.3 Poverty in Santiago Sacatepéquez 70
5.1.1.4 Accessibility in Santiago Sacatepéquez 70
5.1.1.5 The relation between accessibility and crop choice in Santiago Sac. 75
5.1.2 The case study of San Andrés Itzapa *82*
5.1.2.1 Roads and transport in San Andrés Itzapa 83
5.1.2.2 Land-use and market situation in San Andrés Itzapa 86
5.1.2.3 Poverty in San Andrés Itzapa 90
5.1.2.4 Accessibility in San Andrés Itzapa 90
5.1.2.5 The relation between accessibility and crop choice in San Andrés Itzapa 93
5.2 THE COMPLETE STUDY AREA 97
5.2.1 Roads and transport in the study area *97*
5.2.2 Land-use and market situation in the study area *98*
5.2.3 Poverty in the study area *101*
5.2.4 Accessibility in the study area *101*
5.2.5 The relation between accessibility and crop choice in the study area *103*
5.2.6 The role of accessibility on poverty in the study area *107*
5.2.7 The relation between poverty and crop choice in the study area *111*

CONCLUSION AND RECOMMENDATIONS **115**

REFERENCES **119**

APPENDIX .... **A**

LIST OF ACRONYMS

2D:	Two-Dimensional
AGEXPRONT:	Asociación Gremial de Exportadores de Productos No Tradicionales
ASTER:	Advanced Spaceborn Thermal Emission and Reflection Radiometer
CATIE:	Centro Agronómico Tropical de Investigación y Enseñanza
CBS:	Centraal Bureau voor de Statistiek
CONAMA:	Comisión del Medio Ambiente de Guatemala
DEM:	Digital Elevation Model
DPE:	División de Planificación y Estudios
DTED:	Digital Terrain Elevation Data
ETM+:	Enhanced Thematic Mapper Plus
FAO:	Food and Agriculture Organization of the United Nations
GDP:	Gross Domestic Production
GIS:	Geographic Information Systems
GPS:	Global Positioning System
IGN:	Instituto Geográfico Nacional de Guatemala
ILO:	International Labour Organisation
INE:	Instituto Nacional de Estadística de Guatemala
JICA:	Japan International Cooperation Agency
LMT:	Ladinos-controlled Market Town
LU:	Land Use
MAGA:	Ministerio de Agricultura, Ganadería y Alimentación de Guatemala
ME:	Ministerio de Educación
MPHSAS:	Ministry of Public Health and Social Assistance
NASA:	National Aeronautic and Space Administration
NDVI:	Normalized Difference Vegetation Index
NIMA:	National Imagery and Mapping Agency of the USA
RBC:	Rural Bulking Centres
RS:	Remote Sensing
SEGEPLAN:	Secretaría de Planificación y Programmación de la Presindencia de la República de Guatemala
USGS:	United States Geological Survey
UTM:	Universal Transverse Mercator
WOLA:	Washington Office on Latin America

List of figures

Figure 1. Maize in the western highlands of Guatemala ……………………………..2
Figure 2. A typical road throughout the milpa fields in the Guatemalan highlands….4
Figure 3. The study area…………………………………………………………6
Figure 4. Population of the biggest cities in Guatemala according to INE (2002)…...8
Figure 5. Contrast between small (A-C) and big (D-E) scale farming in the highlands of Guatemala…………………………...…………………....10
Figure 6. Population of the biggest municipalities in the study area (2002)………..16
Figure 7. Typical agricultural landscape in the study area. The big scale agriculture is strongly contrasting with the small plots in the background…………...18
Figure 8. Different crop types of the Guatemalan highlands. (A-B: milpa, C: coffee, D: vegetables and E: blackberry)……………………………….19
Figure 9. Rural landscape in the municipality of San Martin Jilotepeque……….....24
Figure 10. Simple conceptual model………………..……………………………25
Figure 11. The economic and spatial dimension of the von Thünen model…………29
Figure 12. Location of the two case study areas in the study area……………..…...34
Figure 13. Methodology scheme…………………………………………………36
Figure 14. A typical market in the Guatemalan highlands……………………….…….39
Figure 15. The agricultural practice of partly 'cutting' the top of the maize plant….43
Figure 16. Different roads in the study area………………………………………48
Figure 17. The assignment of the vertical cost factor according to the slope……….51
Figure 18. Schematic example of the methodology to make the relation between accessibility and crop choice…………………………………...54
Figure 19. View over a part of the case study area of Santiago Sacatepéquez. The village of Santiago is situated in the middle of the picture while Santa Maria is located in the right corner………………………………...60
Figure 20. Some transportation means in the Guatemalan highlands………………..63
Figure 21. Interview results of the case study area of Santiago Sacatepéquez. ……..64
Figure 22. Map showing the land-use and road quality in the case study area of Santiago Sacatepéquez……………………………………………...…68
Figure 23. Accessibility map considering transport on foot to the village in the case study area of Santiago Sacatepéquez……………………………………..71
Figure 24. Accessibility map considering the `fastest` transport to the village in the case study area of Santiago Sacatepéquez………………………………...72
Figure 25. Accessibility map considering the `fastest` transport directly to the market of Guatemala City in the case study area of Santiago Sacatepéquez……………………………………………………..73
Figure 26. Percentage of the three big land-use classes (of the total area) considering transport to the village on foot in the Santiago case study area………………………………………………………75

Figure 27. The relation between accessibility and crop choice in the Santiago Sacatepéquez study area…………………………………………….....77
Figure 28. Other factors influencing crop choice. A-B: irrigation; C: ground………81
Figure 29. Interview results of the case study area of San Andrés Itzapa…………….84
Figure 30. Map showing the land-use and road quality in the case study area of San Andrés Itzapa……………………………………………………..87
Figure 31. Accessibility map considering the transport on foot to the villages in the case study area of San Andrés Itzapa……………………………...91
Figure 32. Accessibility map considering the `fastest` transport directly to the market of Guatemala in the case study area of San Andrés Itzapa…...92
Figure 33. Distribution of the three major LU classes according to accessibility to the village on foot in the San Andrés Itzapa study area………………..93
Figure 34. In the fertile but difficult accessible plain in the north of San Andrés Itzapa, milpa is the only crop type cultivated………………..94
Figure 35. The relation between accessibility and crop choice in the San Andrés Itzapa study area……………………………………………..95
Figure 36. Land-use map for the departments of Chimaltenango and Sacatepéquez……………………………………………………...99
Figure 37. Map representing the distribution of agricultural products from the study area to the market of Guatemala City……………………………..100
Figure 38. Accessibility map considering transport on foot to the village followed by motorized transport to Guatemala City for the departments of Chimaltenango and Sacatepéquez…………………………………...102
Figure 39. Relation between crop choice & accessibility in the whole study area…105
Figure 40. Map representing the 2D-relation between accessibility and the choice of vegetables/milpa for the departments of Chimaltenango and Sacatepéquez……………………………………106
Figure 41. The relation between poverty & accessibility in the study area………...108
Figure 42. Map representing the 2D-relation between accessibility and poverty (of the urban areas) for the departments of Chimaltenango and Sacatepéquez……………………………………………………..109
Figure 43. Map representing the 2D-relation between accessibility and poverty (of the 'living environment') for the departments of Chimaltenango and Sacatepéquez……………………………………….110
Figure 44. Relation between crop choice & poverty in the study area…………………………………………...……..………..113
Figure 45. Map representing the 2D-relation between poverty and the choice of vegetables/milpa for the departments of Chimaltenango and Sacatepéquez……………………………..……...114
Figure 46. Harvested maize close to Lago Atitlan in the department of Sololá …...118

List of tables

Table 1. Data collection method…………………………………...………………35
Table 2. Some characteristics of the remote sensing images used in this work……...41
Table 3. The confusion matrix for the land-use map of the study area………………44
Table 4. Indication of the classification of other not considered land-use classes…...44
Table 5. Some characteristics of the different road types. …………………………..47
Table 6. Simple comparison concerning speed and cargo between different transportation means…………………………………………………………...61

Content of appendix

Appendix 1: Poverty in Guatemala…………………………………………....…a
Appendix 2: Poverty in the study area……………………………………………...b
Appendix 3: The central place theory………………………………………………f
Appendix 4: The mapping-out procedure…………………………………………..k
Appendix 5: Importing and pre-processing of the RS images………………………..m
Appendix 6: Conversion of the coordinate system……………………………………o
Appendix 7: Accessibility maps of Santiago Sacatepéquez…………………………..p
Appendix 8: Accessibility maps of San Andrés Itzapa………………………………..s
Appendix 9: Distribution of agr. products in the study area…………………………..y
Appendix 10: Accessibility maps of the study area………………………………….bb

List of figures in appendix

Figure A1. Map representing % of poverty in the departments of Guatemala………...a
Figure A2. Map representing % of poverty in the municipalities of the departments of Chimaltenango and Sacatepéquez…………………………………….....b
Figure A3. Map representing % of extreme poverty in the municipalities of the departments of Chimaltenango and Sacatepéquez………………………...c
Figure A4. Map representing the severity index of poverty in the municipalities of the departments of Chimaltenango and Sacatepéquez……………...…..d
Figure A5. Map representing the severity index of extreme poverty in the municipalities of the departments of Chimaltenango and Sacatepéquez…..e
Figure A6. The central place theory; K=3, 4 and 7 respectively……………….……..g
Figure A7. Dendritic market pattern…………………………………………………...j
Figure A8. Accessibility map considering the transport on foot to the village and then motorized to the market of Guatemala City in the case study area of Santiago Sacatepéquez……………………………………p
Figure A9. Accessibility map considering transport on foot to the `closest` road passable by car in the case study area of Santiago Sacatepéquez…………q

Figure A10. Accessibility map considering the `fastest` transport to the `closest` relative good, all year-round passable road in the case study area of Santiago Sacatepéquez……………………………………………….r
Figure A11. Accessibility map considering the `fastest` transport to the village in the case study area of San Andrés Itzapa……………………………..s
Figure A12. Accessibility map considering the `fastest` transport directly to Chimaltenango City in the case study area of San Andrés Itzapa………...t
Figure A13. Accessibility map considering the transport on foot to the village and then motorized to the market of Guatemala in the case study area of San Andrés Itzapa…………………………………………...u
Figure A14. Accessibility map considering the transport on foot to the village and then motorized to the market of Chimaltenango City in the case study area of San Andrés Itzapa………………………………………..v
Figure A15. Accessibility map considering the transport on foot to the `closest` road passable by car in the case study area of San Andrés Itzapa……..…w
Figure A16. Accessibility map considering `the fastest` transport to the `closest` relative good, all year-round passable road in the case study area of San Andrés Itzapa…………………………………………...….x
Figure A17. Distribution of agricultural products to the market of Chimaltenango City…………………………………………………..y
Figure A18. Distribution of agricultural products to the market of Antigua Guatemala……………………………………………………...z
Figure A19. Distribution of agricultural products from the study area to the market of Sololá…………………………………………...……aa
Figure A20. Accessibility map considering the `fastest` transport directly to the market of Chimaltenango City in the departments of Chimaltenango and Sacatepéquez………………...……………………...…………bb
Figure A21. Accessibility map considering the `fastest` transport directly to the market of Antigua Guatemala in the departments of Chimaltenango and Sacatepéquez……………………………………………………cc
Figure A22. Accessibility map considering the transport on foot to village in the departments of Chimaltenango and Sacatepéquez………………………dd
Figure A23. Accessibility map considering the `fastest` transport to the villages in the departments of Chimaltenango and Sacatepéquez………………..ee
Figure A24. Accessibility map considering the transport on foot to the `closest` road passable by car in the departments of Chimaltenango and Sacatepéquez……………………………………………………ff
Figure A25. Accessibility map considering the `fastest` transport to the `closest` relative good, all year-round passable road in the departments of Chimaltenango and Sacatepéquez……………………………………gg
Figure A26. Accessibility map considering the `fastest` transport directly to the market of Guatemala City in the departments of Chimaltenango and Sacatepéquez……………….………………….…………….…..…hh

1) Introduction

A typical characteristic of most developing countries is the huge inequality. Incomes are concentrated in the hands of a relative small group, while the majority of the people live in poverty. Also in Guatemala this gap between rich and poor is big. With a GINI coefficient of 0.58, Guatemala is even one of the counties with the highest concentration of income. The government has to play an important role in reducing this dualism of the society and in the Peace Agreements of 29th of December 1996, it committed itself in ‘improving the quality of live of all Guatemalan people and especially these who are in extreme poverty’. Nevertheless, since this agreement, poverty has not decreased considerably and inequality of income even increased.

Too often poverty is seen as a one-dimensional parameter, neglecting all spatial variations and causes. Nonetheless, breaking down the deep-rooted spatial inequalities is an indispensable step to a sustainable development. In this work especially the role of ‘infrastructural’ accessibility, as such a spatial constraining factor will be highlighted. Watanabe (1981) and Smith (1984a) mentioned already its importance in the Guatemalan highlands. However, a formal detailed study that links the spatial distribution of poverty with accessibility in a contextual manner has never been performed.
The same applies to the relation between accessibility and crop choice. It has long been seen as a side effect rather than a central issue in the different scientific branches. However, accessibility can be a powerful brake on agriculture productivity and can limit considerably the choice of crops. According to Leclerc (2001) accessibility is even the single most important eco-regional factor driving land-use change.

This thesis aims at providing more insight in the spatial relations between accessibility, crop choice and poverty. While remote sensing was enlisted for a part of the land-use data collection, GIS techniques were used to calculate the accessibilities and to make the different relations. In order to collect a sufficient amount of data and information in this data poor region, a fieldwork of two months was executed. The departments of Chimaltenango and Sacatepéquez in the western highlands of Guatemala were chosen as study area.

After formulation of the objectives in the next chapter, a description of the study area and a small discussion of the accessibility and poverty problem will be given in the third chapter. The data collection and methodology will be outlined in chapter 4 and the result will be given and discussed in the fifth chapter. This thesis will be finished with a general discussion and some recommendations.

Figure 1. Maize in the western highlands of Guatemala.

2) Objectives

To create a sustainable development in a country as Guatemala, it is of the utmost importance that governments and international aid programs focus on breaking down the dualism of society. This process is however cumbersome. A thorough understanding of the different constraining factors could help to point out and reduce these bottlenecks. The role of accessibility as such a constraining factor and its ability to diminish crop choice and its efficiency as a poverty trap are investigated here. This thesis hopes to deliver some tools and knowledge to tackle this vital problem.

Research questions:

Does accessibility influence the crop choice in the study area?

Is there a relation between accessibility and poverty in departments of Chimaltenango and Sacatepéquez?

What is the relation between crop choice and poverty in the study area?

Figure 2. A typical road throughout the milpa fields in the Guatemalan highlands.

3) **Background**

This chapter starts of with a description of the primary sector, the road network and the poverty situation. While in 3.1.1 these topics are presented for the country of Guatemala, paragraph 3.1.2 zooms in on the study area. In the last part of this chapter, the relation between accessibility, poverty and crop choice are discussed in more detail.

3.1 The study area

3.1.1 Guatemala

Guatemala is located in Central America, just below Mexico (see figure 3). It has borders with Belize to the northeast and with El Salvador and Honduras to the east. In the northeast and the southwest, it is encircled respectively by the Caribbean Sea and the North Pacific Ocean.

The relief of this Central American country is especially mountainous (82 %). Geologically, Guatemala is situated in the extreme south of the occidental mountain system of North America. Two offshoots of this system, the Sierra Madre and the Los Cuchumatanes system cross the whole country from west to east. The movement of three tectonic plates (Caribbean, North American and Cocos) make the history of this country a chronicle of constant catastrophes. Every generation had its big disaster. Due to several volcanic eruptions and earthquakes, the whole capital of the country had to be replaced two times. The 34 volcanoes, from which five are active this moment, mean a constant threat for the surrounding population. Even more devastating are the earthquakes. Since 1900, two earthquakes of 8 degrees on the scale of Richter or higher and four of more than seven were registered. In 1902, 1917 and 1918 several thousands of people were killed. The last heavy earthquake was in February 1976 when more than 22000 deads were registered. Also tropical storms do not spare Guatemala. In 1998 the hurricane Mitch left a ‘street’ of destruction

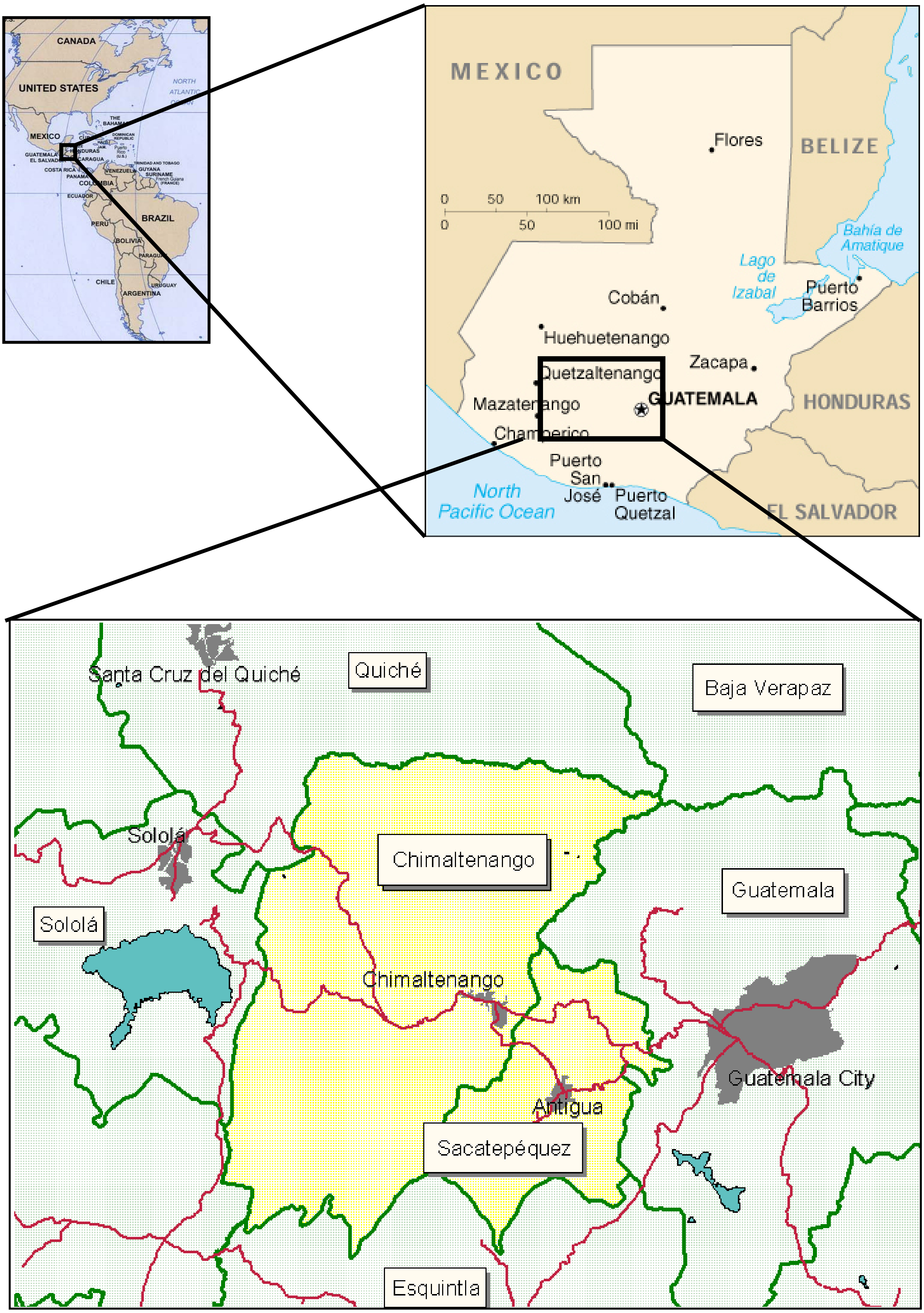


Figure 3. The study area.

throughout Central America. In Guatemala, 400 people died and more than one million people were affected.

As in many other tropical countries, the environment is under high pressure. The biggest risk is the deforestation with all its consequences, especially, erosion of the soils, the decrease of rainfall, the degradation of water resources and the loss of biodiversity. In 1986 'la Comisión Nacional del Medio Ambiente' (CONAMA) was founded to counter this trend. Nevertheless, Guatemala is nowadays still one of the countries with the highest rate of deforestation.

Guatemala is known as the country of the everlasting spring as its temperature is the whole year-round mild. The mean temperature is 18.2 °C. There are however big variations based on altitude and local conditions like winds. The seasons in Guatemala are based on the rain regime. May until October is the rainy season, while the months of November until April represent the dry period. The biggest precipitations occur in May - June and September - October, when the sun has an almost perfect vertical position. During the months of July and August the sun elevation is lower and as a consequence a recess of rain, called canícula, occurs. The average annual rainfall for Guatemala is 2218 mm but varies considerably between the different regions of the country. Annual precipitation ranges between 400 and 5000 mm and days of rainfall can vary from 45 to 200 days. The mean relative humidity varies between sixty and eighty %.

In this rather small country of only 109000 square kilometres, the ancient Maya civilisation had its heyday in the first millennium of our calendar. In 1523, the Spaniards launched the conquest of Guatemala and in 1524 the colonial era opened. This period saw an impressive cultural development experienced by few other places in the New World. Guatemala was freed of Spanish colonial rule in 1821. During the second half of the 20th century, it experienced a variety of military and civilian governments as well as a 36-year guerrilla war. In 1996, the government signed a peace agreement formally ending the conflict, which had led to the death of more than 100.000 people and had created some 1 million refugees.

Over half of the population is made up of 22 Maya groups (the indigenous). The Mestizos, or "Ladinos", product of the biological and cultural mix between Indians and Europeans, make up less than half of the population. Like most of the Central American countries, an impressive increase of inhabitants occurred during the last decades. Since 1960, the population almost tripled to over 12 million currently (FAO, 2002). Especially Guatemala City exploded. This metropolitan area inhabits nowadays more than 2.5 million people (INE, 2002). The second city does not reach 10 % of this population number (see figure 4). This huge gap is a reflection of the extreme 'centralistic' position of the capital in Guatemala. While almost all political, financial and economic power is concentrated in Guatemala City, the rest of the country is reduced to a second-rank role. This also becomes clear in the following discussions about the agriculture, the road network and the poverty in Guatemala.

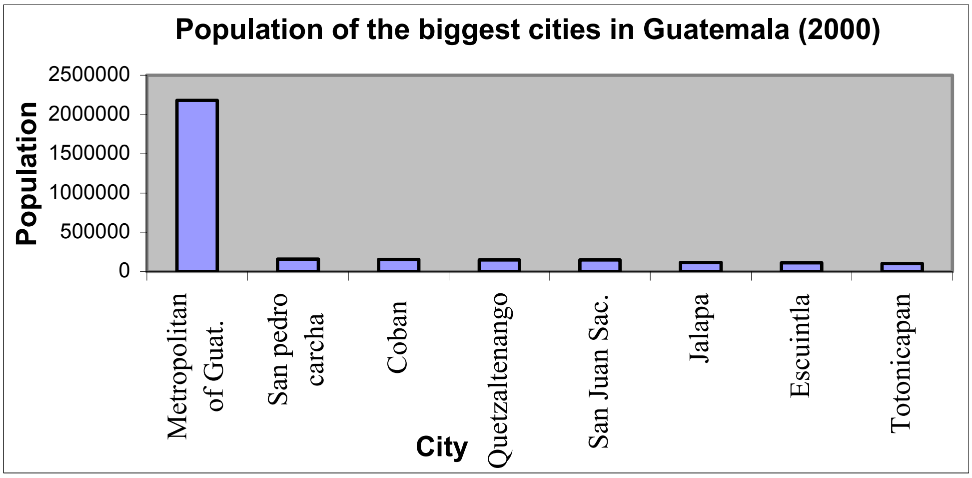


Figure 4. Population of the biggest cities in Guatemala according to INE (2002).

<u>*3.1.1.1 The primary sector of Guatemala*</u>

Guatemala always was and still is characterised by an agricultural economy. In ultimate years the growth of the sector decreased but is still the most important sector of the economy (25 % of GDP) and contributes for two-thirds to the export earnings (FAO, 2002). The primary sector is also the most important provision of work. In recent years the percentage of people working in the agriculture still increased in absolute terms but due to the population boom, it became less than 50 % of the total population (FAO, 2002). The agricultural production can be split up in three types: 1) subsistence (primarily maize, beans, and squash); 2) commercial (onions, potatoes, etc.); and 3) export. Export products can be divided in two: traditional (coffee, banana's, sugar, meat) and non-traditional (broccoli, green beans, strawberries, etc.).

Guatemala has a highly dualistic agricultural structure. An export oriented, large-scale farm sector (latifundios) and a traditional, more subsistence oriented, small-scale sector (minifundios) coexist. The minifundios (figure 5 A-C) consist mainly of indigenous people and have a familiar character. They cultivate their land intensively but with little technological innovations. The small farmers' production is confronted with a series of problems like the lack of efficient technologies and the difficulty to access the productive means of land and capital. When the agricultural production is not sufficient to fulfil the basic needs, farmers are forced to search other forms of income like work for big landowners or in the commercial sector. The latifundios (figure 5 D-E) is a typical big-scale farming with several employees. In most cases, the proprietor of these farms lives in the capital or abroad.

Almost two-thirds of the cultivatable land is in hands of only 2.3 % of the total amount of farms and 10 % of the land is owned by hardly 0.1 %. This polarisation of land ownership is known as the problem of 'lati minifundismo'. A good method to measure the degree of polarisation is the GINI coefficient. It is based on the Lorenz curve, a cumulative frequency curve that compares the distribution of a specific variable with the uniform distribution that represents equality. A diagonal line represents this equality distribution, and the greater the deviation of the Lorenz curve from this line, the greater the inequality. Values ranges from zero in a situation of perfect equality to 100 in a situation of maximum inequality. In 1979, the GINI coefficient was 85.1 for land-distribution in Guatemala. This was higher than for all other Latin American countries (Hough *et al*, 1982) and has not improved since then. In contrary, the big population growth even leads to a rapid reduction of the average small farm size. The extremely skewed land-ownership is largely an inheritance of the structural change introduced by the Spanish during the colonisation of the country (Nyron,1983).

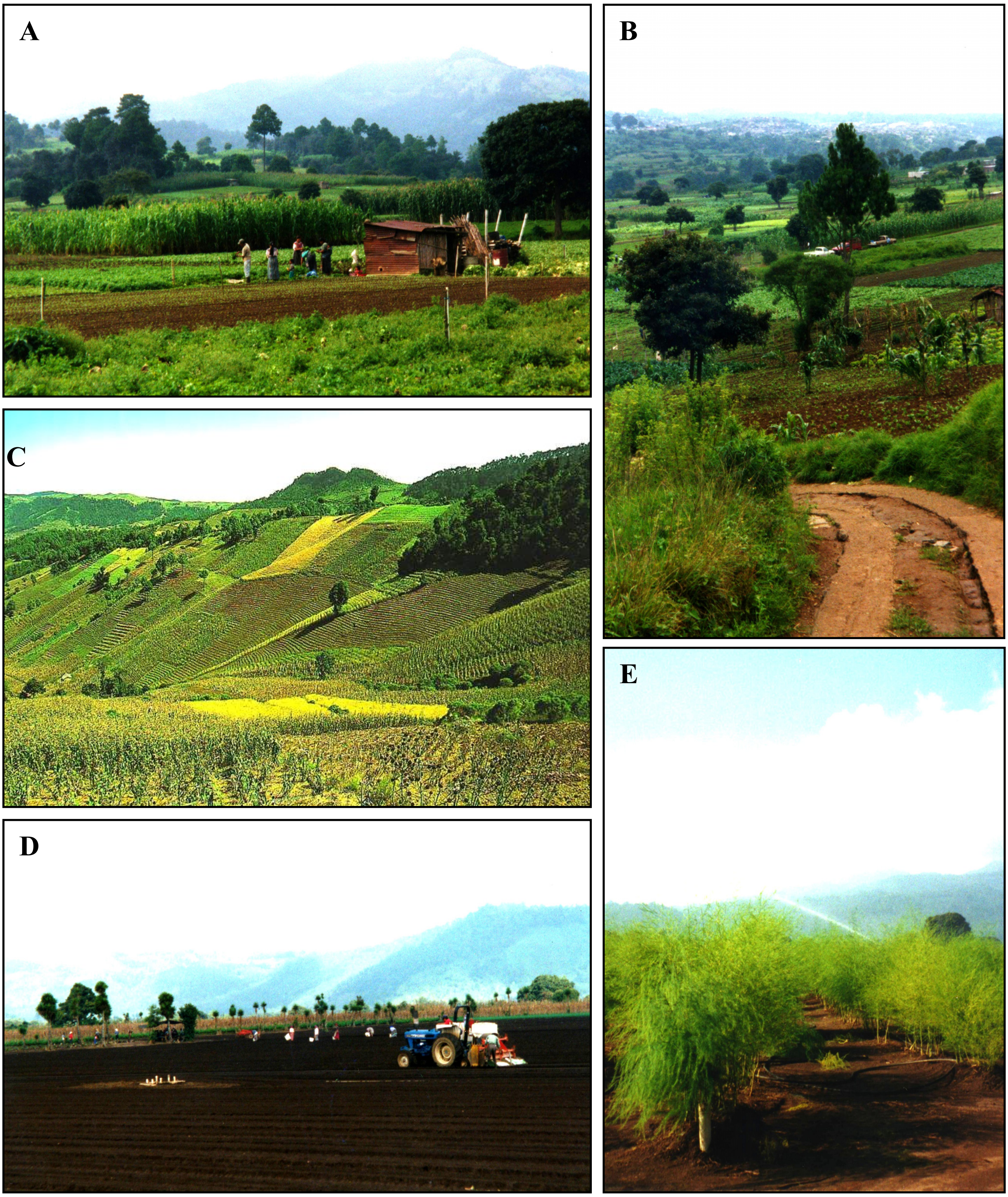


Figure 5. Contrast between small (A-C) and big (D-E) scale farming in the highlands of Guatemala.

3.1.1.2 The road network and transport in Guatemala

When the road network is considered, the 'centralistic' character of Guatemala becomes very clear. The major transport infrastructure is oriented towards the centre of the country. The major roads are the Pan American highway (leading from Mexico to El Salvador), the 'Interoceánica' (connecting the Pacific with the Atlantic coast) and the 'Costanera' (along the Pacific coast). The Guatemalan terminology splits the road network in three types. The first and second order roads are hardened. According to the DPE *et al*. (2001), 5139 km of these roads are found what results in a density of 0.048 km of hardened roads per km^2. This is only 1.41 % of the density of hardened roads in The Netherlands (CBS, 2002). A third type is defined as 'mostly only transmittable in the dry season' and counts 5890 km in Guatemala.

Not only the density and quality of the road network is shocking but also the amount of available motorised vehicles is very low. According to the INE (1994), only 8.3 % of the households have a car. In rural areas this number is even lower. In The Netherlands for example 97 % of the families have their own car (CBS, 2002).

3.1.1.3 The poverty problem in Guatemala

According to SEGEPLAN (2002), poverty is a situation in which the means to fulfil most basic necessities are lacking, generally material things but also social, cultural and even political. Poverty, as a consequence, must be associated with a limitation to comply a human development. Many more definitions and even more possibilities to measure poverty are found in literature. One of the most popular and easy obtainable poverty indicators is based on a poverty line. This line represents a minimum income to fulfil some basic needs. Another type of indicators is based on the measurement of the satisfaction of some necessities. Poverty can for example be measured as a lack of basic facilities as education, availability of water or access to sanitary services. Whatever the measurement type, the poverty figures of Guatemala are alarming.

Using the method based on the poverty line, six million of persons have an insufficient income to satisfy the minimum necessities of calories, as well as other non-food-related necessities like transport, education and health (SEGEPLAN, 2001). This is a little bit more than the half of the total population. According to the same study, 23 % of Guatemalan people even live in extreme poverty. Extreme poverty is defined here as 'not having enough means to only satisfy a minimum consumption of calories'. This high amount of people confronted with a deficiency of food is confirmed by data of the ME (2001) and the MPHSAS (2000). According to the former, 49 % of the students in primary school are chronically under-nourished while data of the latter reveal that almost two persons per 10000 die each year of under-nourishment. Also other measurement types of poverty reveal this dramatic situation. According to the Tenth Population Census / Fifth Housing Census (INE, 1994), still 12 % of Guatemalan people have no sufficient access to drinking water, 22 % lack a sanitary service and 23 % of the population lives in houses defined as bad. With a life expectation of 67.19 year (2000), Guatemalan people live considerably shorter than people in the western world do.

The situation even becomes worse when the population is separated in different groups. In the rural areas for example almost three times more poverty (75.3 % against 28.4 %) is found than when only urban areas are considered. For extreme poverty this is even more striking (40 % against 7 %). Also when indigenous people are compared with Ladinos the differences are huge. Almost three-quarters of indigenous people live in poverty, compared to 40 % for Ladinos. More than the double of indigenous people lives in extreme poverty compared with non-indigenous (40 % against 16 %). Another good method to measure such inequalities in a society is the GINI coefficient. Several variations exist but here the GINI coefficient that shows the concentration of income is used. The more the incomes are concentrated in the hands of a relative small group, the higher the number of persons in poverty. With a GINI coefficient of 0.58, Guatemala is one of the countries with the highest concentration of income in the world. More than sixty % of the total national incomes is earned by 20 % of people. In contrary, the 20 % of people with the lowest income represent only 2.1 % of the national income.

Inequality is however not only occurring between different social groups but is also visible on a spatial domain. The location of birth defines in a big amount the chance of being poor or rich. This can, for example, clearly be seen in appendix 1, as an increasing degree of poverty can be noted with increasing distance to the capital. A thorough analysis of the distribution of poverty and its spatial relation with some influencing factors can teach us a lot about this vital problem. Too often, nevertheless, measurement and discussion of poverty is still a one-dimensional matter. In this work more attention on the spatial dimension of poverty will be given.

Poverty is the result of many processes that are deeply rooted in the society for already some generations. The different factors that stimulate and maintain poverty can be split up in three groups according to SEGEPLAN (2002). The first one covers some economical obstacles like the lack of a sufficient income, the absence of sufficient work or limitations on the access to production factors. Social obstacles form the second group. A bad education or no access to good education, the lack of basic necessities like water and the absence of conditions for a human development can be assigned to this group. The last group is institutional of which a centralised structure of a country or inefficient administrations are examples.

Not only is poverty devastating on a human level, it also impedes a full economical development of a country. Why is the economical development in Guatemala so cumbersome, when all preconditions for industrialisation are there? Why can the capital earned from export not create a better environment for the economy? According to Smith (1976), the answer to these questions is that the capital flows to a few entrepreneurs rather than dispersed in the local system where local specialisation and industry are to develop. Due to the huge inequality of the capital and the huge gap between rich and poor, the local market for goods is restricted to an elite. As a consequence only the external-world market is left for investments. But due to the powerful economy of the developed countries competition is severe, forcing them to keep local wages low. This brings us however in a circular process as low wages and modest profits result in the restriction of the local market and force them even more to the international market. The only way to end this circular process is the development of a local market. This can however only be done by reducing considerably the dual society, which would give the ‘poor’ more financial purchasing- and investment-power. The government has to play an important role here and in the Peace Agreements of 29th of December 1996, it committed itself in 'improving the quality of live of all Guatemalan people and especially these who are in extreme poverty'. Nevertheless, since this agreement, poverty has not decreased considerably and skewness even increased.

Poverty is an attack on human dignity and is, in the beginning of the third millennium, a true anachronism. Besides its human dimension it is also a brake on national growth, the flourishment of the economy and the consolidation of the market. Without any doubt, poverty is the principal and most serious problem of the Guatemalan society (SEGEPLAN, 2002). The moment has come to do something about it.

3.1.2 The departments of Chimaltenango and Sacatepéquez

This research took place in the Guatemalan highlands, more in particularly in the departments of Chimaltenango and Sacatepéquez (figure 3). Smith (1990) considered this area as typical for the whole western highlands as it 'represents the fate of most Indian communities in western Guatemala'. Moreover, the most important crops of the highlands of Guatemala are represented in this study area and the values of accessibility show sufficient variations to do the analysis.

The study area contains zones with heights that vary between 300 m in the valley in the south and 3900 m in the highest peaks of the Sierra Madre. The relief is mountainous, with several volcanoes, hills, mountains, big planes and deep ravines. Several types of soils exist in the study area, however three are dominant. The largest soil types are the acrisols. These are soils with subsurface accumulation of low activity clays and low base saturation (Driessen *et al.*, 1991). They are typical tropical soils that are relative fertile when the surface layer is maintained and a sufficient amount of fertilisers is used. In the central zone of the study area, between the cities of Chimaltenango and Antigua, more nitisols are found. These soils are very deep and well drained. Nitisols are much sought after for smallholders' farm and plantation crops like coffee. The good tilth, easy workability and other physical attributes have contributed to the presence of sustainable low-input agriculture on these soils

(Deckers *et al*, 1998). The third dominant soil type, the andosol, is encountered especially in the northeastern part of the department of Sacatepéquez. This is a relative young soil developed in volcanic deposits. In general they are considered to be very fertile and can be used for a wide variety of crops (Deckers *et al*, 1998).

Rather big variations in temperature, radiation and rainfall occur in the area. The thermal regime is determined especially by the height above sea level but is also influenced by topography, aspect, slope and local winds. In general the valleys have a mean temperature of around 19 °C, while in the mountains temperature descends to 10 °C or lower in the highest regions (CATIE, 1984). Precipitations also vary considerably according to the region and can go up to 5000 mm in some areas. The mean relative humidity is 75 % (MAGA *et al*., 1999b).

Until 1775 the capital of Central America, was located in the present-day department of Sacatepéquez. First Ciudad Vieja had this honour but the city was destroyed in 1541 by an avalanche of water and mud from the volcano 'Agua'. Afterwards the City of Santiago de Guatemala (nowadays Antigua Guatemala) became the capital but again not for too long as it was destroyed several times by earthquakes and volcanic eruptions by the volcano 'Fuego'. After the independence in 1821, Guatemala was split up in seven departments of which Sacatepéquez-Chimaltenango was one. In 1839, nevertheless, this department was separated in the departments of Sacatepéquez and Chimaltenango as they are now.

Due to the relative easy market reach, the department of Chimaltenango was relative prosperous in the 1970's. The devastating earthquake of 1976 and especially the guerrilla war drastically changed these perspectives. Many farmers were murdered and at least 20 % of the population was displaced for some period of time (WOLA, 1988). Krueger and Enge (1985) reported that the economic situation in March 1985 was disastrous. Destroyed harvests, malnutrition and indebtedness were common. The government did very little to help them and the impact of the development efforts, initiated in 1986, were extremely uneven (Smith, 1990). Moreover, Smith (1990) also detected a clear relation between the economic situation of a community and the proximity of this community to good roads. In remote communities the wages were very low and especially women could not find any work. The result was that for the first time in local memory, the majority of the people sought work outside their areas (Smith, 1984b). In the communities well serviced by roads, there was plenty of work because of highly intensified vegetable production. Nevertheless, also in these more prosperous communities the economic situation of about half the population was nearly as desperate as that of almost everyone in the more remote communities. Over half of the land there was owned by less than 10 % of the owners and the number of completely land-less people was striking (more than 20 % in 1988). After the peace agreements in 1996, the situation in the study area became more stable but the vital problems like land distribution skewness, bad economy and poverty did not disappear.

The study area consisted of the departments of Chimaltenango and Sacatepéquez and was 2444 km^2. The department of Chimaltenango is with its 1979 square km and 449134 inhabitants in 2002 considerably bigger and more populated than the department of Sacatepéquez, which reaches 465 km^2 and harboured 276769 people (INE, 2002). The latter, nonetheless, was denser populated (595 compared to 227 people per km^2) and contained relative more 'Ladinos'. In Sacatepéquez, 41.6 % of the people in 1994 were indigenous, while in Chimaltenango (77.7 %) this was considerably more (INE, 1994). The first language of the indigenous people in the study area was Cakchiquel. Nevertheless most people also speak Spanish. The 'Ladino'-population spoke Spanish and lived especially in the urban centres like

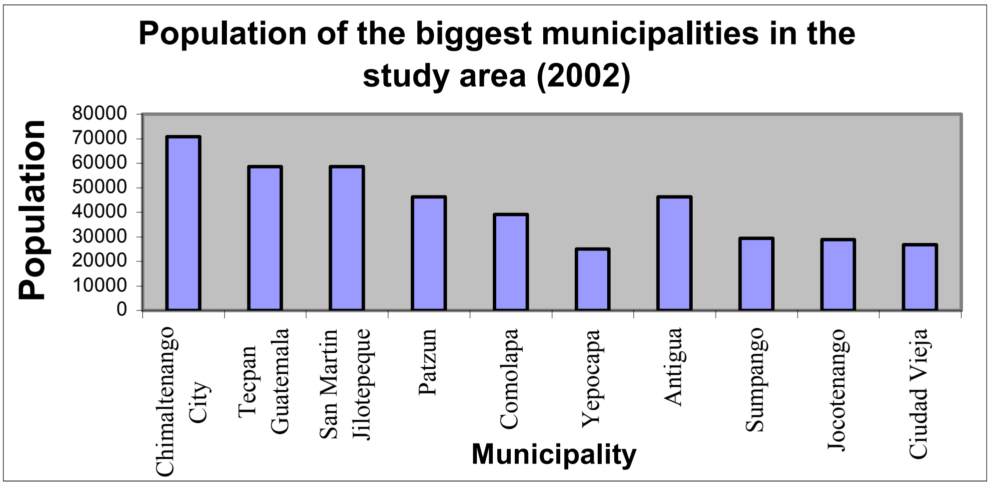


Figure 6. Population of the biggest municipalities in the study area (2002).

Antigua and Chimaltenango. These two cities were the most important in the study area as they harboured some political power and had relative big markets. In figure 6, the municipalities with the highest populations are represented.

3.1.2.1 Agriculture in the study area

During the late 80's, the commercial agriculture production in the study area expanded considerably. Smith (1990) reported that this was the case for all the communities but especially for those near roads (50 % compared to 15 %). The production of maize decreased. It was not profitable anymore to grow them due to the extreme high cost for fertilisers. The maize from the lowlands, where the conditions for maize production are far favourable, was available in the highland markets and the price was lower than the locally grown products (Horst, 1989). Virtually no one planted maize for sale but most households continued to produce some corn for subsistence (Smith, 1990). Horst (1989) argued that the commercialisation will only occur to the extent that the peasants perceives the potential monetary gain to outweigh the security and cultural good embodied in traditional customs and practices.

In the late 80's the department of Chimaltenango was more rather than less dependent on agriculture than in the past. Except for some storekeepers and truckers, almost all people worked in the agricultural sector. But the majority of the people worked for others rather than for their own profits. The variable success of the market and the need for high inputs made a lot of farmers go smash. Only the large farmers who could diversify their crop mix and who could afford the necessary amounts of fertilisers, insecticides and other capital goods, could maintain a profitable level of commercial farming (Smith, 1990).

Anno 2002, the economy of the departments of Chimaltenango and Sacatepéquez is still characterised by a dependence on the primary sector. The major crops in the study area are milpa crops, coffee, traditional vegetables, non-traditional vegetables, non-traditional soft fruits and highland fruits. The first and the last are especially small-scale crops, while the rest is cultivated by both small and big landowners. Also here the problem of 'lati minifundismo' is prevalent (figure 7) and together with some other factors like lack of capital it constrains the agricultural development of the area. There are however considerable agriculture possibilities for the area. CATIE (1984) classified both departments as ecological optimal areas where a diversity of agricultural productions is possible. Moreover, the study area does hold some strong trumps concerning the commercialisation of the agriculture. It is located close to the capital, especially compared to the major part of the other departments of the highlands. It is also relatively good provided by primary roads with good access to the principal points of consumption in the country.

Figure 7. Typical agricultural landscape in the study area. The big-scale agriculture is strongly contrasting with the small plots in the background.

In the western highlands of Guatemala, farmers have maintained the milpa agriculture (Horst, 1989). This is a very old and traditional agriculture system that is subsistence orientated. Notwithstanding that the production system can vary strongly with the physical and cultural settings, milpa can simply be defined as the cropping of maize (*Zea mays*) inter-cropped with other crops (see figure 8 A-B). Maize is the most important crop as it is the dietary staple in Guatemala. It comprises about 90 % of all starches in Guatemalan diets (Smith, 1972). Not only the huge amount of

Figure 8. Different crop types of the Guatemalan highlands. (A-B: milpa, C: coffee, D: vegetables and E: blackberry).

consumption of the grains make maize so important, also the leaves (for cattle feeding) and the stem (for fences and housing) are used intensively. Maize demands no high labour and technological inputs and is considered a very stable and secure crop. Although the test of time has proven this, there exist still some risk as a storm in September 2002 has shown (figure 8 B). A considerable amount of maize could not cope with the heavy winds and fell on the ground where the grains were destroyed by humidity and rats. In the study area maize is especially meant for self-sufficiency and as a consequence is seldom sold. Only when there is an over-production, a part is sold on local markets. According to Nations & Nigh (1980), the inter-cropped crops can go up to more than 80 different sorts. The most popular in the study area is black bean (*Phaseolus vulgaris*). It is the second most important crop in the diet of the indigenous people (CATIE, 1984) and is sown mostly in between the maize, one or two months after the maize. This way an optimal use of the land and of the water is guaranteed. A lot of studies have reported that the milpa agriculture in the highlands provides relative low rates of return of investments. In contradiction to the counsel of well-intentioned advisors, the Guatemalan farmers persist in their adherence to the traditional milpa. But what agricultural experts fail to recognise is that the milpa agriculture is so physically complex, so inextricably intertwined with cultural values, and practised on such a small scale that the maximisation of yield of maize is not the central goal for these farmers (Horst, 1989). The assurance of a yield, even if marginal, is of far greater importance. The production of at least some milpa for security reasons is common in the study area. Another factor of success of this millennium old system is the fact that it is capable of accommodating change. In recent decades, for example, the milpa system has evolved to accommodate the production of cash crops and the use of fertilisers, herbicides, pesticides and improved varieties of seed.

Coffee (figure 8 C) is traditionally the product with the highest economical importance in the study area, but is losing ‘terrain’ to the vegetables. The collapse and the constant fluctuations of the coffee prices are undoubtedly the main reasons for the abortion of coffee plantations. Moreover, only 16 % of the money the consumer pays for coffee (8 % for the workers on the field, 5 % for the land owner and 3 % for taxes) flows back to the country of production (Talbot, 1997). The reason for this is the almost direct transport of coffee after harvest to the western world where the main processes (burning and grinding) are executed. Nevertheless the difficulties with coffee, there are still big possibilities in this region as it produces one of the best coffees of the world (MAGA *et al.,* 1999b & IGN, 1983). Because coffee is very demanding concerning humidity and hours of light and very sensitive to frost, it is mostly associated with shadow plants (like Avocado, Gravilea and Macadameia Nuts). This is an important fact for remote sensing classifications as these plants cover at average 40 % of the soil. Coffee is mostly not found above 1800 meter. The cultivation is characterised by high labour inputs, especially in the months of harvest. After harvest a pre-processing process is necessary. This process involves the removal of the shell, fermentation and drying. This pre-processing can be cumbersome for some small-farmers, which force them to sell the un-pre-processed coffee to intermediaries, loosing this way another considerable part of the already low earnings.

Traditional vegetables (figure 8 D) include onion (*Allium cepa*), radish (*Raphanus sativus*), cabbage (*Brassica oleracea capitata*), carrots (*Daucus carote*), cauliflower (*Brassica oleracea botrytus*) and lettuce (*Lactuca sativa*). It are typical cash crops that are sold in the big markets of Guatemala and neighbouring countries as El Salvador and Honduras. Few rural peasants eat many of these products themselves. As the harvest is perishable, a quick transport is important. Vegetables demand a high labour and technology input. The use of fertilisers, pesticides and fungicides is necessary. These crops are especially popular in areas where irrigation is available. Irrigation permits harvest up to four times a year with the dry season even the most beneficial.

In the mid-1970's new export crops like 'arveja china' (*Apium graveolens*), 'arveja dulce' (*Pisum sativum*), broccoli (*Brassica oleracea*), 'ejote francés' (*Phaseolus vulgaris spp.*) were introduced in the highlands of Guatemala with substantial foreign investment. These non-traditional vegetables seemed to be promising because of their high labour intensity and expanding demand in industrialised countries. Although the success is a little bit over its top, it is still popular in the study area. Not only big landowners can profit but also small farmers are involved as co-operatives promote the vegetables by providing access to credit and technical assistance. Nevertheless, when no (or bad functioning) co-operatives exist in an area, small farmers will hardly cultivate these crops. Just as traditional vegetables, it is very labour and technology demanding. For reasons of perishability, transport has to be quick. A lot of times a pre-processing and packing process is executed before export of the product to especially North America and Europe (Agexpront, 2002).

The non-traditional soft fruits (see figure 8 E) include strawberry (*Fragaria spp*.) and blackberry (*Rubus spp*.) and are exported to predominantly the United States of America (MAGA *et al.*, 1999b). When the strawberries are too small at harvest, they are sold in the capital. The characteristics and demands are more or less the same as these discussed for non-traditional vegetables. Especially the speed of transport to the airport is crucial. The berries are especially popular around Zaragoza.

Traditional highland fruits, like apples (*Malus spp*.) and peaches (*Prunus persica L*.), are produced exclusively for internal markets, like Guatemala City. They are especially cultivated for cash, but the peasant producer is seldom a full-time specialist. Inter-cropping with other crops like maize and vegetables is common. The basic problem of these fast perishable types of fruits lies in poor transport facilities and the low level of demand (Smith, 1972). The major quantity is found in the municipality of San Bartolomé. Also the municipalities of San Lucas, Santiago and Antigua contribute considerably to the importance of this type of fruits (MAGA *et al.*, 1999a).

3.1.2.2 The road network in the study area

The major road in the study area is the Pan American highway, which connects some municipals like Santiago Sacatepéquez, Tecpán, Patzún and Tejar with the city of Chimaltenango and more importantly with Guatemala City. It has an average daily traffic of over 5000 vehicles (MAGA *et al.*, 1999b). Two other major roads connect the city of Antigua with the Pan American highway. One of them intersects in Chimaltenango City while the other one 'meets' the Pan American highway in San Lucas Sacatepéquez.

According to the DPE *et al*. (2001), 282 km of hardened roads are found in the departments of Chimaltenango and Sacatepéquez, what results in a density of 0.115

km of hardened roads per km^2. As the study area was situated quite close to the capital it is higher than for the whole country but still remarkably low.

3.1.2.3 Poverty in the study area

Although poverty is slightly lower in the study area than the values presented for the whole country, it is still a major problem. According to SEGEPLAN (2001), 33.45 % and 57.92 % of the population of respectively Sacatepéquez and Chimaltenango live in poverty and 4.62 % and 13.46 % in extreme poverty. In Chimaltenango, 4.93 out of 10000 persons die every year due to under-nourishment (MSPAS, 2000) and more than 60 % of the students in primary school are chronic under-nourished (ME, 2001). In Sacatepéquez these values are respectively 1.62 per 10000 and 45 %. According to the Tenth Population Census / Fifth Housing Census (INE 1994), still 9 % of Chimaltenango`s people have no sufficient access to drinking water, 23 % lack a sanitary service and 30 % of the population lives in houses defined as bad. For Sacatepéquez these values are respectively 6 %, 26 % and 31 %.

3.2 Accessibility and its relation with crop choice and poverty

Accessibility is an intuitive concept that can be defined in many ways. Deichmann (1997) sees accessibility as the ability for interaction or contact with sites of economic or social opportunity. Nelson (2000) refers to accessibility as the time to reach a desired location and Goodall (1987) as the ease in which a location may be reached from other locations. Whatever the definition, access is a precondition for the satisfaction of almost any need and certainly for all physical needs (Nelson, 2000).

Figure 9. Rural landscape in the municipality of San Martin Jilotepeque.

The target locations and the available infrastructure are the central pillars to determine accessibility. But there is a lot more to consider. Accessibility is also influenced by social and economic factors. Lack of knowledge and information about transportation facilities and the existence of the target locations (like markets) can contribute considerably to the degree of remoteness. Also the high monetary cost of transport means can result in the economic impediment of the use of existent infrastructure facilities. It is also important to mention that rural accessibility is more than just roads. In some ‘developing’ regions the farmers’ world is still largely a walking world (Barwell, 1996).

From an economic point of view, accessibility can be seen as the costs of overcoming friction of space. Less accessible areas have to operate under the economic disadvantage of having to overcome costs (like transport of their agricultural goods) that are higher than other places, which are less remote. This disadvantage can be considerable and can have a huge impact on poverty and crop choice, especially in inhospitable areas in less ‘developed’ countries.

As can be seen in figure 10, accessibility, crop choice and poverty can interfere with each other in many ways. In this work only three of these relations (the full lines in figure 10) are investigated. In the remaining part of this chapter these three relations are discussed shortly.

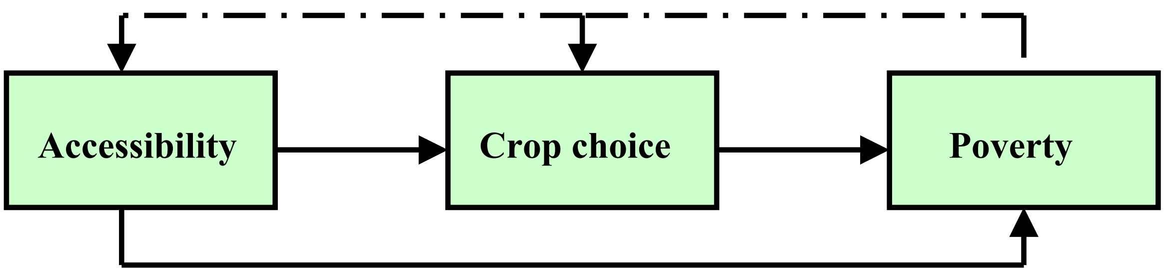


Figure 10. Simple conceptual model.

3.2.1 The spatial distribution of poverty and its relation with accessibility

Development economists usually ignore spatial variability and are more concerned with general production inputs and outputs. The development problem, however, should be approached in a spatial way. The accumulation of export earnings, as mentioned in 3.1.1.3, occurs in little hands all living in a core area. This leads to an extreme centralisation of the country with some urban centres enriching at the expense of the remote hinterland. In the case of Guatemala, especially the capital plays the role as all-dominating centre. Smith, (1976), argues that "if development efforts are aimed at alleviating poverty and the gap between the industrialised and the underdeveloped worlds, it will not be realised without attention to the regional development process". Guatemala should get rid of its centralised functioning if it ever wants to develop sustainable. Internal diversification and growth in the poor rural regions by taking away at least the constraints that prevent them to develop a financial purchasing and investment-power, should result in possibilities for the local economy and as a consequence for the whole development of the country. Fighting this inequality and the spatial distribution of poverty are therefore of the utmost importance. The spatial distribution of poverty, nonetheless, became with the years an inherent characteristic of the country. This phenomenon is penetrated throughout all parts of society, notable in the tiniest things. So does the same newspaper cost considerably more in the periphery region than in the metropolis. It may then also be no surprise that fighting the spatial distribution of inequality is cumbersome. Accessibility plays without any doubt a central role in its occurrence and maintenance. Ravallion (1996) even speaks of accessibility as a "spatial poverty trap" that may prevent the poor from breaking out of local level constraints. Accessibility is not only a cause of poverty; it is also a result of poverty (figure 10) as the poor lack the financial and political power to improve the infrastructure themselves. Being poor implies dependence of the willingness of others. It does not suffice for governments and the 'rich part of the society' to stop living on the expense of the poor hinterland to reduce equality. They should also make work of the reduction of spatial constraints like accessibility that impede the poor of breaking out of their poverty trap. In this perspective, a thorough understanding of accessibility and its relation with the spatial distribution of poverty is vital. Watanabe (1981) and Smith (1984a) mentioned already its importance in the Guatemalan highlands. However, a formal detailed study that links the spatial distribution of poverty with accessibility in a contextual manner has never been performed.

3.2.2 The influence of accessibility on crop choice

'Accessibility is arguably the single most important eco-regional factor driving land use change, and development in general. It is surprising, therefore that the relation between crop choice and accessibility has long been seen as a side effect rather than a central issue in the different scientific branches' (Leclerc, 2001). Underestimating or even neglecting the spatial impact of remoteness is of daily occurrence. Nelson, (1984), Deaton & Webber (1988), Deaton & Nelson (1992) and Hite (1999) mentioned in this perspective 'a lack of concern with space by the economists'. Other researchers in other scientific branches have mentioned the effect (Smith, 1975; 1990) but never sketched the full impact of accessibility on the crops farmers can build.

In the conceptual model as represented in figure 10, the occurrence of infrastructure is considered independent of the crop choice. In reality, this is not always the case. Crop choice can have an influence on infrastructure as certain markets, intermediate trading places and even better roads can arise due to the boom of some crops. A nice example is for example the introduction of some export crops like coffee and banana, which resulted in better roads between the crop regions and some ports. Nevertheless, this influence can also be seen indirectly as crop choice has an influence on the financial power of the landowner and as a consequence on a whole community. If the impact of the crop is positive, the area will become more 'powerful'. As a result it will have more to say in the decisions for new or better road constructions. This indirect influence seems more reasonable and that is why the direct influence of crop choice on infrastructure is not considered in the conceptual model and in the rest of this work.

It may be clear that the choice of the crops is not only determined by the available infrastructure. Also other factors like ecological environment, knowledge of the different crops, tradition, available ‘area’, irrigation, available manpower, market conditions and price will have their influence on which crops will be grown. Though these other factors are not the central issue of this thesis, they are investigated shortly to get an understanding of the degree in which access influences crop choice.

The first thorough description of the correlation between agricultural land-use and ‘accessibility’ was given by Johan Heinrich von Thünen (1783-1850). This farmer-amateur economist gave the most basic analytic model of the interplay between markets, crop production and geography. The von Thünen model is highly ‘reductionistic’. It assumes:

- an isotropic, totally flat plain with no interruptions like rivers and no roads;
- consistent environmental conditions, like soil and climate, over the whole area;
- there is only one market, located centrally, within the ‘isolated state’ which is self sufficient and has no external influences;
- farmers bring there goods themselves to the market;
- farmers act to maximise their profits/rents.

von Thünen described each crop by a rent function (see the green, pink and brown lines in figure 11):

$$\boxed{R = Y(p - c - f.m)}$$

with R = rent (per unit of land);
Y = yield (per unit of land);
p = price that the farmer receives at the market per unit of product;
c = (average) production cost per unit of product;
f = freight rate (per distance and product unit);
m = distance from the market.

This means that Y.p is the total revenues at the market (per unit of land), Y.c the production cost (per unit of land) and Y.f.m the total transport cost (per unit of land). In von Thünens' model the Y, p, c and f for a certain crop are considered constant in the whole area under consideration. With increasing distance from the market (m), R is diminishing linearly. The slope of this rent function is dependent on the freight rate (f). Crops that are very difficult to transport will have a high freight rate and thus a hard sloping rent function. When several crops ‘compete’ with each other, a series of land-use rings around the centre appear (see figure 11). At a certain distance from the market, the crop is grown that has the highest rent in that place. Close to the market, products are preferred that are costly to transport but with a high market price. Further away, products with a lower market price but with also lower transport cost will become more profitable. A transition from crop A to crop B occurs where $R_{crop\ A} = R_{crop\ B}$.

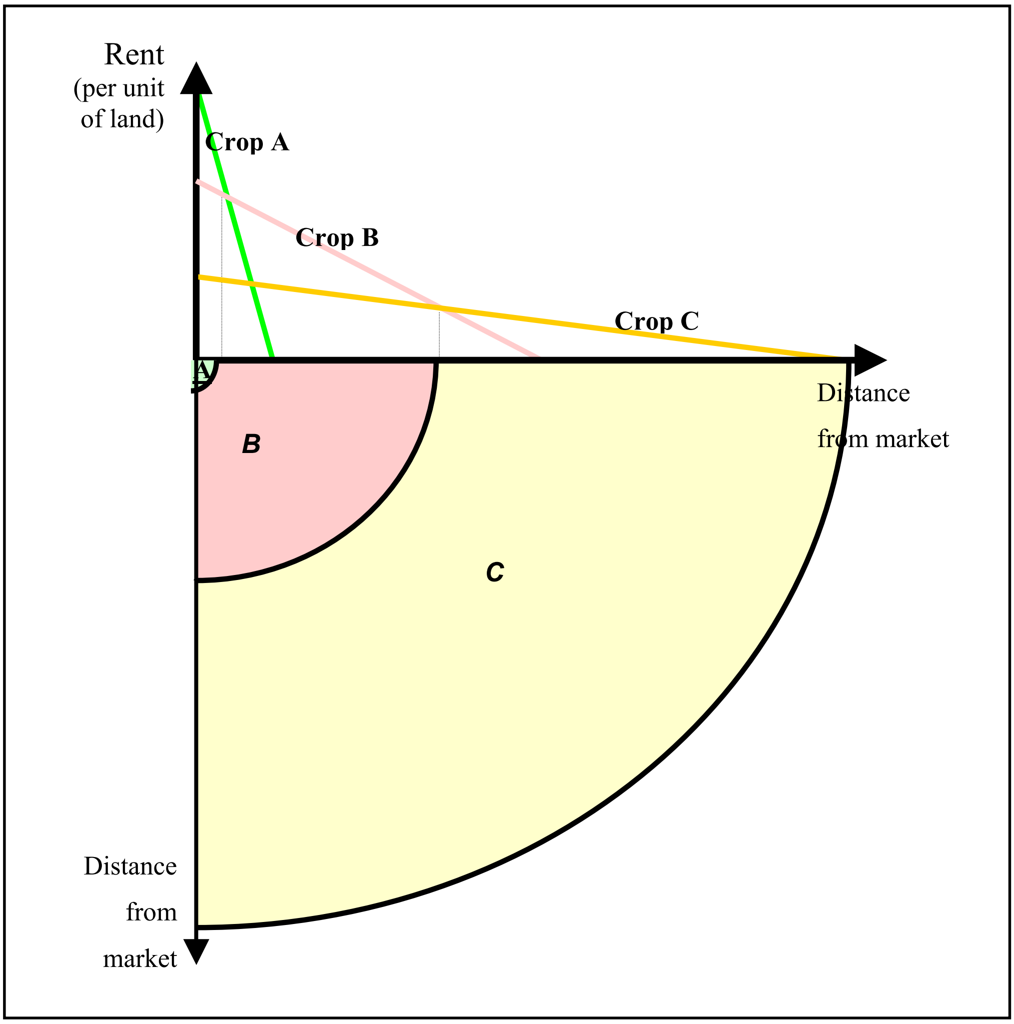


Figure 11. The economic and spatial dimension of the von Thünen model.

‘Remote’ places in the von Thünen plain are considered more specialised (only specific agriculture), low-densely populated, relatively poor and conservative, as they are relatively slow to adjust to changing market signals. Only if the place is so remote that it is beyond the influence of the commercial market, exceptions can be expected. Less specialisation in order to meet the needs of subsistence existence is a must in these areas.

Of course a lot of critic can be given at the high ‘reductionistic’ model of von Thünen. The real world is much more complicated than the simple world of the isolated plain postulated by von Thünen. Notwithstanding, the model is still very valuable. It provides an overall framework for this research and helps in isolating essential relationships and generalise about the fundamental nature of rural economies (Hite, 1999). In literature many variations, updates and improvements of the von Thünen model are found. For this work, however, the original model suffices. In the following paragraphs some limitations will be discussed.

The static character of the model is seriously abrupted by changing market situations. Also, the costs of overcoming the distance are not forever fixed and are radically altered by innovations in transport. This will result in constant shifts through time of the degree of remoteness and as a consequence a risky economic environment for the farmer who has to choose a certain crop. This is especially true when drastic changes in the market conditions occur (due to e.g. civil war or big international market shiftings) or when disasters (like earthquakes, hurricanes) destroy the infrastructure. Especially remote areas will recover more slowly from these negative shifts. ‘The short run is longer in remote places than in less remote areas’ (Hite, 1999).

The assumption of the von Thünen model that farmers act to maximise their profits can be questioned in the highlands of Guatemala. Tradition and security are two points that can direct the farmer in cultivating a crop that is not maximising its profit. The milpa agriculture, as explained in 3.1.2.1 illustrates this remark. The land value of milpa cannot be factored simply as a cost of production (Horst, 1989). Most farmers will cultivate at least a minimum of subsistence crops for own consumption even if this is not the profitable choice (Smith, 1990). Consequently, subsistence crops should be approached differently as will be explained in the next chapter.

Another important aspect to consider is the 'responsibility' of transport. For a long time the farmers themselves were responsible for the transport to the market (Smith, 1975). Nowadays, this is not always the case anymore. Sometimes co-operatives or export companies perform a part of the transport to the market. The price the co-operative gives for the product instead of the market price and the cost of the transport only until the gathering place should then be considered in the Von Thünen model. In this work information about 'responsibility of transport' will be gathered by interviews. This is outlined in more detail in the materials and methods.

With GIS the 'reductionistic' assumption, 'an isotropic, totally flat plain with no interruptions like roads', can easily be excluded from the list of assumptions of von Thünens' model. GIS software is ideal to include for example topographical and infrastructural variations and to calculate the cheapest or fastest route to the 'closest' market. This means that the freight factor (f) is no longer constant throughout the whole area and varies according to factors like passability. In the same way GIS could be useful in working with place specific values for yield (y) and maybe also production cost per unit of product (c). This would result in a more accurate and place specific use of the model. Nevertheless its use, this falls out of the scope of this thesis. Defining yields and productions cost for every crop for the whole area would lead us to far. Moreover, it would be almost impossible to obtain this data because high qualitative core datasets for the study area are lacking.

Maybe the biggest problem of the von Thünen model is its one-centre perspective. Translation into the geography of many urban places of different sizes and functions is crucial to derive the impact of accessibility on crop choice in bigger areas. In reality, this translation comes down to the assignment of lines, which divides the area in different parts according to the used market. These lines represent the locations where the extra cost of transport for a market less accessible compared to a 'closer' market is equalised by advantages like better and less variable price and more change to sell the product. The central-place theory can be useful here as it explains patterns of urbanisation and establishment of market areas for different goods and services. It offers insight into the reasons of presence or absence of specific goods and services in a particular community. Carol Smith (1975) stated that in the seventies the central place theory was very 'visible' and useful in the western highlands. In appendix 3 this and also the general concepts of the central-place theory are outlined in more detail. Due to the improved transportation facilities which make direct trade with the desired market possible and the relative proximity of the study area to the dominant capital, this is however not the case anymore for the departments of Sacatepéquez and Chimaltenango. That is why the delineation of the different market influences will be based solely on interviews in this work (see chapter 4).

3.2.3 The relation between crop choice and poverty

Although hardly any literature is available about the relation between crop choice and poverty, it may be clear that these two factors are intertwined strongly. Moreover, their relation is bi-directional as, at the same time, limitation in crop choice (e.g. only maize) can result in lower income, and poverty can limit considerably the cultivation of certain crops. Some crops can be prohibitive because necessary inputs like seeds, fertilisers and pesticides are to expensive or because the financial conditions to install irrigation and to procure a transportation mean or even bus ticket for necessary fast transport are too limited.

4) Material and methods

The relation between accessibility and crop choice was investigated by spatially overlaying and comparing the accessibility maps of the different crops with the location of these crops. The same procedure was followed to study the relations between poverty and accessibility on the one hand and crop choice and poverty on the other hand. The analysis was performed at two different 'levels' of detail (figure 12). First two smaller case study areas were investigated intensively. Later the obtained information was used to scale up to a more regional level being the departments of Chimaltenango and Sacatepéquez.

The choice of these case study areas was based on their representativeness of the whole area. Both of them harboured locations with considerable differences in access and all the important types of crops (like subsistence crops, traditional export products or non traditional export crops) were cultivated. A more thorough description of the case study areas and the reason for their choice will be given in chapter 5.

As Guatemala is a data poor country and this topic demands a lot of high qualitative input data, a lot of attention and work was spent on data collection. In table 1, a summary of the different data and their collection procedure on the two different 'levels' of detail is given. An overview of the methodology is shown in figure 13. As already mentioned, this thesis focuses on three central themes: crop choice, access and poverty. The procedure to obtain crop choice data is outlined in 4.2. Information about the reasons for this choice was gathered by means of interviews. Interviews were taken during a two months fieldwork period. The interview strategy to obtain this crop choice and other crucial information is explained in 4.1. For the creation of good accessibility maps, data about roads and their quality, the functioning of transport, the market situation and also height data were needed. The gathering of these data and the final model to make the different accessibility maps is explained in 4.3. The poverty data are discussed in 4.4. The approach to compare access, crop choice and poverty with each other is given in the last part of this chapter.

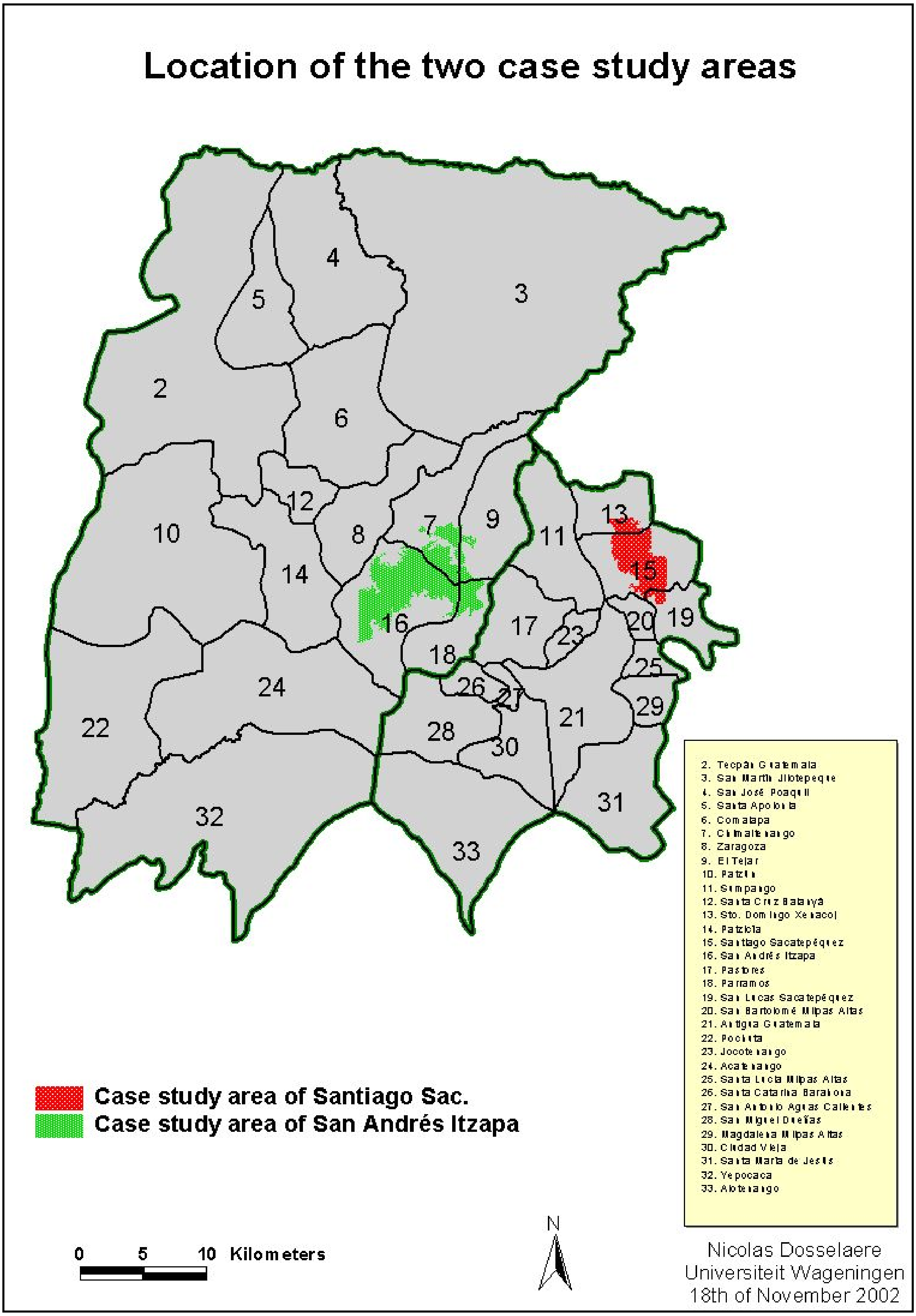


Figure 12. Location of the two case study areas in the departments of Chimaltenango and Sacatepéquez.

Table 1. Data collection method.

Data	**Origin and collection method for:**	
	case study areas	**whole study area**
Road data	Fieldwork (mapping out + interviews)	from MAGA data
Land use data	Fieldwork (mapping out + interviews)	RS images + fieldwork (GPS)
Crop choice data	Interview + literature	Interview + literature
Data about market situation	Interview + literature	Interview + literature
Data about transportation functioning	Interview + literature	Interview + literature
Poverty data	from SEGEPLAN	from SEGEPLAN
Height data (DEM)	from USGS	from USGS
General & related data	from MAGA data	from MAGA data
	from INE	from INE
	from municipality	Interviews
	Interviews	

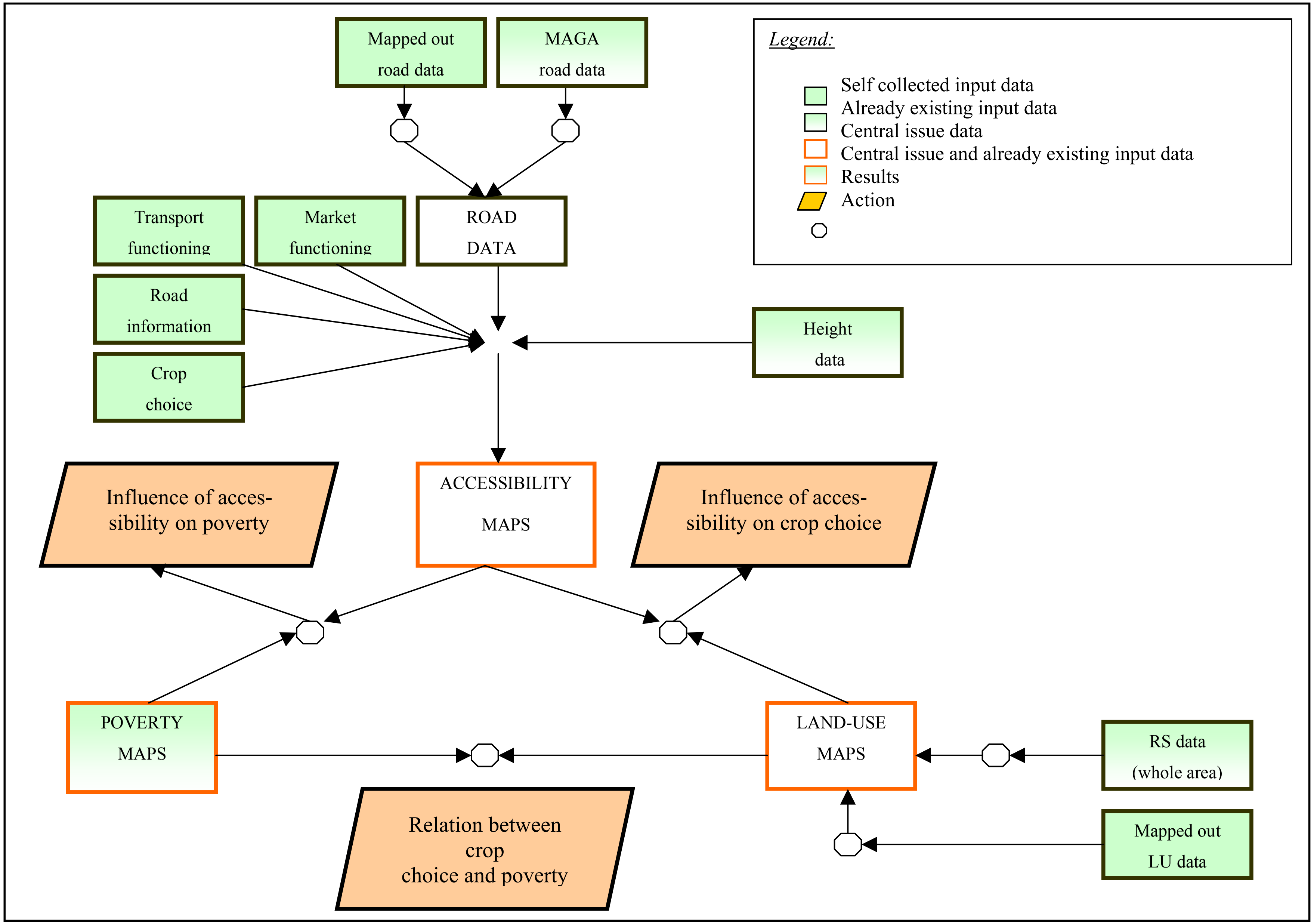


Figure 13. Methodology scheme.

4.1 Interviews

Interviews were performed to get a general understanding of the area and the topic and to find out the importance and the effect of accessibility on crop choice and poverty in the highlands of Guatemala. Depending on the situation, on the interviewed person and on the previous obtained information, different kind of questions about access, roads, transport, crop choice and functioning of the market system were asked.

The biggest group of interviewed persons were farmers. Nevertheless also other people related to the topic (like responsibles of agricultural co-operatives, the local municipalities and transport companies) were heard. In a period of 6 weeks in the third quarter of 2002, 211 interviews were performed in the highlands of western Guatemala. The majority of these interviews were taken in two small case study areas (San Andrés Itzapa and Santiago Sacatepéquez). The locations of the other interviews were scattered over the rest of the departments of Chimaltenango and Sacatepéquez. For this research a combination of a formal and informal interview approach was used. This means that a number of fixed open questions were woven into a more informal conversation about the topic. With this approach a more friendly atmosphere was intended and as a consequence a more reliable answering of the sometimes suspicious farmer. Moreover, it allowed seeing the problem from the farmer's perspective and diminishes the risk of overlooking some important factors.

Topics and frequently asked questions are listed below:

- *Questions about crop choice and reasons for it*:

  1) about the plot of the farmer itself (what, why, agriculture practices, …?);
  2) about neighbouring farmers (why does the farmer likes this and the neighbour that, …?).

- *Questions about marketing and transportation functioning*:

  * where is the product sold and why there? (price, personal relationships, reliability, language, culture, tradition, contract, …?);
  * how and who does the transport and how long does it take?
  * mode of payment/ contract?
  * is maize also sold and if yes where and in which amount?

- *Socio-economic questions about:*
  * price of the land;
  * land property;
  * the used inputs (fertilisers, pesticides, water, labour);
  * yields and earnings and variations of it in time (risks);
  * other income sources.

To get a thorough understanding of the market situation, not only interviews with the farmers on the field (perspective farmer to market) were performed. The market places (figure 14) themselves were also taken in consideration to check the sphere of influence of the most important markets. Guatemala City, Chimaltenango, Antigua Guatemala and Sololá (respectively the capital of Guatemala and the 'capitals' of the departments of Chimaltenango, Sacatepéquez and Sololá) were for this reason interviewed intensively. These interviews were shorter than the ones explained above as they only dealt with the market functioning, transport and the distribution of the agricultural products.

Typical questions on the marketplaces were the following:

From which village do your products come from?
How are they transported and who does it?
How regularly do you sell in this market?
Do you always come here?
Why is it sold here and not in other market?

Figure 14. A typical market in the Guatemalan highlands.

At last it also should be noted that during the interviews also questions were asked that could be helpful for the remote sensing classification (like agricultural practices and sowing and harvesting date).

4.2 Land-use data

The strategy to collect land-use data differed considerably between the two different ‘levels’ of detail. A complete mapping out of the area was performed for the detailed case studies. The used procedure is outlined in 4.2.1. In the big area, in contrary, a typical remote sensing classification was executed (see 4.2.2).

4.2.1 Land-use data for the case study areas

Natural vegetation, urban settlements and the different crops were assigned to different land-use classes. Although analysis of any of these crops separately would give more exact and specific information, it would distort the general picture and lead us too far. Class separation happened on the basis of their function in the accessibility problem. This function was already explained in general in 3.1.2 and will be discussed more in detail in chapter 5. Distinction between milpa, vegetables, coffee, cold weather fruits and some non-traditional export soft fruits (strawberry and blackberry) was made. Due to inter-cropping and the existence of very small parcels, mixture of some of these classes was possible. This resulted in 'mixed'-classes like e.g. the class milpa (75%)/vegetables (25%), which covered an area of 95-65% milpa and 5-35% vegetables. For practical reasons no distinction was made between the different kinds of vegetables (even not between non-traditional and traditional) in this thesis. The similarity of the different vegetables and their agricultural practices complicated their distinction by remote sensing techniques and even during the fieldwork. Also the inter-cropping of the different vegetables made the spatial 'encircling' of the different vegetables almost impossible. Although the effect of specialisation of some crops in certain areas affects the analysis, the differences between the different vegetables concerning its function in the accessibility problem were rather small. More important in this perspective, was the difference between vegetables cultivated by big farmers and these of small farmers. That is why the distinction between small scale and big-scale vegetables was made.

The case study areas of San Andrés Itzapa and Santiago Sacatepéquez were mapped out completely. A thorough description of this mapping out procedure and the transformation of the resulting 'papers' into a correct two-dimensional projection are given in appendix 4. Notwithstanding some possible human errors and decreasing precision due to the scanning process and the transformations, the accuracy and precision of the resulting land-use and road data were expected to be quite high.

4.2.2 Land-use data for the departments of Chimaltenango and Sacatepéquez

To obtain the land-use map for the whole study area, remote sensing images (ASTER and LANDSAT-7) were classified. As the creation of the land-use data was not the main goal of this work, a rather quick and objective-oriented land-use classification was executed. Information about the used images is shown in table 2. For extra information, see ASTER (2002) and NASA (2002). The different remote sensing operations were performed in ERDAS imagine 8.5.

Table 2. Some characteristics of the remote sensing images used in this work.

	Wet season image(s)	Dry season image
Remote sensing image source	ASTER	LANDSAT-7 ETM+
Spatial resolution	15 m	30 m
Number of bands used	3	6
Spectral sensitivity of the bands (µm)	1: 0.52 – 0.60	1: 0.45 - 0.52
	2: 0.63 – 0.69	2: 0.52 - 0.60
	3: 0.76 – 0.86	3: 0.63 - 0.69
		4: 0.76 - 0.90
		5: 1.55 - 1.75
		7: 2.08 - 2.35
# of images needed to cover the study area	2	1
Date of the image(s)	21st of June 2002	13th of February 2002
Cloud coverage	45%	0%

As some crop types were not cultivated in the dry season, the wet season data were crucial. Nevertheless, in that period of the year cloudiness is inevitable, making the search for good remote sensing images cumbersome. Adding some other restrictions as limited financial means and general low satellite coverage of this area of the world, the two obtained wet season images had some drawbacks. Besides the huge cloud coverage, a small part in the west of the study area was not covered. Moreover, the images were not taken during the field period but considerably earlier in the growing season. As ASTER returns limited spectral information (only three bands) and the spectral signatures of some land-use types differ more in the dry season, a LANDSAT image was 'joined' with the wet season image.

4.2.2.1 Pre-processing

The two ASTER images were obtained from the Earth Observing System Data Gateway. The 'universidad del valle de Guatemala' provided the LANDSAT image. As the three images were already geometrically and radiometrically corrected, the pre-processing process started with a re-projection. The quality of the resulting projections was checked through GPS measurements of characteristic places like intersections of rivers and big roads. They proved to be satisfactory for the LANDSAT image, while for the ASTER images there was a constant difference between the image and control points. This shift was corrected in ERDAS imagine. In a next step, the two ASTER images were 'mosaicked' to one image, covering almost the complete study area. Due to the quality of the DEM and some other reasons (see appendix 5), a topographic normalisation to correct the topographic effect could not be executed. In a last step the spatial resolution of the LANDSAT image was halved and the dry and wet season images were stacked together. This resulted in only one image covering almost the whole study area with nine bands and a spatial resolution of 15 m. A more detailed explanation of the importing and pre-processing process is outlined in appendix 5.

4.2.2.2 The land-use classification

A supervised classification using the Gaussian Maximum Likelihood Classifier was performed on the stacked image (4.2.2.1). The two completely mapped out areas and a randomly chosen non-clouded part of the complete sample point set (72 out of 234) were taken for the identification of a representative training set. A considerable amount of the ground truth data was taken in the two case study areas. The locations of the other points were scattered over the rest of the study area. In appendix 4, more information about the GPS measurements is given. In total 12 different land-use types were sampled. Nevertheless, not all types were sampled in the same amount. Moreover, due to the big cloud coverage, the amount of useful sample points was reduced considerably, for some classes even in such a way that they were not represented sufficiently anymore.

The classification was executed on a trial and error basis. Based on the accuracy and the importance of the different classes for this work, different classifications were performed. Less important land-use types, disturbing considerably the accuracy of the most important classes, were for example left out. The resulting land-use map had, besides the cloud and shadow classes, only five land-use types (urban areas, natural vegetation, milpa, vegetables and coffee). The three latter were far-out the most cultivated crop types in the study area and are crucial in the accessibility and poverty discussion. It may be clear that no distinction between big and small-scale agriculture could be made for these crop classes. As the fields in the study area were very small with fuzzy boundaries, no past-classification smoothing was executed.

4.2.2.3 Classification accuracy assessment

There were several region-bounded factors that made this land-use classification particular difficult. The first and undoubted the most devastating factor was the huge cloud occurrence. For the resulting land-use map, only 52 % of the study area was classified. The consequences of this low coverage for this work will be given in 4.5. Besides the small size and irregular delineation of the fields, differences in agricultural practices made the classification cumbersome. For example the 'topping' of the maize in order to dry (see figure 15) was common in some regions. Nonetheless, the date in which that was done could vary considerably (from more than one month to only one week before harvest), while others left the plant as it was. Also intercropping can alter the spectral signatures of a pixel. Due to the extensiveness and the variable environmental conditions in the study area, the growing seasons could differ considerably, meaning that at the moment a crop in one area was covering already the complete soil, the same crop in another area only started to sprout.

Figure 15. The agricultural practice of partly 'cutting' the top of the maize plant.

In the classification error matrix an indication of the accuracy is given (table 3). While the reference data, a subset (121) of the complete sample point set, are represented in the rows, the columns give the classified results. In table 4, the remaining 21 samples are used to give an indication of the classification of the other not considered land-use types.

Table 3. The confusion matrix for the land-use map of the study area.

	Big-scale veg.	Small-scale veg.	Milpa	Coffee	Nature	Urban areas	Clouds/shades	*Row total*
Vegetables	10	5				1		16
Milpa		3	18					21
Coffee				9	1			10
Nature		1	2	6	6	1		16
Urban areas						11	1	12
Clouds/shades			1	1		4	40	46
Column total	10	9	21	16	7	17	41	121

	Producer's occuracy (%)	User's accuracy (%)	Weighted user's accuracy (%)
Big-scale veg.	100	-	-
Small-scale veg.	56	-	-
Overall veg.	79	94	96
Milpa	95	86	94
Coffee	60	90	83
Nature	86	40	59
Urban areas	65	92	32
Clouds/shades	98	87	98

	Overall accuracy (%)	Weighted overall accuracy (%)
Whole map	83	75
Only land-use area	76	66

Table 4. Indication of the classification of other not considered land-use classes.

	Pasture	Blackberry	Strawberry	Fruits	Greenhouses	Bare soil
Vegetables			2			1
Milpa	3			2		
Coffee						
Nature		1		1		1
Urban areas					2	4
Clouds/shades	1				1	7
Column total	4	1	2	3	3	13

The overall accuracy was 83 %. However, when the no data part (clouds and shades) was left out, the accuracy decreased. 76 % of the non-clouded area covered by the five land-use classes was classified correctly. However, it should be noted that this value only dealt with these five land-use types, leaving classes like fruits and pasture out of the accuracy assessment. According to Congulton (1991), the test data should be weighted according to the class appearance in the map. The weighted overall accuracies were 75 % and 66 % respectively.

As can be seen in table 3, milpa was classified very accurately (95 %). Due to the difference in the cultivation of small and big-scale vegetables, the ground truth data of these two classes were split up. While big-scale vegetables were classified with a high quality, was the small-scale counterpart regularly confused with milpa. Especially the

non-irrigated vegetables seemed to be responsible for this misclassification. Due to the spectral resemblance of the shadow trees and forest canopy, and the variations in type and density of the former, the separation between coffee and nature traditionally is cumbersome. While (semi-) natural vegetation was classified quite satisfactory, only 60 % of the coffee was correctly assigned. The last land-use type, urban settlements, also had a rather low producer's accuracy. Confusion with the shadowed areas was considerably. Moreover, cities also harbour an amount of parks and gardens, which result into vegetable and nature patches in the urban areas.
However, more importantly for this work was the user's accuracy as it indicates the quality in which the pixels classified into a given category actually represent that land-use type on the ground. While this proved to be low for the natural vegetation (40 % and 59 %), it was remarkably high for the three agricultural land-use classes (for both user's accuracies). It can be concluded that as the quality of the classification in the agricultural area was reasonable, this land-use map was appropriate for further use in this work. Nonetheless, it should always be remembered that only a part of the study area was covered, limiting considerably its use in some of the analyses. Moreover, coffee was proportionally over-represented, as clouds covered especially the non-coffee regions.

4.3 Accessibility maps

4.3.1 Input data

As accessibility in this work was approached in a contextual manner, considering local factors as transport mean and marketing network, a considerable amount of data was needed. In the following section, the road quality data, info about market and transport functioning and height data will be discussed.

4.3.1.1 Road quality data

For the case studies of Santiago Sacatepéquez and San Andrés Itzapa, the mapped out road maps (see 4.2.1) were used. During the two months fieldwork, 'quality' values were assigned to the different roads. In this thesis, six ‘quality’ classes were used according to the transportation mean possible on the road and the speed that they could be crossed. In table 5, the different types are listed and described in more detail. Figure 16 shows some of them. To calculate the accessibility to the ‘big’ markets (like Guatemala City), it was necessary to extend the mapped roads leading to these selling centres. MAGA road data were used to perform this. This data set was also taken for the whole study area. In appendix 6 the conversion of the coordinate system and the reclassification are outlined.

4.3.1.2 Information about market and transport functioning

Information about the market functioning included the geographical position of the consumers’ markets, location of possible change of transportation mean (e.g. village) and the point until where the farmer was responsible for the transport of the harvest. This info resulted in the ‘target locations’ needed in the accessibility calculation. Knowledge about the transport functioning was necessary to get a thorough understanding of the accessibility problem, to assign realistic possible speeds to the different roads and to see why and in which amount this possible transportation speed (and capacity) was not reached. All this information was gathered during the fieldwork by means of interviews (see 4.1) with farmers and people from the markets.

4.3.1.3 Height data

A DEM (DTED elevation data) of Central America in ARC/INFO grid format created by the USGS was used as height data of the study area. Again the projection had to be converted to the one used in this thesis. This was done in the same way as already explained in 4.3.1.1.
The DEM had a rather low spatial resolution of 60 meter and probably was ‘derived’ of a DEM of even lower resolution being a 1-kilometer digital elevation model (USGS, 2002). Moreover, as already mentioned in 4.2.2.1, the quality was rather bad. Nevertheless, due to the importance of height data for this research and being this the only available DEM, this one was used for the calculation of the travel cost.

Table 5. Some characteristics of the different road types. Speed is an estimation based on fieldwork measurements.

ROAD TYPE	AVERAGE SPEED OF FASTEST TRANSP. MEAN(*Km/hr*)	PASSABILITY TRANSPORTATION MEAN						COVERAGE	CONDITION OF COVERAGE	OTHER CHARACTERISTICS
		Truck	*Car*	*Horse*	*Bike*	*Wheel-barrow*	*On foot*			
1	90	x	x	(x) *	(x) *	(x) *	(x) *	asphalted	good	* Highway * e.g. figure 16 E
2	75	x	x	(x) *	(x) *	(x) *	(x) *	asphalted	reasonable good	
3	50	x	x	x	x	x	x	asphalted or paved with stones	intermediate	e.g. figure 9
4	25	(x) **	(x) **	x	(x) **	(x) **	x	not paved or paved with stones	bad	e.g. figure 2
5	10	-	(x) **	x	(x) **	(x) **	x	not paved (sometimes stones added)	very bad	* in most cases too narrow for trucks * e.g. figures 16 B & F
6	4	-	-	x	(x) **	(x) **	x	not paved	mostly very bad	* in most cases too narrow for cars/trucks * e.g. figures 16 A, C & D
no road	1.5	-	-	-	-	-	x	-	-	-

x: passable in all times

(x) *: passable but not preferred due to risk/danger

(x) **: passability depending on the temporal conditions (e.g. inaccessible after heavy rainfall)

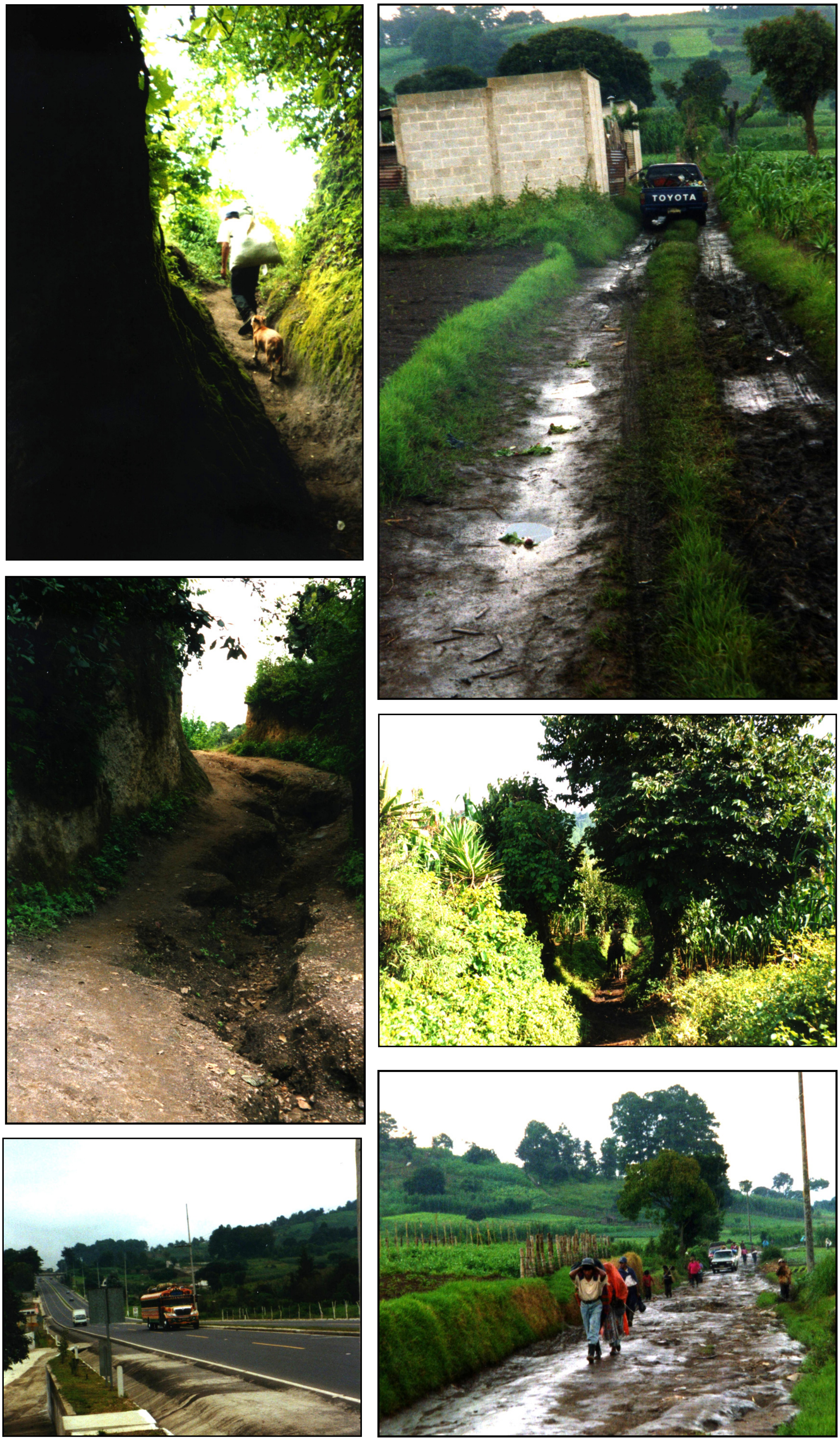


Figure 16. Different roads in the study area.

4.3.2 Creation of the accessibility maps

As the creation of accessibility maps was not the main goal of this thesis and financial inputs and time were limited, a rather simple and flexible computation of access was preferred to a detailed, big data-input accessibility model. Moreover, people in third world countries do often have to work under the same constraining conditions and the available data there is in general limited, which makes the use of such big models exclusive. In this work only a cost surface, the target location(s) and a DEM were used as data input. The first two are compulsory inputs but the DEM can be omitted for calculations in flatter areas.

A lot of definitions and interpretations of the term ‘accessibility’ can be found in literature. Throughout this work the definition of Nelson (‘the time to reach a location’), although adjusted to the local situation, was used. It uses time to measure access and compared with e.g. ‘ease to reach a location’ this is a simple and general applicable measurement unit for accessibility. Time is however, not the only important aspect of access to consider. Also the cargo that can be transported, the cost of transport and ‘access’ to the different transportation means are important but are not directly incorporated in the accessibility calculation. They will, nevertheless, be discussed in the beginning of the fifth chapter. Because in this work the relation between accessibility and crop choice was investigated, accessibility was seen especially from the farmer’s perspective. This is justified by the fact that the study area was almost completely dependent on agricultural activities.

The target location and the available infrastructure (roads) are the two central pillars to determine accessibility. Both were approached in a contextual way. The first one is the point until where the farmers were responsible for the transport of the harvest. This could be e.g. the market where the products were sold but also the village in case of a self-maintenance crop or the existence of a co-operative located in the village, which transports the products itself. Besides the transport of the harvest also the ‘everyday’-access, being these from house to field, was considered. In this thesis every location in the area under consideration was assigned just one target end-location (e.g. the preferred market) for a certain crop type. This was based on information gathered from the interviews (see 4.3.1.2). It may be clear, however, that not all farmers go to the same market and that some farmers do not restrict themselves to just one market. This generalisation was, nonetheless, executed for reasons of simplicity. In the case villages were an intermediate or even end-target, the assignment of all ‘cells’ to the correct village was a tricky task. In this work a specific cell was assigned simply to the village with the lowest access. In reality this is, however, not always the case. Factors as farmer population in the different villages and available agriculture area also play a role. A kind of ‘willingness to overcome bad access’ should be included in the calculations. People from villages with a big farmers community and little of agricultural area in their neighbourhood are prepared to do more effort to obtain land further away than a small village with adjacent sufficient amount of agricultural land. A possible factor would be agricultural land pressure (# of agr. people / area of agr. land in a certain access zone). As ARC/INFO did not contain a command to do this, a new algorithm should be written to solve this problem. Because the calculation of accessibility is not the central issue in this work, this was not executed. In the case the village was just an intermediate target, the accessibility to the village was added to the accessibility from the village to the end-target. Moreover, villages and markets outside the area but influencing the access in this area were incorporated in the calculations. For the second pillar, the speed (km/hr) in which the roads were crossed, was considered. In reality not only the roads but every location of the study area was assigned a possible speed. Moreover, also the parts adjacent to the study areas were taken in consideration as access and roads are not restricted to departmental or case study borders. In the accessibility calculation, the speed didn’t have to be always the fastest one as not all people were in the possession of the best transportation mean for that particular road.

Six combinations of target locations and `speeds` were relevant for the case study areas of Santiago and San Andrés Itzapa and the whole study area:

1. `Fastest` transport to the village;
2. `Fastest` transport directly to the market(s);
3. Transport on foot to village;
4. Transport on foot to the village and then motorized to the market(s);
5. Transport on foot to the `closest` road passable by car (type 1 to 5 for the case studies and type 1 to 4 for the whole area);
6. `Fastest` transport to the `closest` relative good, all year round passable road (type 1 to 3).

The first four are different forms of access depending on the crop, on the difference between transport of the harvest and the daily transport to the fields, and on the available means of transport. The last two result in not 'complete' accessibility maps in that sense that access is not calculated completely until an end-target (e.g. market) but only until an intermediate target being a type of road. They are intended only to show the importance of motorised transport and the therefore needed road network.

The whole accessibility creation was executed in ARC/INFO version 8.1. For the two case studies a grid size of 5 m was used, while for the whole study area this was 15 m. The actual calculation of access to a certain target location was calculated with the PATHDISTANCE command. This command calculates, for each cell, the least-accumulative-cost distance over a cost surface to a target cell. The cost surface in this case was the grid, which contained for each cell a value in minutes per meter (derived from the speed in km/hr). This command also accounts for surface distance and vertical cost factors. The DEM was needed as an input for these factors. The surface distance factor takes in consideration the actual distance that will be covered when passing between cells with a certain slope. The vertical cost factor accounts for a vertical supplementary increase or decrease of cost incurred when moving from one cell to another. In this study area the speed of a movement in a direction in which the slope is different from zero decreased. This was not only the case for the movement in uphill direction but also for this in downhill direction as the state of the roads and dangerous curves made a save transport only possible when speed was reduced. The speed decreased with increasing slope according to a factor. The relation between slope and this factor used in this work is shown in figure 17. It was based on personal experience and field measurements. It should, nevertheless be remembered that this is only a generalisation and that fluctuations occur depending on the specific road and its condition.

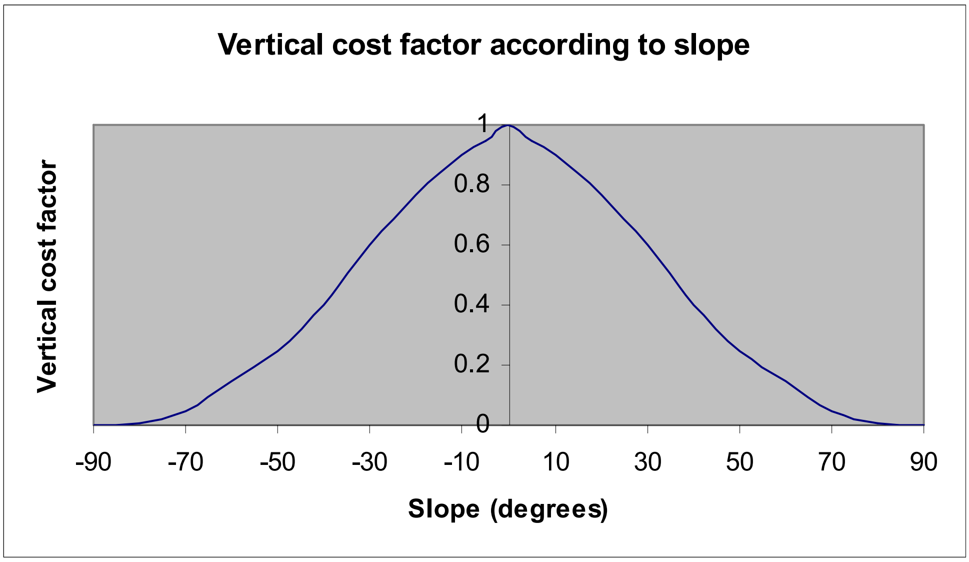


Figure 17. The assignment of the vertical cost factor according to the slope.

4.4 poverty data

Although there are many ways to measure poverty, the 'Mapa de pobreza de Guatemala' produced by the SEGEPLAN (2001) which gives information about poverty on the level of the whole country, of the regions, of the departments and even of the municipalities was used in this thesis. These data were made based on the method of Hentschel *et al.* (1998), which attempts to assign values to different poverty indicators based on the comparison of the local situation with a poverty or extreme poverty line. An important separation between poverty and extreme poverty is made here. Poverty is seen here as the lack of sufficient means to satisfy the minimum necessities of calories, as also other non-food-related necessities like transport, education and health. In the case of extreme poverty only food necessities are considered. People living in extreme poverty have not enough means to satisfy a minimum consumption of calories.

In this work four (existing) poverty indicators were used. The first two simply give the relation (in %) between the number of poor or extremely poor people and the total population of the area under consideration. The other two are severity indices, which not consider only the amount of poor people, but also the degree of their poverty. In appendix 1, the percentage of poverty per Guatemalan department is given. The % of poverty and extreme poverty and the severity indices of poverty and extreme poverty of the study area on a municipality level are shown in appendix 2.

It should be remembered that these poverty data do not show variations between certain groups (like indigenous against non-indigenous people). These difference can nevertheless be considerably and important. Moreover, this method is based on income. Poverty, nonetheless, is more than just a financial problem as has been discussed in 3.1.1.3.

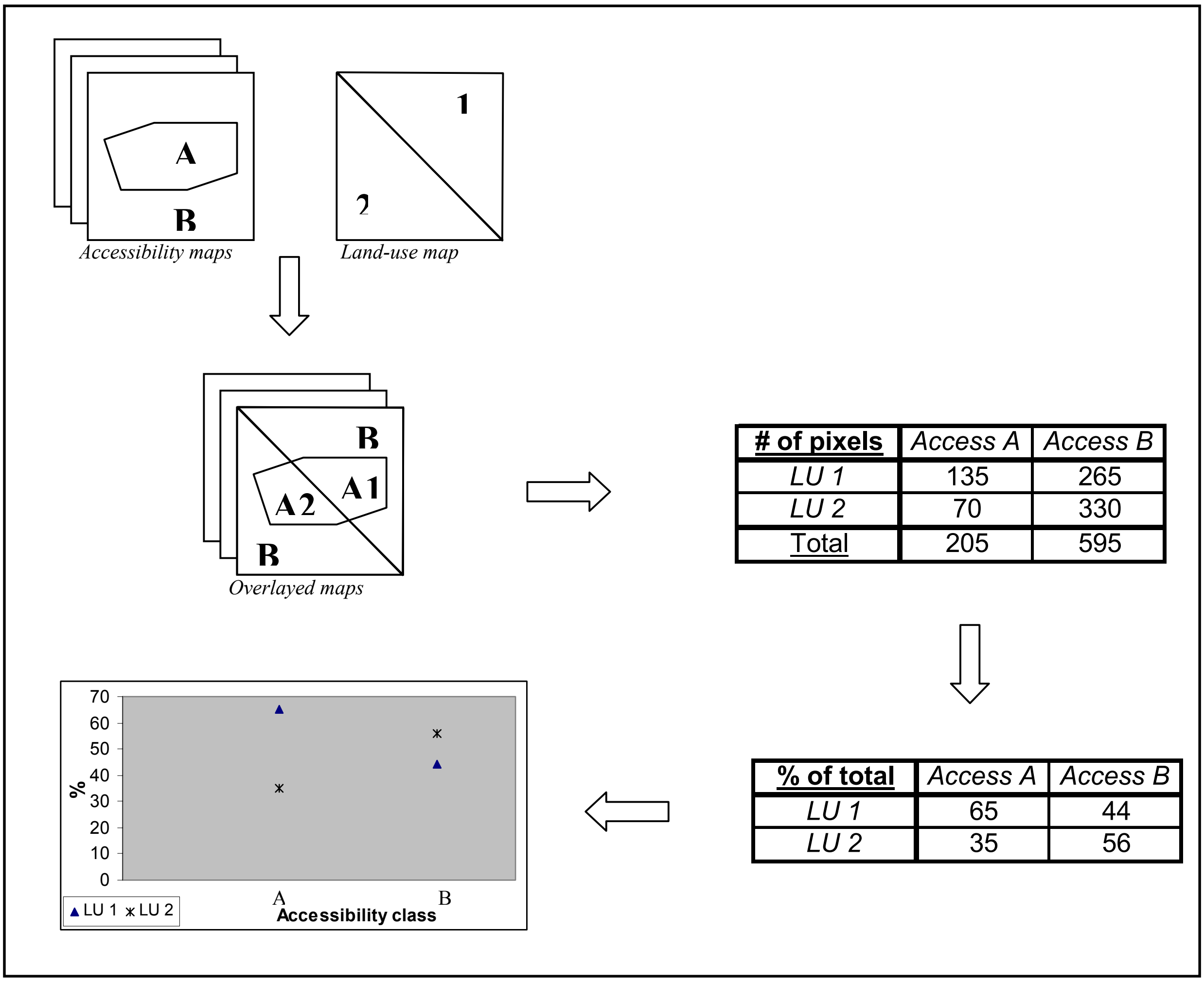
4.5 Methodology to investigate the relation between accessibility, crop choice and poverty.

All the data and information, outlined in the previous part of this chapter, were used to determine the relations between accessibility, crop choice and poverty, and to evaluate and explain the results.

4.5.1 The influence of accessibility on crop choice.

The relation between accessibility and crop choice was investigated by spatially overlaying and comparing the accessibility maps of the different crops with the location of these crops. The accessibility (time) values were reclassified in classes of 5 minutes (class 1: 0 – 5 minutes; class 2: 5 – 10 minutes; etc.). The % of a crop type in a certain agriculture area was used to 'measure' the crop choice. Several figures, showing accessibility in relation with this %, were used to determine the impact of access on crop choice. The procedure followed to obtain these figures is outlined in the following paragraph (see also figure 18).

For all the different accessibility maps, the land-use classes were combined with the accessibility classes in ARC/INFO. Because the land-use data did not completely cover the whole study area (see 4.2.2.2), only these parts of the accessibility maps where LU data was available were taken for the analysis. The number of pixels for every possible combination of LU and access classes were imported in Microsoft Excel. For these crop types where mixed LU classes were used, the number of pixels of pure LU types were calculated. For all the LU classes in the (case) study areas and this for all the accessibility classes of the correspondent accessibility map(s), the 'amount' (in %) of a LU class in an area with the same accessibility class was calculated. As crop choice only applies to the agricultural area, the percentages of the crop types were defined only considering the agriculture area. To get an idea of the relation between the total agricultural area and accessibility, also the percentages of



# of pixels	Access A	Access B
LU 1	135	265
LU 2	70	330
Total	205	595

% of total	Access A	Access B
LU 1	65	44
LU 2	35	56

Figure 18. Schematic example of the methodology to make the relation between accessibility and crop choice.

the big LU classes (nature, urban settlements and agriculture) considering the total area in an accessibility class were searched. All these percentages were taken to make the figures mentioned above. The accessibility classes were represented on the x-axis while the percentages were given on the y-axis. Some correlation analyses were performed to statistically confirm certain trends.

Besides this one-dimensional analysis, also a more spatial perspective was considered. This was only done for the whole study area, as the case study areas were too small. The departments of Chimaltenango and Sacatepéquez were split up in big cells of 5 km and in each pixel, the % of the different crops and the mean accessibility of its agricultural area were calculated. The accessibility, considering transport to the village on foot followed by a motorised transport to the capital, was considered. As will become clear from the following chapter was this accessibility 'type' the most dominant for most farmers. Especially the vital relation between accessibility and the choice between cash (like vegetables) and subsistence crops (like milpa) can be checked excellently in this way. In order to check the importance of local accessibility and the proximity of good roads, also the accessibilities to the village and to good all year-round passable roads were considered. The mean accessibility and % of a certain crop type were grouped in different classes and were overlaid in order to visualise the spatial variation of this relation.

It may be clear that crop choice is not only determined by accessibility. Factors like tradition, irrigation, soil, slope, aspect, height, temperature, rainfall, humidity, market situation (like prices), technical knowledge, assistance (e.g. co-operatives), money to pay inputs, land-ownership, available manpower and some contextual factors like fabrics in the neighbourhood can influence the crop choice considerably. Though these factors are crucial to understand the full impact of access on crop choice, only some of them were, due to lack of time and data, discussed shortly. Especially interview information was used. For irrigation, field knowledge and the LANDSAT image were taken to delineate the irrigated areas in the case study of Santiago Sacatepéquez. It was used to study the crop choice in the irrigated areas and make the relation between irrigation and accessibility.

4.5.2 The relation between accessibility and poverty.

More or less the same procedure, as outlined in 4.5.1, was followed to study the relations between poverty and accessibility. Nonetheless, this could only be done for the whole study area, as the spatial resolution of the poverty data was too coarse on a case study level. Again two procedures were followed.

The first one resulted again in figures with in the x-axis accessibility and in the y-axis poverty with each point representing the values of one municipality. Only the accessibility map, that considers the transport to the village on foot followed by a motorised transport to the capital, was used. The dominance of Guatemala City as a selling and working centre in the study area and the central role of the capital in the spatial perspective of the poverty problem (see 3.1.1.3 and 3.2.1), justified this choice. For accessibility, the means of the different municipalities were considered. The calculations, however, were performed in two different ways due to the difficulty to appoint these land-use classes (and their importance) where accessibility influences poverty (for further discussion see last paragraph of 4.5.2). For the first case only the weighted mean access of the different urban settlements was taken, while in the second case the mean accessibility was calculated for the whole 'living environment'. Consequently, the second accessibility calculation was more agricultural oriented, as the 'living environment' is the area where the majority of the people live and work (thus also agricultural areas). The weighting of the access in the first case was based on the number of habitants in the different urban settlements of a municipality. To avoid situations where for example huge areas of inaccessible forest would decrease the mean accessibility considerably while the rest of the municipality is very accessible, were the (semi-) natural areas excluded in both cases. As the land-use data obtained from RS was not completely covering the area (see 4.2.2.2), MAGA land-use data were used. Although these data were of a less quality, they sufficed, as only broad LU classes were needed. The y-axis values in the accessibility-LU figures were the % of poverty and extreme poverty (see 4.4) for each municipality.

The second procedure was again more spatially oriented. The study area was split up in grid cells of 5 km and the mean access and poverty in each pixel were calculated. Both were reclassified and a spatial overlay resulted in a visualisation of the spatial variations in this relation. Again was accessibility calculated in the two ways discussed in the previous paragraph.

Also other factors influencing poverty (and especially its spatial distribution) and accessibility should be considered. Nevertheless, this fell out of the scope of this work. More research in this perspective is recommended. Furthermore, more emphasis on the calculation method of the mean accessibility in a certain area is needed. Accessibility is not equally influencing poverty over a whole area. The accessibility of some land-use types (like urban centres) will determine more the poverty degree of an area (e.g. a municipality) than for example the accessibility of a forested part. Knowledge about the degree in which accessibility in the different land-use types influences poverty, is crucial.

4.5.3 The relation between crop choice and poverty.

As the spatial resolution of the poverty data was too coarse on a case study level, the relation between crop choice and poverty could only be performed for the whole study area. Although the methodology was very similar with these of the two previous relations, it was more cumbersome. Especially the non-complete land-use coverage (see 4.2.2.2) of the municipalities (or pixels), made the comparison with poverty tricky. Just like in the previous two relations, the analysis was performed in two different ways. The first one showed the relation between certain crop types and poverty in the form of simple one-dimensional figures, while the second one was more spatially oriented showing the variations over the study area.

The land-use and poverty data were these previous discussed in 4.2.2 and 4.4. For the first procedure, the percentages of the total agricultural area covered by the different crop types were calculated according to the municipality borders. For the 2D-analysis, mean poverty and % of the crop types were determined on a pixel basis. The % of the ‘non-clouded’ agricultural area of a municipality in perspective to the total ‘non-clouded’ agricultural area in a particular pixel was taken as weighting factor to determine the mean poverty. The grid was the same as outlined in 4.5.1 and 4.5.2. Poverty and land-use were reclassified and overlaid in the same way as outlined in the previous relations.

It may be clear that the use of highly qualitative, completely covering land-use data would increase considerably the quality of this analysis.

5) Results and discussion

To understand the role of accessibility as a key factor in the developing process and its relation with crop choice and poverty, it is of the utmost importance to have a thorough understanding of the local situation. In this perspective, two case studies were investigated. The results are highlighted and discussed in 5.1. The resulting information is used in 5.2 to 'scale up' and discuss accessibility for the whole study area.

5.1 The case studies

5.1.1 The case study of Santiago Sacatepéquez

The study area of Santiago was situated in the northeast of the department of Sacatepéquez (figure 12). It had an area of 18.2 km^2 and was made up mainly of the municipality of Santiago Sacatepéquez. In the north also a small part of the case study area fell in the municipality of Santo Domingo Xenacoj and in the south a little area of San Lucas Sacatepéquez was considered. Four urban settlements were located in the case study area (figure 22). The two most important ones for this study were the villages of Santiago and Santa Maria Cauqué (figure 19) as they were populated predominantly by farmers. The two other populated areas (the Residenciales Jardines de Santiago and another residence in San Lucas Sacatepéquez) had no connection at all with agricultural activities and as a consequence had little influence on this study. According to the population census of 1994 (INE, 1994), the village of Santiago harboured 9834 people and Santa Maria Cauqué 3004. Both consisted almost completely of indigenous people working in the primary sector.

The study area of Santiago Sacatepéquez was mountainous with an altitude of 1750 meter and higher. It also contained several big ravines, which made some agricultural areas very difficult to reach. That is why this area, nevertheless its small size, had relative big differences in accessibility and as a consequence was an excellent study area. No specific soil and meteorological data is available for this area. The only information about the fertility of the volcanic soils was given by the farmers, who generally described the cultivated soils as fertile.

Figure 19. View over a part of the case study area of Santiago Sacatepéquez. The village of Santiago is situated in the middle of the picture while Santa Maria is located in the right corner.

5.1.1.1 Roads and transport in Santiago Sac.

Before discussing the accessibility problem in Santiago Sacatepéquez, a general look at the different transportation means in the highlands of Guatemala is taken. In table 6 the important characteristics, speed and cargo, are highlighted. The represented values are estimations of an average 'sample' of these different means of conveyance. The differences are substantial. Motorised transportation means are far out faster and more 'capable' in transporting big loads than traditional transport (ranging up to differences of more than factor 20). The astonishing advantage of motorised vehicles becomes

Table 6. Simple comparison concerning speed and cargo between different transportation means. This representation intents only to point out some important characteristics of the different transportation possibilities and has not a scientific value as such.

	Small truck	**Pick-up**	**Car**	**Bus**	**Horse**	**Wheel-barrow**	**On foot**
Estimated speed (km/h)	70	80	90	60	4	3	4
Speed factor with regard to the speed on foot	17,5	20	22,5	15	1	0,75	**1**
Estimated mean possible cargo (kg)	600	250	150	50	80	50	25
Possible cargo factor with regard to the possible cargo while walking	24	10	6	2	3,2	2	**1**
Amount of possible cargo (kg) per hour over a distance of one km	42000	20000	13500	3000	320	150	100
Factor of amount of possible cargo per hour over one km with regard to this of walking	420	200	135	30	3,2	1,5	**1**

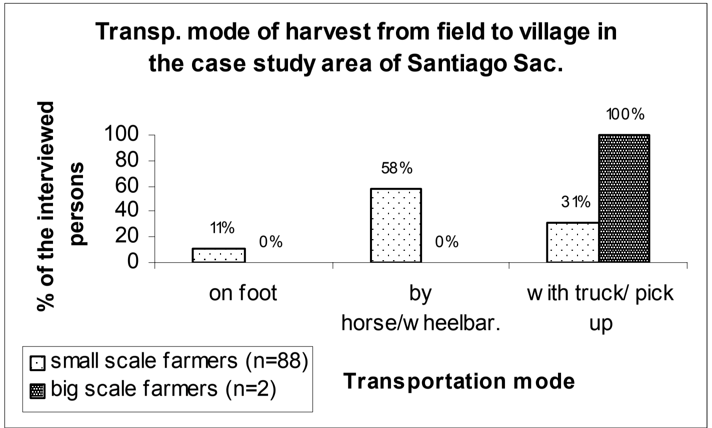
even more striking when both characteristics are combined. A small truck can cope up to 420 times more load over the same distance and time compared to transport on foot. Notwithstanding, the motorised means also show some considerable drawbacks. In the case of a small truck, pick-up (figure 20 A) and car, the inevitable high cost of hiring or buying (+ maintenance, petrol and insurance) makes them very exclusive for a lot of farmers in the Guatemalan highlands. Moreover, these transportation means demand a minimum road quality, which is not always the case. Also time losses, due to the loading and unloading, can be considerable. For the bus (figure 20 C), the available routes and stop places can eliminate its use for people of remote areas. Also its cost, although considerably less than this of cars and trucks, can be exclusive for some people. Moreover, does a bus always require a minimum of transport on foot. Another drawback is the dependence of time schedules and connections. In the case a horse (figure 16 D) is used, the demand for a minimum of place for the animal, its cost and maintenance can give problems. A huge advantage is its 'all-passability' as it can cross narrow, steep and muddy places. This is not the case for the wheelbarrow, which needs a better and more flat underground. So the wheelbarrow is an excellent and cheap alternative for a horse for poor farmers with fields accessible through better roads.

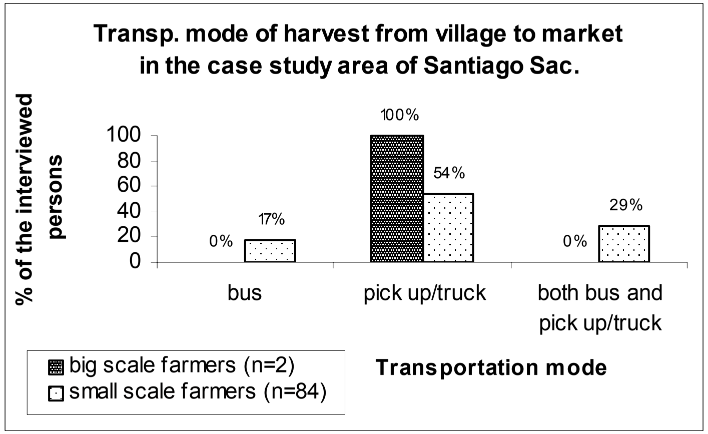
The use of these transportation means in the case study area of Santiago Sacatepéquez is represented in figure 21. An important distinction between daily transport to the field and transport of the harvest from the field to the village and/or the market was made. In the first case, transport was especially on foot (figure 20 B). When big weights like fertilisers had to be carried, horses and wheelbarrows were intensively used. The latter was especially popular in the plain in the north of Santa Maria Cauqué where roads are quite flat and relatively good. Horses in contrary were used more intensively in the rather mountainous areas around Santiago, especially when ravines had to be crossed. The percentage of farmers (or workers in the service of big landowners) using motorised transport to go to their fields on a daily basis is negligible.

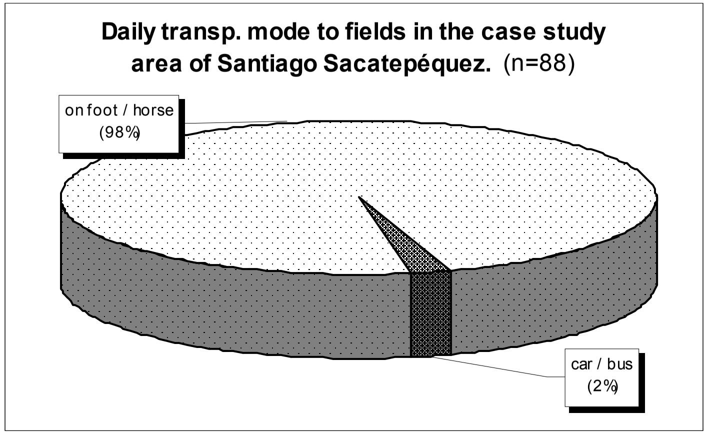
These motorised modes became more relevant when the harvest had to be transported. A distinction between small farmers and big landowners was made here. Big farmers always used pick-ups or trucks to bring their products from the field directly to the market. In most cases they also owned these means of conveyance. One of them even

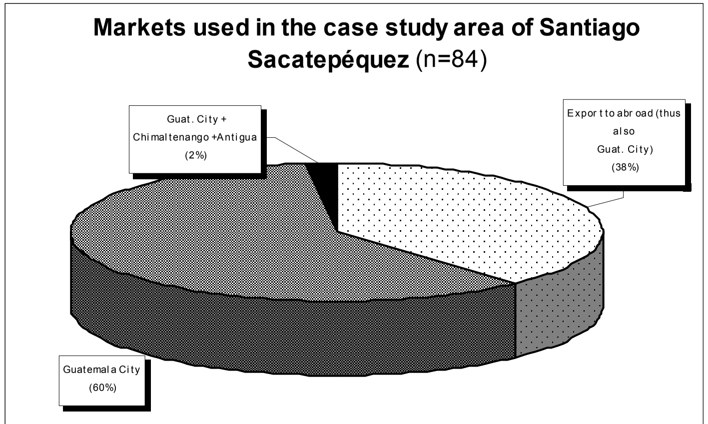

A
B
C

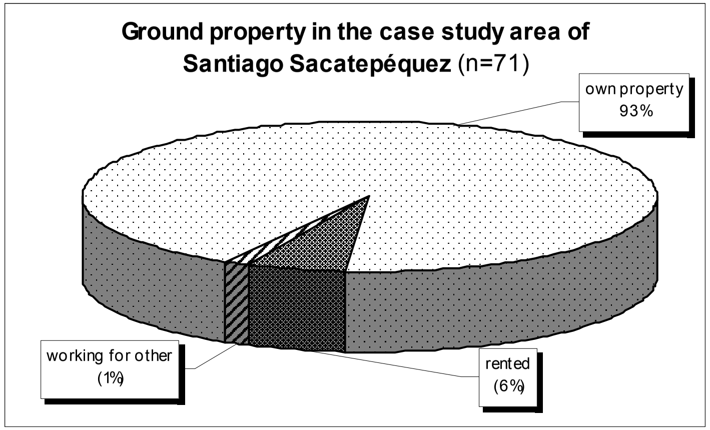
Interview results of the case study area of Santiago Sacatepéquez











Mean area cultivated in the study area of Santiago Sacatepéquez (ha):	
per family of small farmers (n = 24)	0.621
for big farmers (n = 1)	7.012

Price (in quetzal *) per ha of agr. land in the Santiago study area (n = 21):	
mean	81. 000
range	30.000 - 1.000.000

Figure 21. Interview results of the case study area of Santiago Sacatepéquez. These results are not meant as a statistical basis but as an indication of the local situation.

* 1 Quetzal = 0.13432 EURO at 01-10-2002

had a bus that brought the workers everyday from Alotenango to Santiago and the other way around. This will be discussed further in 5.1.1.4. The transport of the harvest for the small farmers was separated into that from the field to the village on the one hand and that from the village to the market on the other hand. The first reason for this distinction was the deep-rooted desire for food security offered by the milpa products being especially maize and black beans. These crops, the most important ones in the region, were in most cases not transported to a market and, as a consequence, only had to be brought to the houses. A second reason for splitting up transport in two parts was the striking importance of the village in the transportation functioning. The road network in the study area was constructed 'around' the villages of Santiago and Santa Maria Cauqué (as can be seen clearly in figure 22) with as a consequence that most farmers always had to pass the village when transporting their product. From the village onwards better transport means were available for the simple reason of quite good roads compared to the ones from the fields to the village. Moreover, the villages were the locations where the busses to Chimaltenango and Guatemala City departed and where other transport was organised. The meeting-place for farmers working together for transport was located most of the times in or near the village. In the village of Santiago even some transport companies were offering their services to the farmers. These firms charged 2.5 quetzal[1] per big basket (of more or less 50 litres) for transport to the capital. Another factor favouring the village as a central role in the transport functioning in this study area was the location of the packing 'factory' of the co-operative Cuatro Pinos near the village centre of Santiago. Over there, all the Cuatro Pinos products were pre-processed and packed for transport to abroad. For Cuatro Pinos-farmers with a big harvest and a field easily accessible with a car, the co-operation came to pick up the harvest. In the other cases the farmers themselves were responsible for the transport to the 'packing centre'. The important role of Cuatro Pinos in the area will be outlined in more detail in 5.1.1.2.

Horse, wheelbarrow and the strong shoulders and back of the farmers are the most important transport modes of the harvest to the village in Santiago Sacatepéquez. Again were horses favoured in the less accessible areas while the wheelbarrow was popular in the flatter, better accessible areas. In these last areas, the importance of the motorised transport increased considerably and on the plain in the north of Santa Maria Cauqué, car and pick-up even became the dominant transportation means of the harvest. The little amount of cars and pick-ups in the study area were used intensively

[1] :1 Quetzal = 0.13432 EURO at 01-10-2002

by the owner as it was borrowed and rented to and shared with other farmers frequently. Farmers picking up their harvest from the field directly with motorised transport, most of the times did not split up their journey in two parts but directly took off to the markets.

In total 95.6 km of roads and tracks were found in the Santiago case study area. This was 5.2 km per km^2 . The problems concerning roads in this area however was not the amount of them but their quality. In figure 22, the different roads and their quality type of the case study area are represented. The only road of type one in this region was the Pan-American highway, situated in the west of the study area. The village of Santa Maria Cauqué was located very close to it. The village of Santiago lied further away and could be reached by car from the highway in two ways. The first one was a non-paved one, which started near the village of Santa Maria and leaded to the centre of Santiago after passing a big ravine. The other road was longer but of a better quality and thus preferred. It left the village in eastern direction and ended up in the Pan-American highway in San Lucas Sacatepéquez. All the other roads and tracks were of quality type 4 or higher. They made up of 81.2 km of the in total 95.6-km roads in the 18.3 km^2 study area. This means that 85 % of the roads were almost never paved and couldn't be passed with a speed a lot higher than 20 km/h. Even 43.5 % of the tracks were not accessible at all by cars or pick-ups. Most of the time this was due to the fact that the tracks were too narrow or the quality was too bad. As the tracks were not asphalted or paved, they were most of the times in a very muddy and difficult 'passable' condition, especially in the rainy season. In mountainous areas these constraining effects were even amplified by the slope as climbing and descending of these tracks limited considerably the walking speed. Some farmers even mentioned tracks, which descended very steeply into ravines, turning into small rivers during heavy downpours. This was for example the case for the few tracks leading to the fertile but very difficult reachable plains in the North of Santiago.
Roads were used very intensively, sometimes even too intensive as cars entered in roads not suitable for these vehicles. This 'over-use', but also erosion and especially lack of maintenance resulted most of the times in roads with big pits and huge gullies (see e.g. figure 16 C & F). The municipality was the main responsible for the roads. According to the municipality board, the quality of the roads in Santiago Sacatepéquez was quite good and all the possible efforts with the limited amount of

available money were done. Habitants, nevertheless, did not agree with this optimistic view of the board and complained about the road quality and lack of interest of the municipality for this for them so important topic. Corruption and self-enrichment were the most encountered accusations towards the in majority non-indigenous municipality board. Moreover, road investments were firstly intended for 'viewable' projects in and near the village. Areas further away were 'electively' seen not so interesting with all possible consequences concerning the road quality in these areas.

5.1.1.2 Land-use and market situation in Santiago Sacatepéquez

Santiago Sacatepéquez traditionally was an 'active' agricultural municipality. Next to the cultural embedded 'milpa' crops, different types of vegetables were cultivated for especially the market of Guatemala City. From the eighties on, also non-traditional export vegetables like 'arveja china' (*Apium graveolens*) and 'ejote frances' (*Phaseolus vulgaris* spp.) became popular in the area. The agricultural co-operative Cuatro Pinos, founded in 1979, played an important role in the success of these crops. They promoted these non-traditional export vegetables by providing access to credit and technical assistance to its members. The high rate of participation in this boom and the initial high profitability of these crops, fuelled initial hope that also the smallest farmers would benefit in the long run as it also increased smallholders' ability to accumulate land and so decrease the highly skewed distribution of land and income in the region (Carletto, 2000). Due to constant disturbances in the market and even corruption in the co-operative itself, the success and its 'social articulation' slowly peeled of in the second half of the 90's. Nevertheless, in 2002 still almost 600 small farmers participated in the co-operative.

A small 40 % of the total 18.3 km^2 study area was cultivated. More than the half of it, were the different types of vegetables, including the non-traditional export ones. As already explained in 4.2.1, no distinction was made in this work between the different kinds of vegetables. All the different vegetables were cultivated very intensively with relative high amount of inputs like fertilisers and pesticides. Further made the use of irrigation a harvest up to 4 times a year possible. Vegetables were typical cash crops and were often the only source of income. Due to huge price variability on the

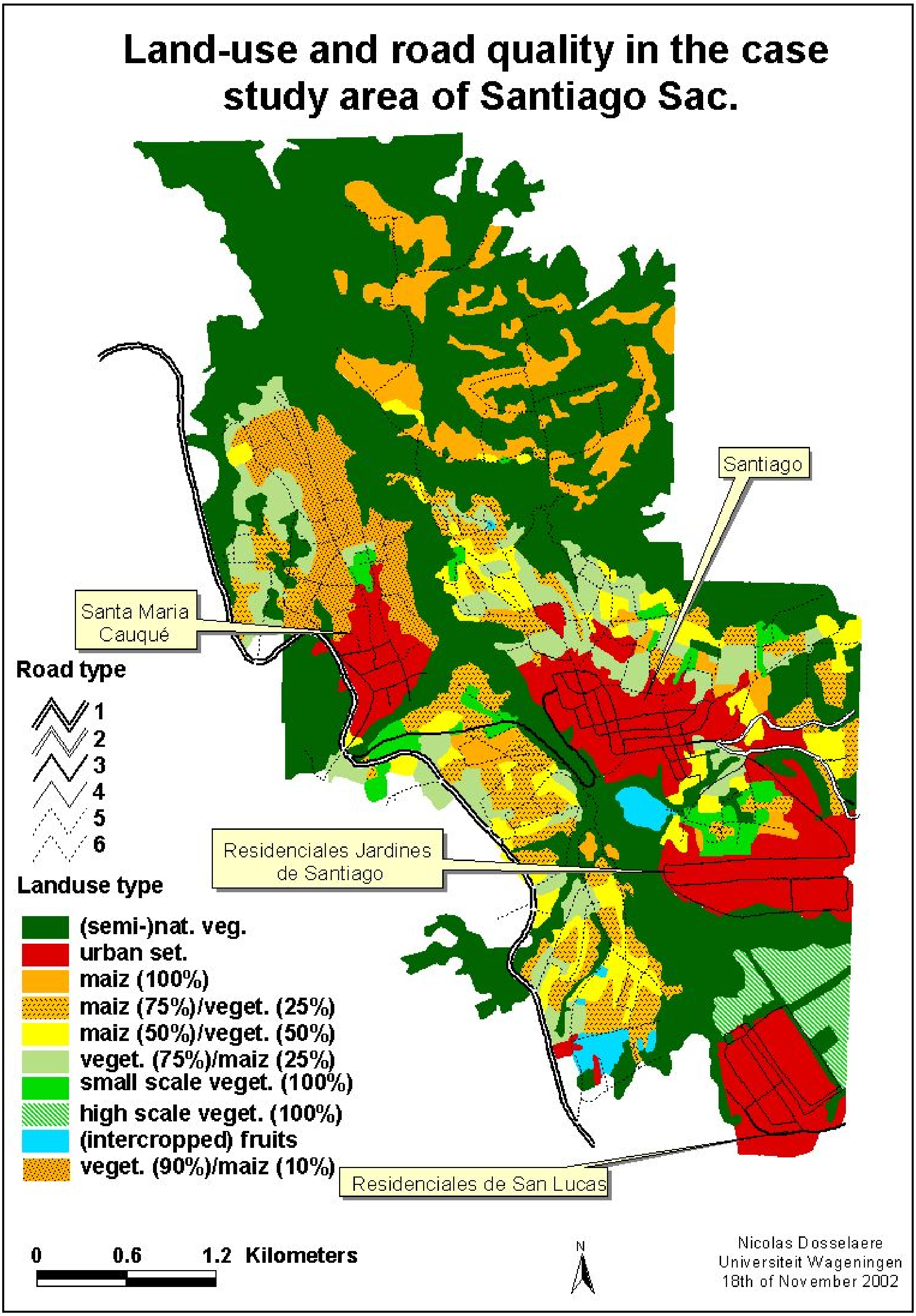


Figure 22. Map showing the land-use and road quality in the case study area of Santiago Sacatepéquez.

different markets and a constant treat of disease outbreaks, vegetables were hardly ever the only crops farmers cultivated. A minimum of milpa had to offer the strongly desired food security. Still 47 % of these traditional subsistence-oriented crops were encountered in the study area. A third major type of agriculture in the study area, although less than milpa and vegetables, were the traditional highland fruits, like apples (*Malus spp*.) and peaches (*Prunus persica L*.). As explained in 3.1.2.1, these were produced exclusively for internal markets, like Guatemala City. It was especially cultivated for cash, mostly inter-cropped with other crops like maize and vegetables. The major amount of these fruits was found close to the municipality of San Bartolomé.

To get a thorough understanding of the accessibility problem, it is also important to consider the market functioning. The figure 21 gives some characteristics of the markets situation in the case study area of Santiago Sacatepéquez. Maize and black beans were not taken into consideration in this figure, as they were cultivated mostly only for own consumption. In the few cases where these products were sold, this happened in small quantities in the local market or markets of neighbouring municipalities (like Sumpango). In contrary, the cultivation of vegetables and fruits was seldom for own consumption and the products were almost always transported to big market places. An impressive majority of the farmers had Guatemala City as the only destination for their products. Although closer, the markets of Chimaltenango and Antigua could not compete with the dominant and centralised role of the capital. In Guatemala City do not only live millions of possible consumers but also most products are redistributed here to other regions of the country and even to neighbouring countries like El Salvador and Honduras. Moreover, it harbours the only big international airport in Guatemala from which most products like non-traditional export ones to the west were transported. Also in Santiago more than one third of the products were transported to Guatemala City but did not have the capital as an end-destination. From there these products were exported to the neighbouring countries and especially to North America and to Europe. The export products in the Santiago Sacatepéquez originated especially from the big-scale farmers and the co-operation Cuatro Pinos.

Another important issue in the accessibility problem is ‘the question of responsibility for the transport to the market’. Farmers cultivating traditional vegetables had to do the trip to the market themselves while farmers working with Cuatro Pinos did not have to worry about the transport from the village to the market. Cuatro Pinos had trucks and pick-ups to do this. Also the big farmers in Santiago Sacatepéquez owned their own transportation means and executed the transport to the capital themselves. One of them even transported the products sometimes directly to El Salvador.

5.1.1.3 Poverty in Santiago Sacatepéquez

Because the municipality of Santiago Sacatepéquez made up the biggest part of this case study area, only this municipality was considered for the discussion of poverty in the case study area. According to SEGEPLAN (2001), 42.03 % of the people of Santiago Sacatepéquez were living in poverty and 4.07 % in extreme poverty. Nevertheless, these high values, they were rather ‘low’ compared to other municipalities of the departments of Sacatepéquez and Chimaltenango and even ‘very low’ when considering the whole country. Also the severity and extreme severity indices reveal this (4.70 and 0.17 respectively). Nevertheless, still 29 % of the people in 1994 had no sanitary system, 11 % absented electricity, 23 % lived in a house in bad condition and 32.8 % of the population older than 15 year was illiterate (INE, 1994). According to the ME (2001), even 52.2 % of the students in primary school were under-nourished.

5.1.1.4 Accessibility in Santiago Sacatepéquez

In the figures 23-25 and A8-A10, the accessibility maps of the case study area of Santiago Sacatepéquez are represented. These maps resulted from six relevant combinations of target location and ‘speed’ (see 4.3.2). Due to the very detailed level of road data collection (including even the thinnest tracks), the resulting accessibility values were of a remarkable quality. This was confirmed by the test data gathered during the fieldwork (time information from the farmers and own measurements). Nonetheless, for two ‘zones’ accessibility values were much too high. In the first case, the area was situated in the extreme south of the study area (see figure 22) and only occurred in the accessibility maps, which had the village as an (intermediate) target.

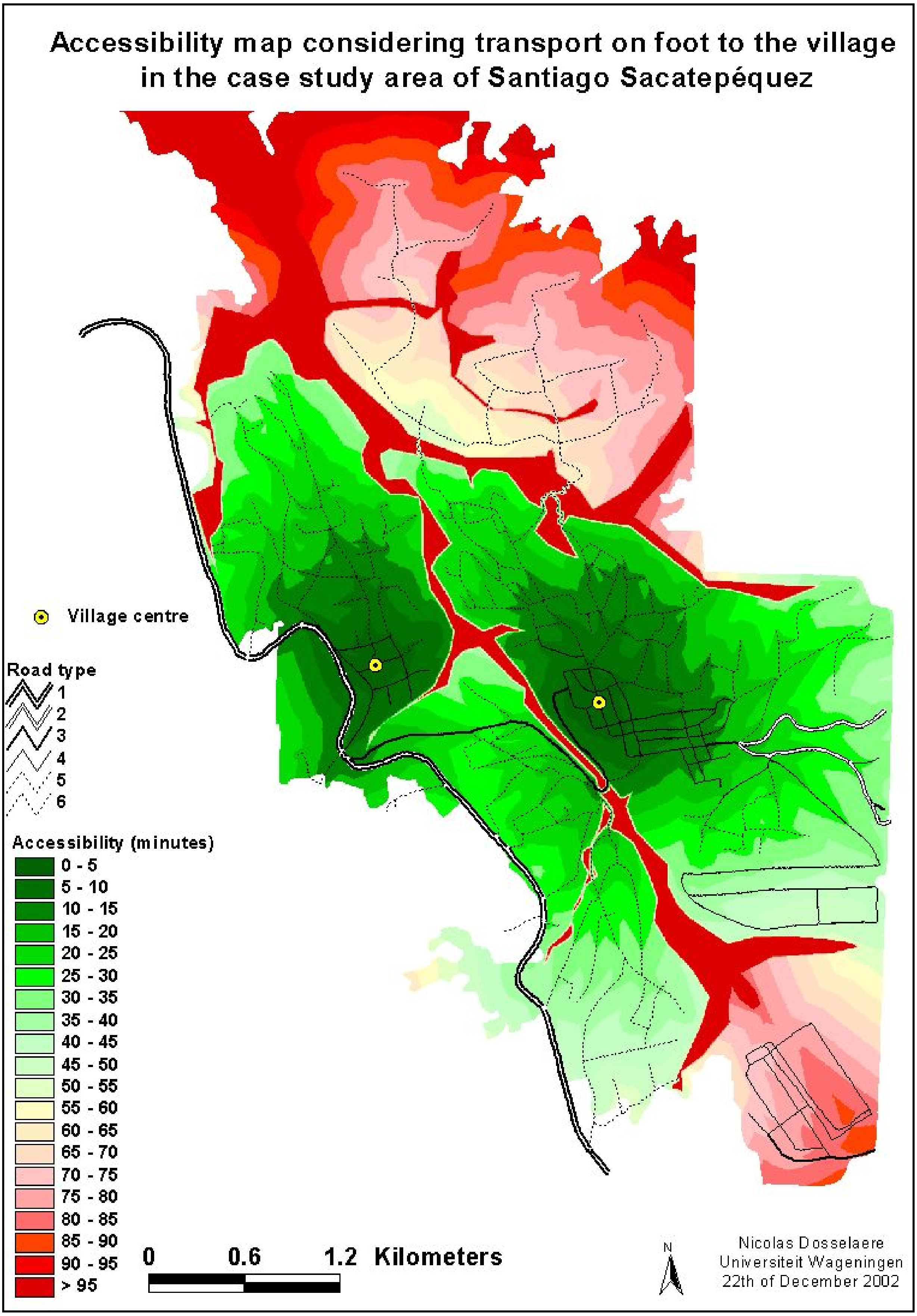


Figure 23. Accessibility map considering transport on foot to the village in the case study area of Santiago Sacatepéquez.

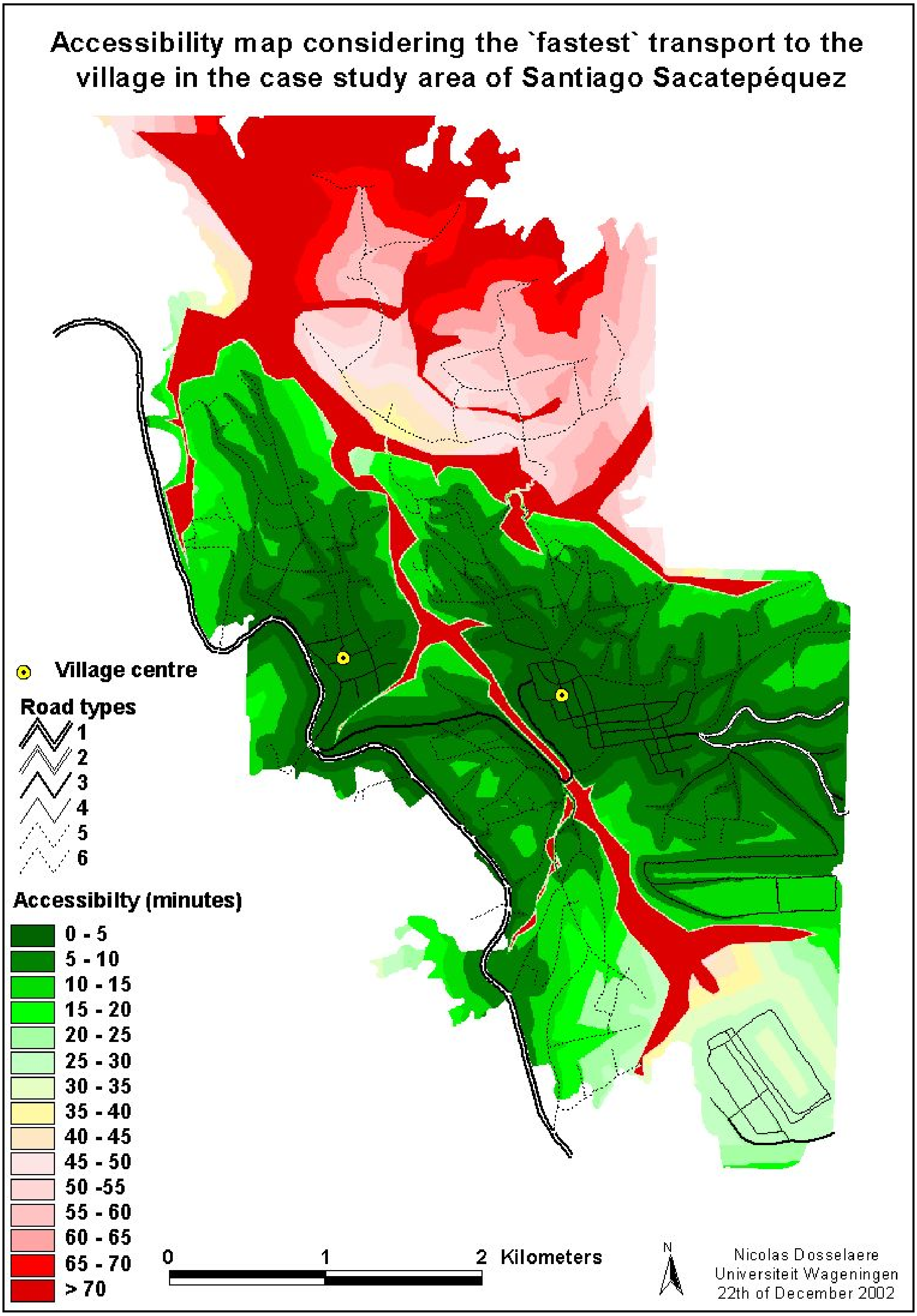


Figure 24. Accessibility map considering the `fastest` transport to the village in the case study area of Santiago Sacatepéquez.

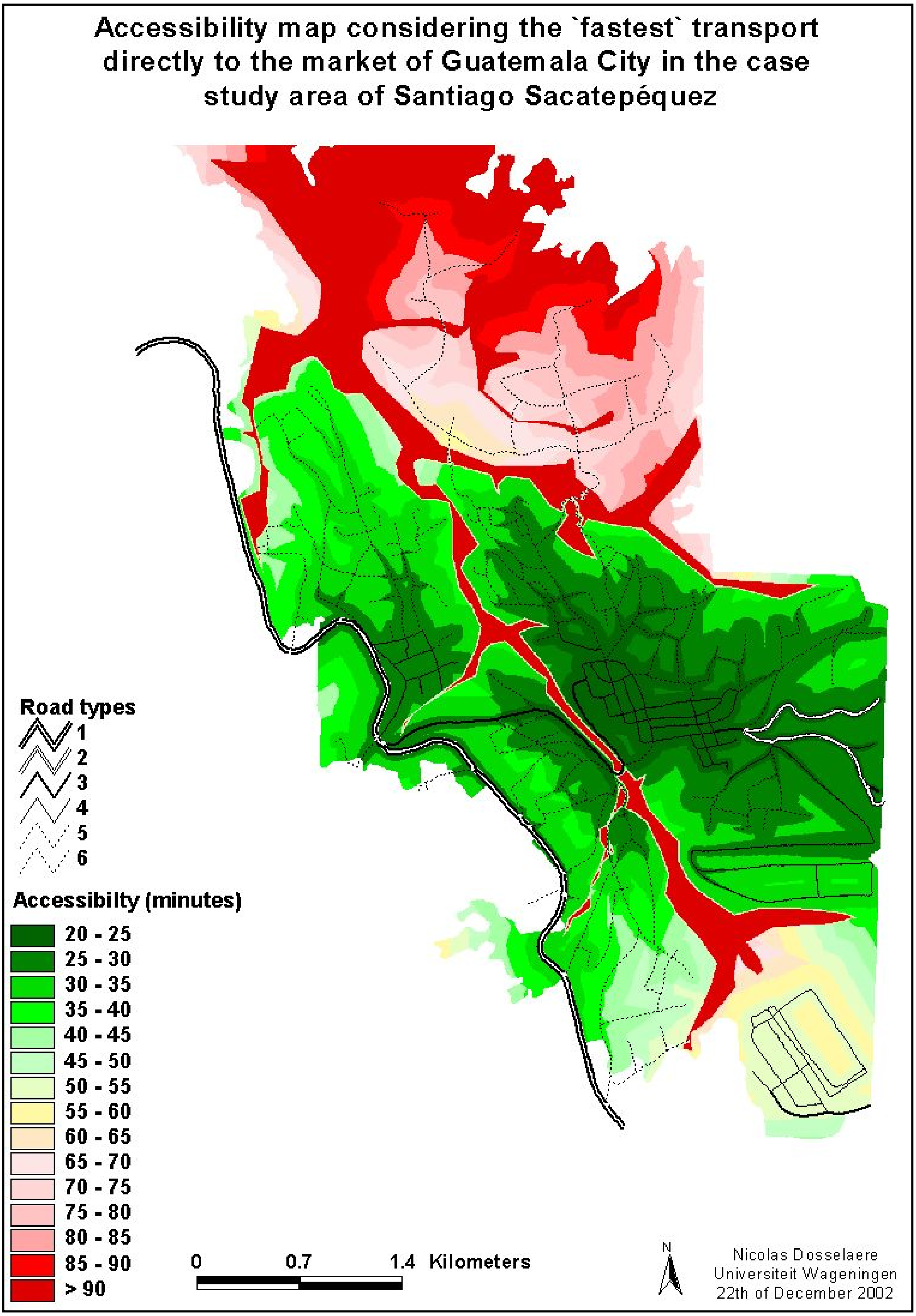


Figure 25. Accessibility map considering the `fastest` transport directly to the market of Guatemala City in the case study area of Santiago Sacatepéquez.

Due to the proximity of the village of San Bartolomé Milpas Altas and in lesser extent San Lucas Sacatepéquez, the agricultural land where fruits were cultivated was in reality considerably better accessible. Inclusions of these villages would have increased the accessibility quality for these fruit areas, but at the same time negatively altered the values for the adjacent milpa areas, which were owned by dominantly farmers from Santiago. As fruits were less important for this study area, only the villages of Santiago and Santa Maria were considered in the accessibility calculation. The same applies to the two urban areas (Residenciales Jardines de Santiago and Residenciales de San Lucas) and the big scale agricultural fields in the south. The former, nevertheless, had no importance for this study and the accessibility of the big scale fields had nothing to do with the village as (intermediate) target because transport of the workers happened by bus from Alotenango and the harvest was directly brought to the capital. The second case of over-valuation was the result of an artificial action, needed to improve the bad calculation of the vertical cost in the very steep ravines due the low spatial resolution of the DEM (see 4.3.1.3). The pixels of the ravines were assigned very high 'cost' values, forcing the computer to cross the ravines only by means of the roads and tracks. This action improved considerably the quality of the accessibility calculation for these agricultural areas situated after a ravine but made the values for a part of the 'ravine' pixels exaggerated.

Even in an area where the biggest distance to the centre was hardly 3.5 km, differences in accessibility were considerably. Due to the existence of big inaccessible ravines, accessibility to the closest village on foot could run up to one and half-hour. The striking advantage of motorised transport became clear when access on foot and motorised were compared. In the plain north of Santa Maria for example, walking could easily be two to three times more time consuming than when a car was available. As Guatemala City was less than half an hour removed from the villages of Santiago and Santa Maria, the short trip to the village was even more time consuming for many farmers than the actual transport to the market, illustrating the importance of the local transport facilities. The difference between motorised and walking transport becomes even more striking when the possible cargo is considered (see 5.1.1.1). It may be clear that the improvement of the road network could considerably change the overall accessibility. Especially the construction of bridges would make some fertile but bad situated areas (like in the north of the study area) much more accessible. It should, however, always be remembered that for some poor people the effect of these improvements would be rather small, as motorised transport is exclusive for them.

5.1.1.5 The relation between accessibility and crop choice in Santiago Sac.

Before considering the different crop types separately, it is interesting to start of with a short discussion about the relation between accessibility and the overall agricultural area. In figure 26, the three major land-use classes in relation to access to the villages on foot are represented. With very low accessibility values, the urban areas dominated. Because the other urban areas besides the villages of Santiago and Santa Maria were not considered in the accessibility calculation, some high representations were found in less accessible regions. This resulted also in the rather irregular behaviour of agriculture in relation to accessibility. However, the main reason for this phenomenon was the 'random' spatial distribution of the ravines, which were not suitable for agriculture.

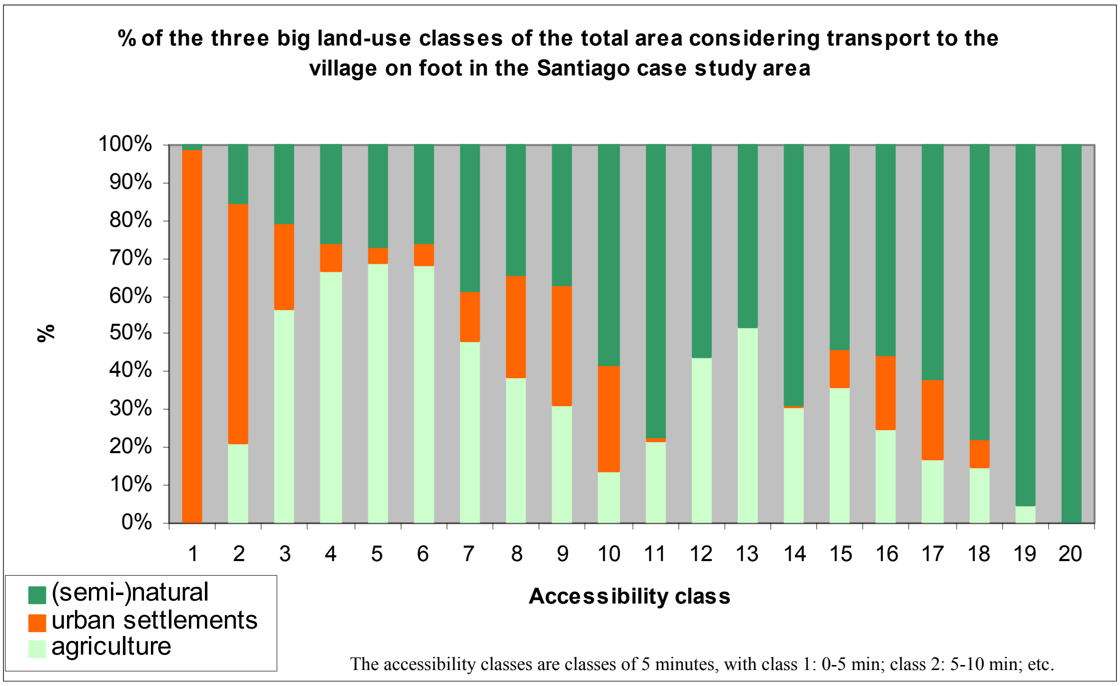


Figure 26. Percentage of the three big land-use classes (of the total area) considering transport to the village on foot in the Santiago case study area.

The municipality of Santiago Sacatepéquez is traditionally an area where both milpa and small-scale vegetables are cultivated in abundance. The crop choice of the small farmers is, except for some cold weather fruits, reduced to these two crop types. This made the study area particularly interesting to check the relation between accessibility and the choice farmers had to make between agriculture for subsistence (milpa) and for monetary (small-scale vegetables) reasons. In figure 27 A, the relation between milpa and accessibility on foot to the village is represented. In figure 27 B, this is shown for the small-scale vegetables, with that difference that four different accessibility 'types' were used. The accessibility maps used for a certain crop type were based on the results given in 5.1.1.1 and 5.1.1.2.

The % of the total agricultural area cultivated by milpa was increasing with decreasing accessibility (increasing accessibility values). This was confirmed by a strong positive correlation of 0.86. The outliner at accessibility class 10 is explained by the extreme high occurrence of fruits in that class. In reality, this was not the case. Accessibility for this 'fruit area' was over-valuated (see 5.1.1.4), what resulted in the extreme low % of milpa in that class. To discuss the crucial choice of small farmers between agriculture for self-maintenance and this for monetary reasons, it was better to consider only the milpa and small-scale vegetable areas (figure 27 D). With a positive correlation of 0.94, the role of accessibility in the crop choice of small farmers was striking. While in areas, removed by more than one hour from the village, only milpa was cultivated, hardly one fifth of the fields adjacent to the villages were covered with this subsistence crop type. There are several reasons why farmers favour milpa in less accessible areas. First of all does the milpa harvest only need to be transported to the village, which make the already long transport considerably shorter and cheaper. More important, however, is that maize in the highlands only needs to be harvested once a year (compared to several times for vegetables), reducing considerably the cumbersome task of transporting the harvest. Moreover, the transport of the relative big quantities of the vegetable-harvest has to happen rather quickly due to its perishable character. As maize is less sensible to time demands, it can more easily be cultivated in remote areas. The last reason for the popularity of milpa in remote areas is the fact that milpa is less time and input demanding, resulting in considerably less 'cargo' (like fertilisers) to transport and less visits to the fields.

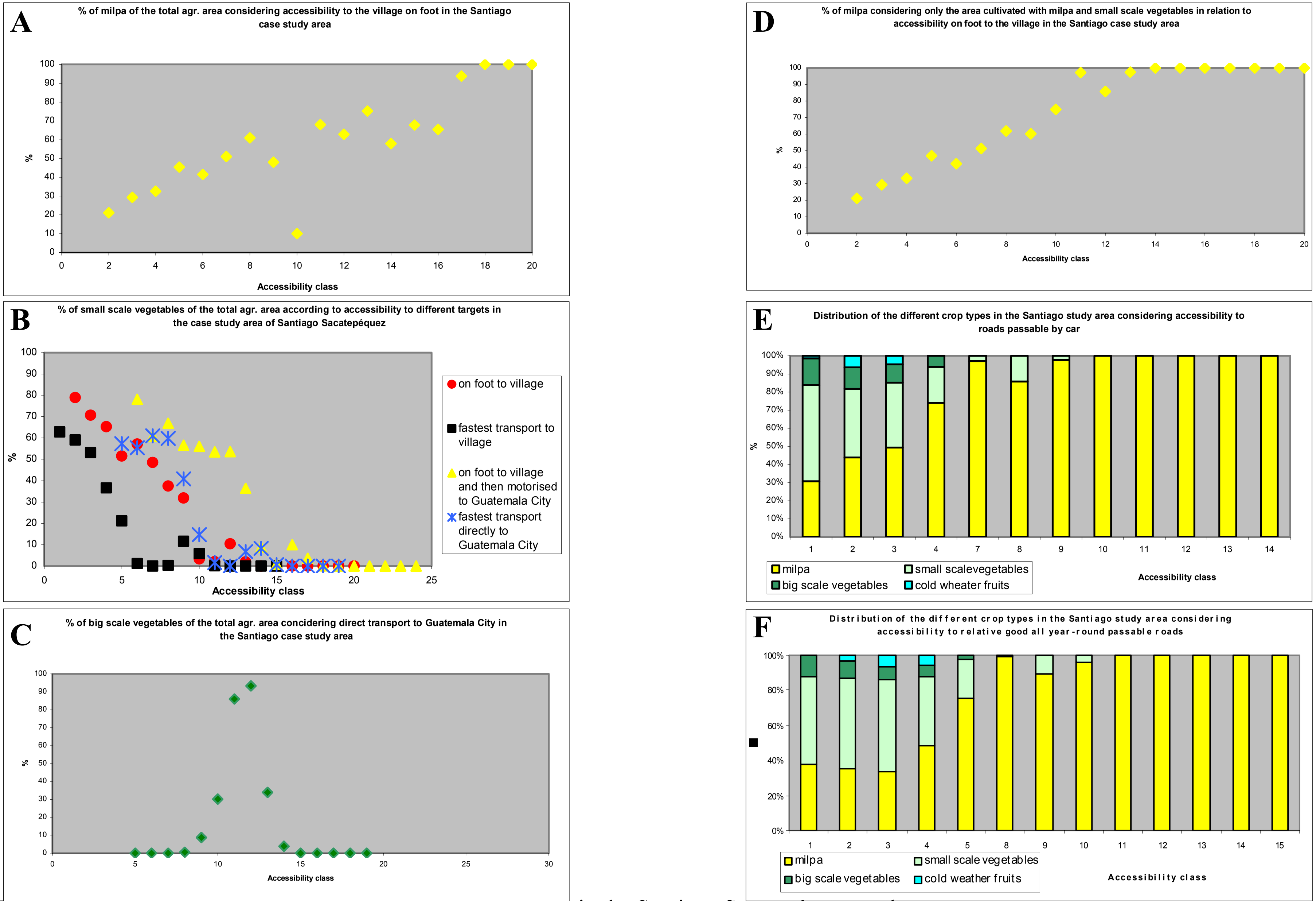


Figure 27. The relation between accessibility and crop choice in the Santiago Sacatepéquez study area. The accessibility classes are classes of 5 minutes, with class 1: 0-5 min; class 2: 5-10 min; etc.

For all four accessibility 'types', the % of the agricultural area considering the small-scale vegetables decreased strongly with decreasing accessibility. The transport on foot with the village as an end-point and the same transport but followed by motorised transport to the capital, had a negative correlation of 0.91. For the fastest transport to the village and direct transport to Guatemala City, this was respectively 0.84 and 0.87. The first accessibility 'type' was important for almost all small-farmers as daily transport to their fields was on foot. The interview results and the strong relation between this access and the number of cash crops cultivated revealed the exclusive character of the hard and time consuming daily 'walk'. As always were especially the poorest farmers affected the most as they lack horses or other transport aids and cultivate mostly the cheapest but most distant fields. Nevertheless its importance, the accessibility problem in most studies is focused solely on a global access to the urban centres, neglecting the local transport facilities. Without attention for the latter, however, the accessibility problem can never be solved.
In 1989, the International Food Policy Research Institute stated that the adoption rate to the co-operative Cuatro Pinos increased when there was access to good roads and infrastructure. Although this statement could not be checked directly as also non Cuatro Pinos farmers were considered, do the interview results and the relation considering the two relevant accessibility types (transport of the harvest to the village on foot and motorised) point in the same direction. For the farmers not connected to the co-operative, transport was considerably longer (to the capital instead of the village). The extra cost and time for these farmers, however, was outweighed by advantages like better price and direct 'contact' with the market.

It may be clear that the small farmers' choice between agriculture for subsistence and agriculture for monetary reasons was strongly intertwined with accessibility in the study area of Santiago. The principle of von Thünen (see 3.2.2), stating that high-value transport-sensible products are positioned closer to the market, proved to be still valuable here. It should, however, be noted that a relation between crop choice and accessibility not necessarily means that a part of the farmers are not able to cultivate a sufficient amount of cash crops. Even if all farmers would have enough accessible land to cultivate vegetables, the relation between access and crop choice would still exist, although in a lesser extent. This can be explained by the individual farmers' choice to cultivate cash crops in its most accessible fields (in the case the farmer owns several plots with different accessibility). This was confirmed by the interviews, in which 95 % of the interviewed persons in this case study area (n = 56) said that they cultivated the more demanding crops (like vegetables) in the most accessible of their fields and milpa in the more distant plots. Nevertheless, it is unlikely that this individual choice was the only reason for the strong relation between access and crop choice. The degree of this relation and especially the unequal land distribution (both quantitatively as spatially) indicate the exclusive character of accessibility for some farmers. This was confirmed by interviews with farmers, who only possessed fields too distant for cash crops. For these people, 'crop choice' was no longer a choice as they were doomed to cultivate only milpa. Moreover, they were mostly the poorest farmers and had no other sources of income, leaving their milpa fields the only straw left to catch at.

The relation between crop choice and access to roads passable by car (type 5 or better) and access to relative good all year-round passable roads (type 3 or better) are represented in the figures 27 E and 27 F. They are especially interesting for the crop types where motorised transport is involved. In both figures was the amount of small-scale vegetables decreasing with decreasing accessibility (correlation of respectively 0.86 and 0.93), showing the importance of the proximity to the 'motorised' road network for farmers with a car. Interviews revealed that the importance of these accessibility 'types' were considerably for this group of farmers as the transport from the field to the closest place reachable by car can be very time and labour consuming when big harvests are involved.

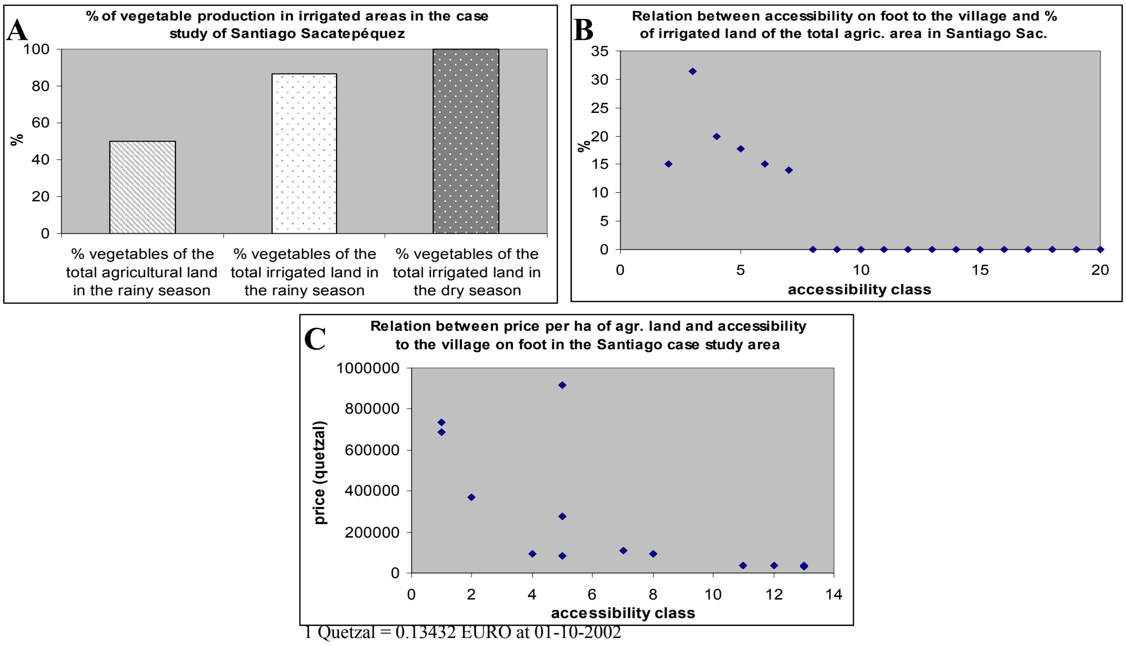
As already mentioned was the accessibility calculation of the fruit areas rather bad (see 5.1.1.4). Adding the extreme low number of fruit fields, it was cumbersome to draw any conclusions. The same applied to the big-scale vegetables (figure 27 C). The relation between access and the amount of big-scale vegetables will be checked in more detail in the case study area of San Andrés Itzapa.

As mentioned in 4.5.1, there are several other factors influencing crop choice. Factors as soil fertility, slope, aspect, temperature and rainfall seemed to have little impact on the spatial distribution of the different crops in this study area. This was confirmed by the interviews in which almost all farmers stated that accessibility was the only reason to cultivate the more demanding crops (like vegetables) in the most accessible areas. Differences in land quality land had little to do with crop choice. Nevertheless, these factors should be investigated more deeply.

A crucial factor defining the degree of vegetables in an area was irrigation. Vegetable production was considerably higher in the irrigated areas (figure 28 A). In the dry season, this was even more striking as irrigated vegetables then were the only crop type cultivated. The vegetable production and prices were good in that period of the year, making it the only crop profitable enough to overcome the high cost of irrigation. It should, however, be remarked that irrigation is not completely independent of accessibility. As irrigation was organised mostly in the villages and these urban areas were located close to water resources, the irrigated areas were located relatively 'close' to the villages (figure 28 B). Most farmers owing irrigated land cultivate a minimum of milpa in their not irrigated, least accessible land. People only owing irrigated land, also cultivate milpa but only during the rainy season and again in their least accessible fields.

Three other important crop choice factors are ground property, working power and financial means. The amount of ground on which a farmer cultivates its crops is influencing crop choice considerably. Especially for the small farmers this factor can limit crop choice. As the mean area cultivated by a small farmers family was less than one hectare (figure 21) and knowing that all farmers cultivate at least a minimum of milpa (see 3.1.2.1), only a small part is left for cash crops. The problem is not likely to improve as the population in the study area is still increasing, resulting in more people to share the land with. Remarkably also was the strong relation between price of the land and accessibility. In figure 28 C, an indication of this relation considering the accessibility to the village on foot is represented. It should, however, be noted that this figure only points out this relation but has no scientific value as such.

For small farmers with little property it is extremely difficult to improve their situation. If they don't buy extra land, these farmers are forced to cultivate milpa and if they buy land they only have the financial means to buy the cheap but also inaccessible land, again forcing them to cultivate milpa. The only possibility left is external work. This was, however, due to the economical condition of the country, cumbersome. In the case external work was done, this could also influence crop choice as people with little time left, cultivated the low labour input milpa. Moreover, this crop provided some degree of security for when the job was lost. For big farmers, the working power is also an important factor, as the cost of the employees can be considerable. As Santiago is a rather rich region, wages were too high. Moreover, the price of the ground in the most accessible areas was expensive. This results that the big farmers were rather absent in the region. The few cases in the study area were located on an accessible location for the big farmer and due to its big distance to the village the ground was rather cheap. As the citizens of Santiago were too expensive, working power was gathered (with a bus) from a region where the wages were lower (e.g. Alotenango). Also the financial means direct crop choice. Farmers lacking the monetary funds to buy the necessary inputs as pesticides or to join an irrigation project are forced to leave the cultivation of cash crop for what it is.



1 Quetzal = 0.13432 EURO at 01-10-2002

Figure 28. Other factors influencing crop choice. A-B: irrigation; C: ground. The accessibility classes are classes of 5 minutes, with class 1: 0-5 min; class 2: 5-10 min; etc.

As the spatial resolution (municipality level) of the poverty data was too coarse, the relation between crop choice and poverty and the role of accessibility on poverty could not be investigated in the Santiago Sacatepéquez case study area.

5.1.2 The case study of San Andrés Itzapa

"Yace este lugar de San Andrés Itzapa en tierra alta de despejada llanura, con claros horizontes y saludables vientos, que haciendo grata y acomodada su vivienda, su tierra fértil y sus pastos feraces y en mucho modo pingües ofrece todo, a sus habitadores mucha comodidad para la vida humana, haciéndola feliz y sin dolencias…"

"You find this place San Andrés Itzapa in a broad highland plane, with clear horizons and beneficial winds, making its houses, its fertile grounds and its fruitful pastures comfortable and agreeable and in many ways it offers abundantly everything to its inhabitants, a lot of comfort for the human life, making them fortunate and without ailments…"

by captain don Fransisco Antonoi de Fuentes y Guzmán, last decade of the 17th century (IGN, 1983).

The 43.2 square km case study area of San Andrés Itzapa was located in the east of the department of Chimaltenango (figure 12). Next to the municipality of San Andrés Itzapa, which made up the biggest area, also small parts of the municipality of Chimaltenango in the northeast, the municipality of Zaragoza in the northwest and the municipality of Parramos in the east fell in the study area. The village of San Andrés Itzapa was the only urban settlement situated in the study area itself (figure 30). Nevertheless, the city of Chimaltenango and the villages of Parramos and Zaragoza were also considered. The villages of San Andrés, Parramos and Zaragoza were mainly agricultural oriented while the city of Chimaltenango had far more other activities besides agriculture ones. According to the population census of 1994 (INE, 1994), the village of San Andrés Itzapa harboured 10622 people, while 6177 and 4913 lived respectively in the villages of Zaragoza and Parramos. The city of Chimaltenango counted 21166 citizens in 1994. In San Andrés, Parramos and Chimaltenango the majority of the population was indigenous (70 %, 53 % and 58 % respectively), while Zaragoza with only 5 % indigenous people consisted almost completely of Ladinos.

In the north and east of the village of San Andrés big planes were situated while the rest of the case study area was more mountainous. The mean altitude was 1927 m, ranging from 1640 meter on the planes to 2517 m in some mountainous parts. The lower parts of the study area there was an average temperature of 23 grades while higher in the municipality this decreased to averages of 18 grades. Rainfall, according to meteorological stations of the agronomic faculty varied between 1299 mm/year and 1323 mm/year (Consuelo *et al.*, 2001). Although no specific soil information is available for this area, the farmers described the volcanic soils on which they cultivated as fertile.

5.1.2.1 Roads and transport in San Andrés Itzapa

Also in the case study area of San Andrés Itzapa the village played a central role in the transport functioning. The same reasons as given in the Santiago case study are valid (see 5.1.1.1). Also the separation between big scale and small-scale farmers was made here. Just as this was the case in Santiago, transport of the harvest for big scale farmers was a complete motorised event with this difference that the importance of big scale agriculture was considerable higher in the San Andrés case study area.

Concerning the small-scale farmers, San Andrés Itzapa was less motorised than this was the case in Santiago. This can be seen clearly in figure 29. Although this difference between the two case study areas was not reflected in the daily transportation mean to the field as both were almost completely non-motorised, it could be seen clearly in the transport of the harvest from the field to the village. This was less motorised than this was the case for Santiago, with the horse still being the most popular transportation mode but the percentage of people carrying the harvest without any 'help' considerably higher. Another striking difference is the increasing importance of the bus as a transportation mean of the harvest from the village to the market compared to truck and car. Also the 'disappearance' of the wheelbarrow in this area was remarkable.

It can be concluded from the previous paragraph that transportation for small farmers was less 'advanced' in the San Andrés area than this was the case for Santiago. There are several reasons for this. The first one is the high percentage of milpa compared to small-scale cash crops in San Andrés Itzapa. The number of harvests from 'milpa'-

crops is less and its transport doesn't need to be so 'speedy'. Consequently, the need for motorised transport was lower. Another reason of the considerably lower amount of available cars and trucks was the fact that the region of San Andrés Itzapa was less 'capital powerful'. This will be explained further on. The lack of a good 'canalisation' of transport is a third reason. No transportation companies or no agricultural co-operatives existed in San Andrés. Especially the possible catalytic power of this last one to group and organise transport was a painful shortage. Also was the co-operation for transport between different small farmers hampered by the considerable spatial separation of these farmers, as the number of them cultivating market crops was scanty.

In the 43-km^2 case study area of San Andrés Itzapa 116.1 km of roads and tracks were found. This resulted in a density of 2.7 km per km^2, which was considerably less than the Santiago case study. Especially the roads and tracks of type four or higher were responsible for this relative small value. While roads of type one to three had almost the same density (0.76 km/km^2 for Itzapa compared to 0.79 km/km^2 for Santiago), roads of type four and higher were with 1.9 km roads per km^2 even not half as dense as in Santiago (4.4 km/km^2). Nevertheless, these roads, which cannot be passed with a speed higher than 20 km/h, still did make up 72 percent. Just as in the previous case study represented the sixth type again the largest group (35.4 %). These tracks were not accessible at all by cars or pick-ups. The same reasons as explained in 5.1.1.1 for this high amount of roads inaccessible for cars can be given. Moreover, some farmers did point out yet another problem being the lack of co-operation between the different farmers. To make roads accessible for cars, for example roads have to be broadened. This means that all farmers with a plot adjacent to this road had to cede a small part of their land to make this operation possible. The willingness and co-operation between all involved farmers can nevertheless be cumbersome. In one case the obstinacy of just one farmer blocked the plans for all persons situated on the 'wrong site' of the farmer.

As can be seen on figure 30, four bigger roads connected the village of San Andrés with the outer-world. The one with the best quality (type two) led in eastern direction to connect with the road between the cities of Chimaltenango and Antigua Guatemala. The second one also ended up in Chimaltenango and was with its 4 km even shorter.

This road, nevertheless, was hardly ever preferred as it was not completely asphalted and its quality was considerably lower. The same could be said for the third road, which led directly to Parramos. The oldest road (according to some farmers even over 2000 years old) ended up directly in the village of Zaragoza and was in a very poor condition.

In general, the road network in this case study area was extremely bad. 'Over-use', erosion and lack of maintenance could also here be appointed as the biggest problems. Improvement was needed urgently but responsibles, like the municipality, claimed lack of money.

5.1.2.2 Land-use and market situation in San Andrés Itzapa

The municipality of San Andrés Itzapa had not such a strong agricultural tradition, as this was the case for Santiago Sacatepéquez. Anno 2002 this was still the case as milpa crops still made up the biggest part of the study area. Big landowners almost exclusively cultivated cash crops. Only a hand full of small farmers sowed some cash crops. Most of the time these were traditional export crops because non-traditional ones were extremely difficult due to the lack of an agricultural co-operative as Cuatro Pinos who promoted and organised the export of these crops.

An exception to this description has to be made for a part of the study area that fell in the municipality of Zaragoza or was adjacent to it. This area had closer resemblance with the Santiago case study area than with the rest of the case study area of San Andrés Itzapa. A bigger amount of traditional and non-traditional export crops, even by the small farmers, were cultivated there.

A little bit more than one third of the total 43 km^2 study area was cultivated. From this cultivated land, 10.2 % was owned by big landowners, accounting for an average of 12.5 ha per big landowner. Compared to 0.4 ha for small farmers, this resulted in an extremely skewed landowner-ship. Milpa was the most important crop in Itzapa and made up the majority of the total cultivated area (85.5 %). This extreme high value is in strong contrast with the 47 % of Santiago. The remaining agricultural area was used for vegetables (10.5 %), strawberries (0.5 %), blackberries (1.6 %), coffee (0.6 %) and greenhouses (0.8 %).

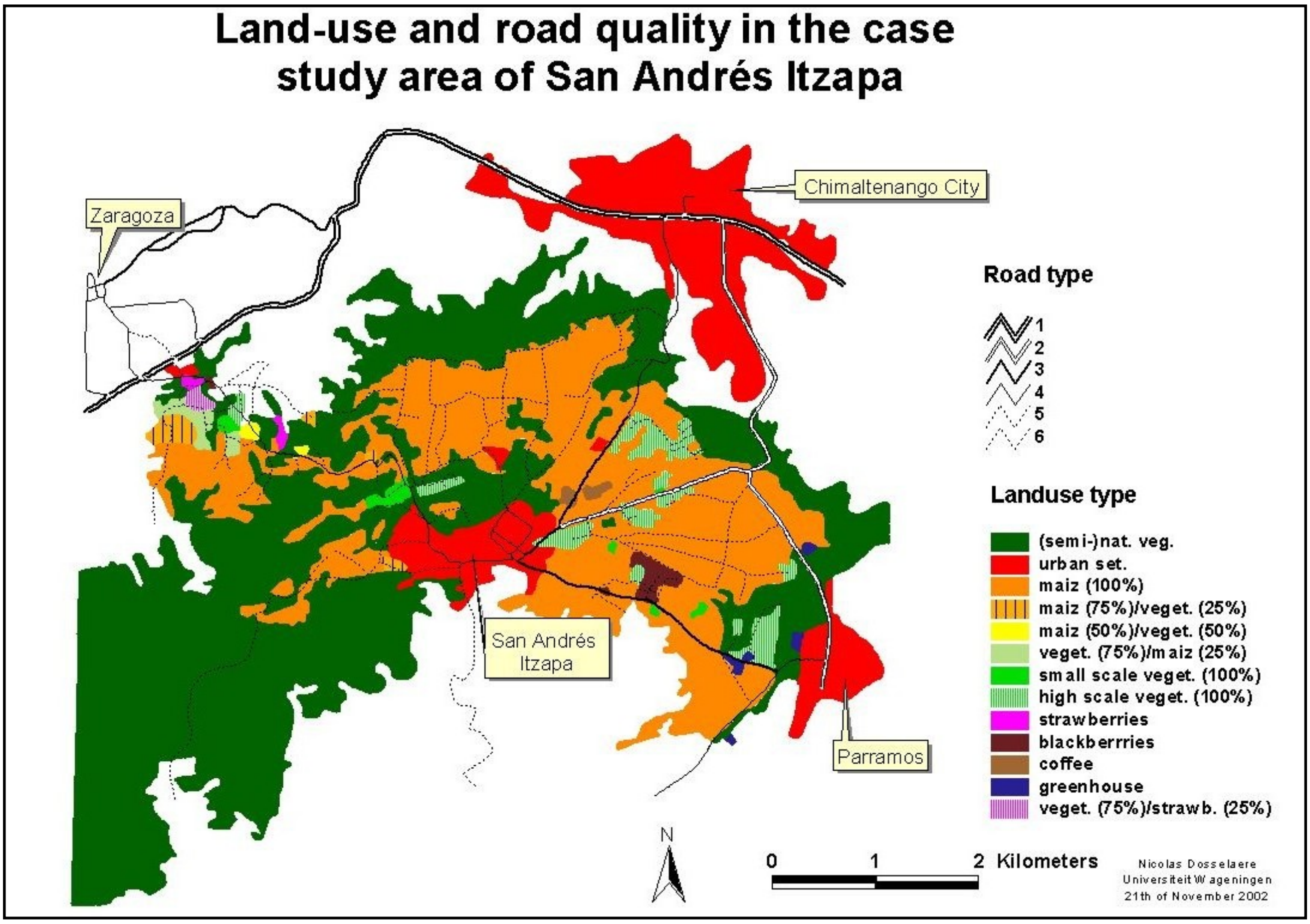


Figure 30. Map showing the land-use and road quality in the case study area of San Andrés Itzapa.

The majority of the vegetables were found on big fields, owned (or hired) by big landowners or fabrics. As already mentioned in 3.1.1.1, this was a typical high input agriculture which used a high amount of labour, agricultural tools like tractors, sophisticated irrigation systems and chemicals like pesticides and fertilisers (see figure 5 D & E). Also transport of the harvest was a private activity. In the case of fabrics, the processing and packing of some vegetables like cauliflower or broccoli even made part of the task. Although two agricultural fabrics were situated in the east of this case study area, the vegetables in the study area were not transported to these two but to other fabrics situated relatively far outside the study area. Labour, nevertheless, came from the closest village, in most cases the village of San Andrés Itzapa. Although the relative success of 'big scale'-vegetables in this area, the 'popularity' of vegetables for small farmers remained striking low (with exception of the part adjacent to Zaragoza). Besides a lack of tradition, several reasons can be given. Probably the most important and also most frustrating one was the financial condition of this area. The relative high minimum amount of inputs needed like fertilisers and pesticides made the start-off very difficult. Moreover, the market prices were not so rewarding, as was the case in the 80's and 90's. Also the fluctuation of the vegetables prices made it a risky business. Just as for Santiago, a minimum of milpa was preferred. The difference however was that the average land ownership for small farmers in Itzapa was rather low (around 0.4 ha per family), with as a consequence the need to completely cover the land with milpa to fulfil the eager for security. A fifth reason was the absence of an organising and grouping body like an agricultural co-operative. They could give technical assistance, credit to start-off and organise other expensive and difficult issues like export and transport. Especially the latter was mentioned as one of the biggest reasons why vegetables were left aside. The lack of a transport company and the high cost of buying and maintaining a car or truck made transport a considerable obstacle for this rather poor area. Some small farmers even argued that the price of the bus was to high to make it a profitable business. A last reason for the low success of 'small scale'-vegetables in this study area was the modest amount of small farmers who made use of irrigation in this region. Irrigation however would make the cultivation of vegetables a year-round business with the irrigated period even being the most lucrative one. The installation and maintenance of an irrigation system however was extremely expensive and co-operation between small-farmers consequently was a must. While this was very common in Santiago, it

seemed here to be very cumbersome. This was due to a lack of willingness of all concerned parties but also because the spatial separation of the small group of farmers who were into cultivating vegetables made co-operation impossible. Some farmers argued that the municipality had to do more effort to organise irrigation. Even if co-operation was no problem, irrigation could be hampered by the lack of a proximate, reliable water source. This can be because the water source is too distant but also because it is not gathering a constant amount of water all year-round. Moreover, in one location was irrigation aborted because the water was to pollute after passing the village. In the study area, only in two locations small farmers used irrigation, namely in the area around Zaragoza and in the bank of a river just before the village of San Andrés Itzapa. The former had a good organisation of this irrigation system. For the latter, however, any co-operation was lacking. They irrigated their fields individually without considering the others.
The soft fruits (strawberry and blackberry) are non-traditional export crops. While the western world was the only export destination for blackberry, strawberry was also sold in Guatemala. All except one of these soft fruit fields were situated in the area close to Zaragoza that had a strong tradition with these crops. The exception was a big-scale blackberry field situated on the road to Parramos. The reasons for this lack of small farmers cultivating soft fruits in this area are the same as these given for vegetables.

When the market functioning is considered, Guatemala was still the most popular market (see figure 29). This is remarkably, knowing that the market of Chimaltenango was situated at less than five kilometres from the village of San Andrés (compared to more than 40 for Guatemala City). An important distinction, however, has to be made between small and big-scale farming and the different crops. First of all were milpa crops not considered for the reasons previously mentioned in 5.2.2.2. Most big-scale vegetables were transported by the big landowner to Guatemala but most of the time with an intermediate stop in a fabric for processing and packing. For reasons of simplicity Guatemala City (without intermediate stop) was used as target location for the accessibility calculation. The little amount of vegetables cultivated by small farmers was transported most of the time to the departmental capital. Although a considerably amount still brought their product to Guatemala City, only Chimaltenango City was used as target location for this type of crops. Soft fruits had to be transported rather quickly after harvest to the airport in the capital where they were flown out of the country. All farmers, both small and big ones, were responsible for this transport to Guatemala City. Only for one 'small' blackberry farmer, a bigger company picked up the harvest.

5.1.2.3 Poverty in San Andrés Itzapa

Because the municipality of San Andrés Itzapa made up the biggest part of this case study area, only this municipality was considered for the discussion of poverty in the case study area. According to the SEGEPLAN (2001), 42.17 % of the people of San Andrés Itzapa were living in poverty and 7.22 % in extreme poverty. The severity and extreme severity indices were 6.08 and 0.42 respectively. These values were not exceptionally high compared to other municipalities of the departments of Chimaltenango and Sacatepéquez (see figures A2-A5 in appendix 2), but already considerably higher (especially for extreme poverty) than the poverty data of Santiago Sacatepéquez (see 5.1.1.3). This observation was also made during the fieldwork as financial inputs were more limited and the total living standard seemed lower. This can also be seen from figures of INE (1994), which shows that still 20 % of the people lacked electrical energy, for 13 % water delivering was still a major problem and more than one third of the families had no sanitary system. Even more striking is that more than the half of the primary students was chronically under-nourished in 2002 (ME, 2001).

5.1.2.4 Accessibility in San Andrés Itzapa

The accessibility maps for the case study area of San Andrés Itzapa are given in the figure 31-32 and in appendix 8 (figure A11-A16). The accessibility values of mainly the agriculture areas were quite accurate (tested by field data). Due to the little importance of some urban areas (especially Chimaltenango and Parramos) and remote forests, the road infrastructure was of a lesser detail in these areas, resulting consequently in proportional less accurate accessibility values there.

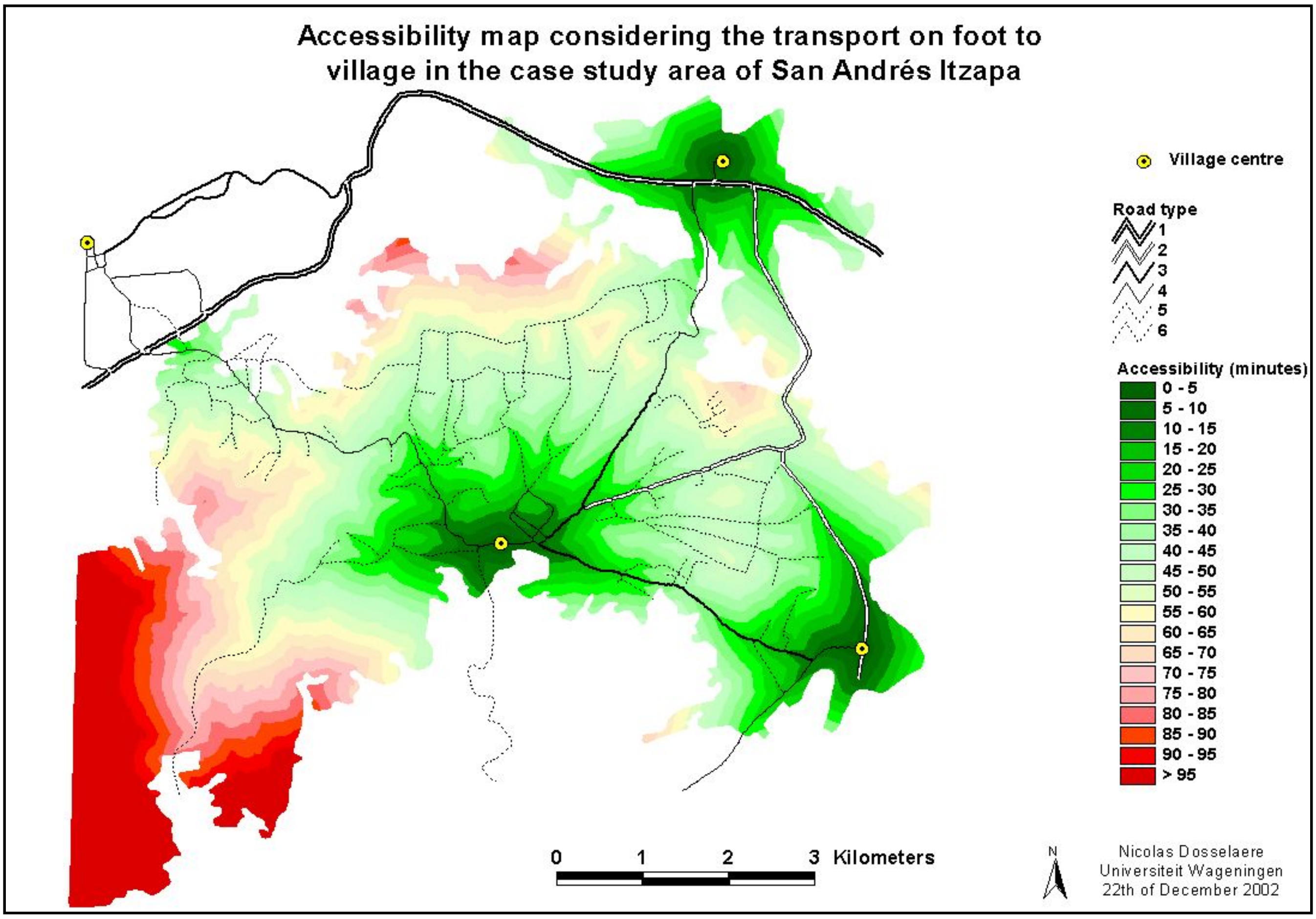


Figure 31. Accessibility map considering the transport on foot to the villages in the case study area of San Andrés Itzapa.

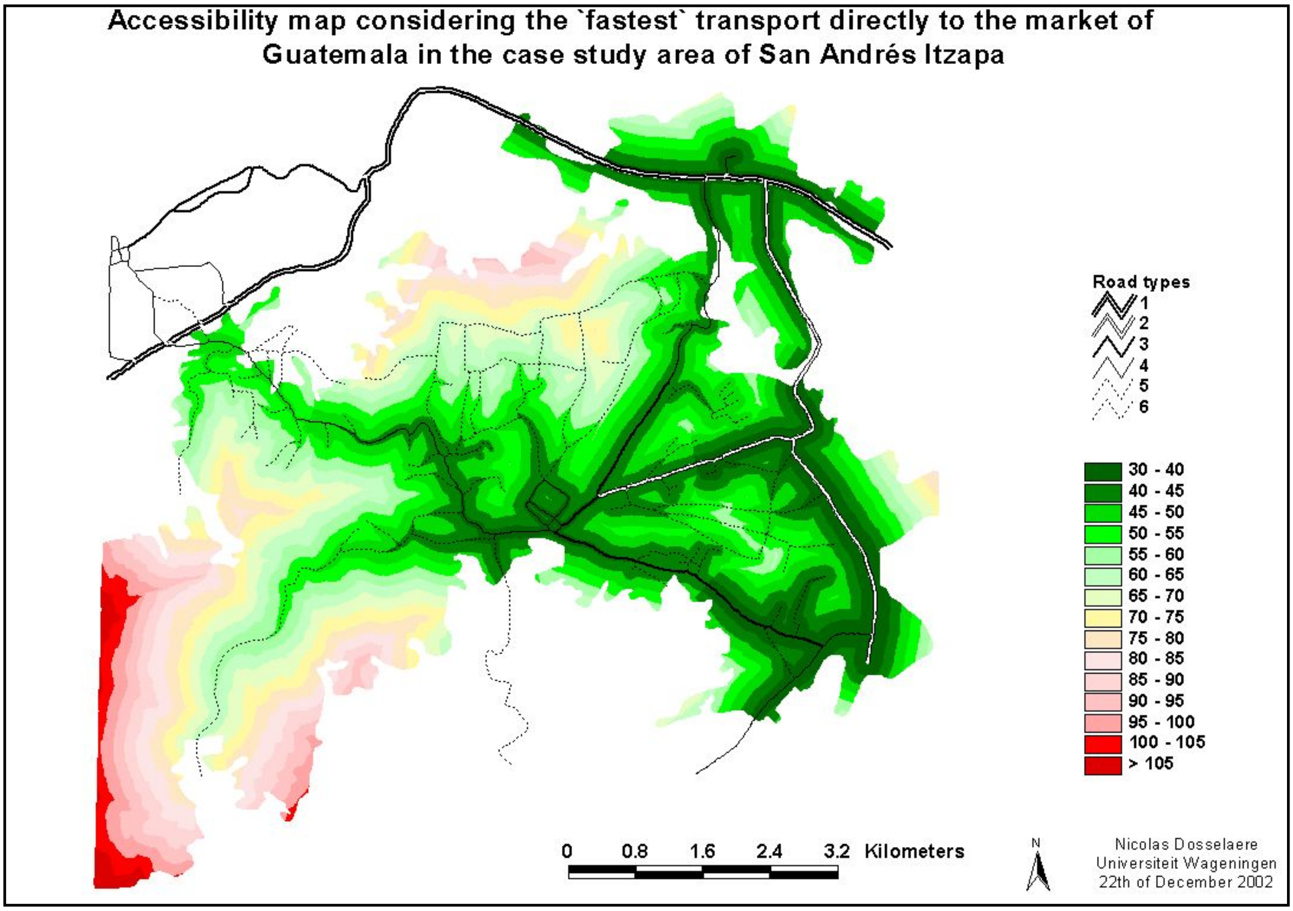


Figure 32. Accessibility map considering the `fastest` transport directly to the market of Guatemala in the case study area of San Andrés

In contrary to Santiago, no steep ravines appeared in the proximity of San Andrés. However, this study area was more extensive and the road infrastructure less dense (5.1.2.1), resulting in accessibility values of the same order as the previous case study. Remarkably also was the high amount of farmers not making optimised use of the roads (5.1.2.1). Except for the big farmers, the transport activity was largely a walking event. Investment in the local road network is a must but will only be successful if it is accompanied by other related improvements as transport facilities.

5.1.2.5 The relation between accessibility and crop choice in San Andrés Itzapa

Because all villages were considered in the accessibility calculations and the extreme vertical cost values due to ravines were lacking, the three big land-use classes were more regular distributed than this was the case for Santiago Sacatepéquez (figure 33). The urban areas dominated in the lowest accessibility classes, decreasing with decreasing accessibility. The (semi-) natural areas 'behaved' in the opposite way and were all-occurring in the most remote areas. The curve representing the relation between access and the agricultural area had a more normal distributed shape with a peak at class eight (35-40 minutes walk to the villages). Nonetheless the delineation of the different land-use types was not that sharp as described by von Thünen, it again

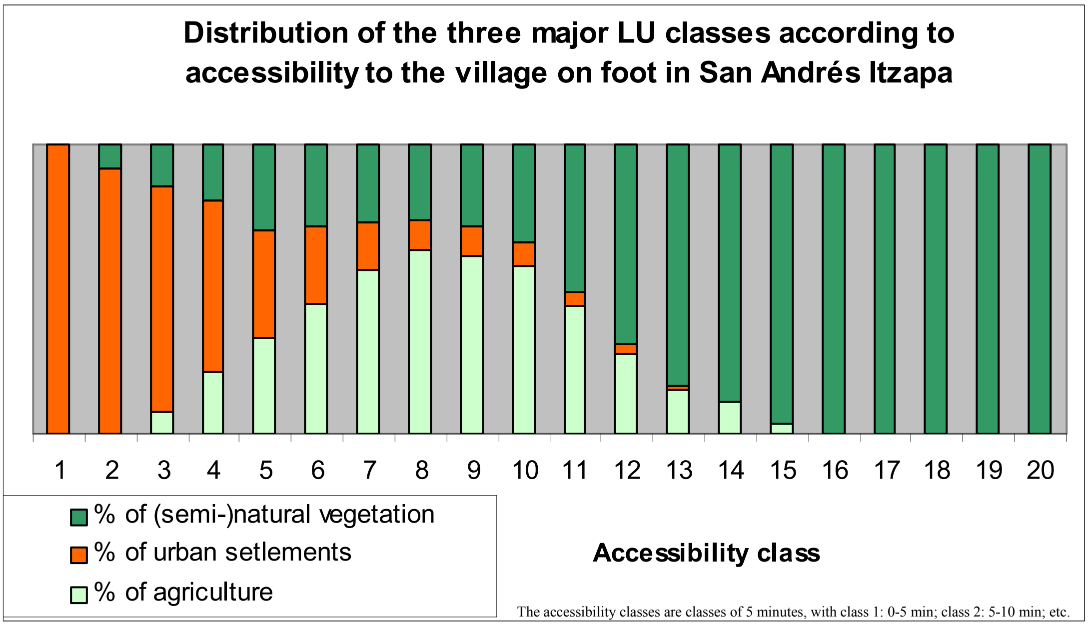


Figure 33. Distribution of the three major LU classes according to accessibility to the village on foot in the San Andrés Itzapa study area.

illustrated nicely the validity of this model. Although the economical and social role of forests as fuel provision should not be neglected, the importance of agriculture 'forced' the natural areas to the more remote regions.

With exception for the area adjacent to the village of Zaragoza, milpa completely dominated the small farmers crop choice. Nonetheless, as the success of the big scale vegetable production showed, the area was suitable for this crop type. In figure 35 A, the accessibility figures for milpa and small-scale vegetables are represented. The distribution of milpa was just like in the previous case study strongly correlated with accessibility (0.81). However, the small-scale vegetables, which behaved very irregular, were not responsible for this. Because a too small amount of small farmers cultivated this crop type and only the more remote vegetable areas of the village of Zaragoza were taken in consideration, little attention at these results should be given.

Figure 34. In the fertile but difficult accessible plain in the north of San Andrés Itzapa, milpa is the only crop type cultivated.

More interesting here are the reasons of small farmers not cultivating more cash crops. Even in the most accessible areas small farmers preferred milpa above vegetables. The reasons for this were discussed thoroughly in 5.1.2.2. Especially the

Figure 35. The relation between accessibility and crop choice in the San Andrés Itzapa study area. The accessibility

overall financial condition, tradition and 'low' land ownership can be appointed. This case study nicely illustrates the complicated nature of crop choice. Access undoubtedly influences crop choice but not necessarily in a dominating way. It can be stated that bad access unarguably is the most hampering factor for crop choice in fertile agricultural areas. However, the opposite is not true. A good access, not necessary means that the farmer's crop choice is inexhaustible and that cash crop will dominate over subsistence agriculture. As long as other factors, like financial means, impede a full crop choice, the role of accessibility will be less visible. This, however, is not a plea to neglect the accessibility problem in these regions. Accessibility still limits the crop choice but its role will only become visible under the form of spatial unequal distribution of the different crops, when the other factors reduce.

Big-scale vegetables were the second important crop type in San Andrés Itzapa. This high-valuable and transport-sensible product was encountered in the most accessible areas as can be seen on figure 35 B (correlation: + 0.89). Besides access to the capital, also the proximity of good roads is important (correlation: + 0.82; see figure 35 F). As time differences to the market ones on a good road are rather small, the most crucial transport action for big-scale farmers is the loading and unloading activity. This can be very time-consuming and labour-intensive when the field is badly reachable by truck. The fact that many big farmers invest considerably in a small road network in their field, nicely illustrates the importance of this type of reachability. However, the role of accessibility as a 'positioning factor' in this case study area is clear, it does not explain why big-scale farming was almost absent in the previous case study although accessibility to the capital in Santiago was less. While in the latter the accessible land was very expensive and wages were relative high, ground in Itzapa was five times cheaper in the most accessible areas (see figure 29) and the wages considerably lower. The proximity to villages as a source of cheap working power was important (figure 35 D). It can be concluded that localisation of big scale farming is based on a minimization of production costs. As long as access to good roads is good and over-all access to the capital is reasonable, pressing of the input costs, like ground and wages, is determinative.

Probably the same conclusions, as given for small and big-scale vegetables, can be given for the role of accessibility for respectively small and big-scale soft fruits. However, the number of fields in this case study was too small to confirm this. Moreover, the relation with accessibility was extra disturbed as the considered soft fruit area was only a rather low accessible zone of a complete soft fruit area around Zaragoza. Nonetheless, both had a positive correlation (figure 35 C).
Also the number of greenhouses was too scarce. Nevertheless, correlation with access to the capital and access to the village on foot was considerable (respectively 0.68 and 0.76). Especially the latter nicely illustrates the importance of proximity to villages as a source of working power for this labour intensive agricultural activity.

5.2 The complete study area

5.2.1 Roads and transport in the study area

The major points discussed in 5.1.1.1 and 5.2.1.1 were also valuable for the road network and transport functioning of the complete study area. While high-quality roads were too scarcely distributed and the local network was generally over-used and lacked a sufficient maintenance, differences in access to motorised transport resulted in considerable inequalities amongst farmers. The crucial role of the village and the differences between big and small-scale farmers in the transport functioning should again be taken in consideration. Nevertheless, as no spatial data were available for the latter, this factor could not be fully incorporated in this part of the study. In paragraph 3.1.2.2, a more detailed description of the road infrastructure in the departments of Chimaltenango and Sacatepéquez was given.

5.2.2 Land-use and market situation in the study area

For the reasons outlined in 4.2.2, agricultural land-use was separated into only three crop classes (milpa, vegetables and coffee). Moreover, the land-use map (figure 36) had a relative low accuracy and coverage of the area and big and small-scale farmers could not be separated. It may be clear that these factors restricted considerably its use for the analyses.
In total, 48.5 % of the classified area was agricultural. Coffee was the most represented crop in the land-use map with 58 % of the agricultural area. It was especially dominating in the south of the study area. In contrast, milpa and vegetables were found especially in the higher regions in the rest of the study area (30 % and 12 % respectively). A deeper discussion about these three crops was given in 3.1.2.1.

In order to approach accessibility in a contextual manner, it was important to get a thorough understanding of the marketing functioning. The figures 37 and A17–A19 give an indication about the distribution of the commercial agricultural products in the study area. While the impact of the markets of Chimaltenango, Sololá and Antigua was rather limited, the sphere of influence of the capital covered the complete study area. Moreover, interviews revealed the striking dominance of the market of Guatemala City, even in areas relatively close to other big markets. Only in municipalities adjacent to another market, a considerable proportion of the commercial agricultural products was sold there. As in most cases this was still less than the proportion sold to Guatemala City and transport of export products exclusively was directed to the latter, the capital was taken as the only target location in the accessibility calculation for commercial and export crops in the study area. The only exception to this story was coffee. The market functioning of this export crop was considerably different as not Guatemala City, but some ports and especially a network of intermediate middlemen and pre-processing factories were vital points in its distribution. However, due to lack of access to the coffee plantations and time restrictions, this topic could not be investigated sufficiently in this work.

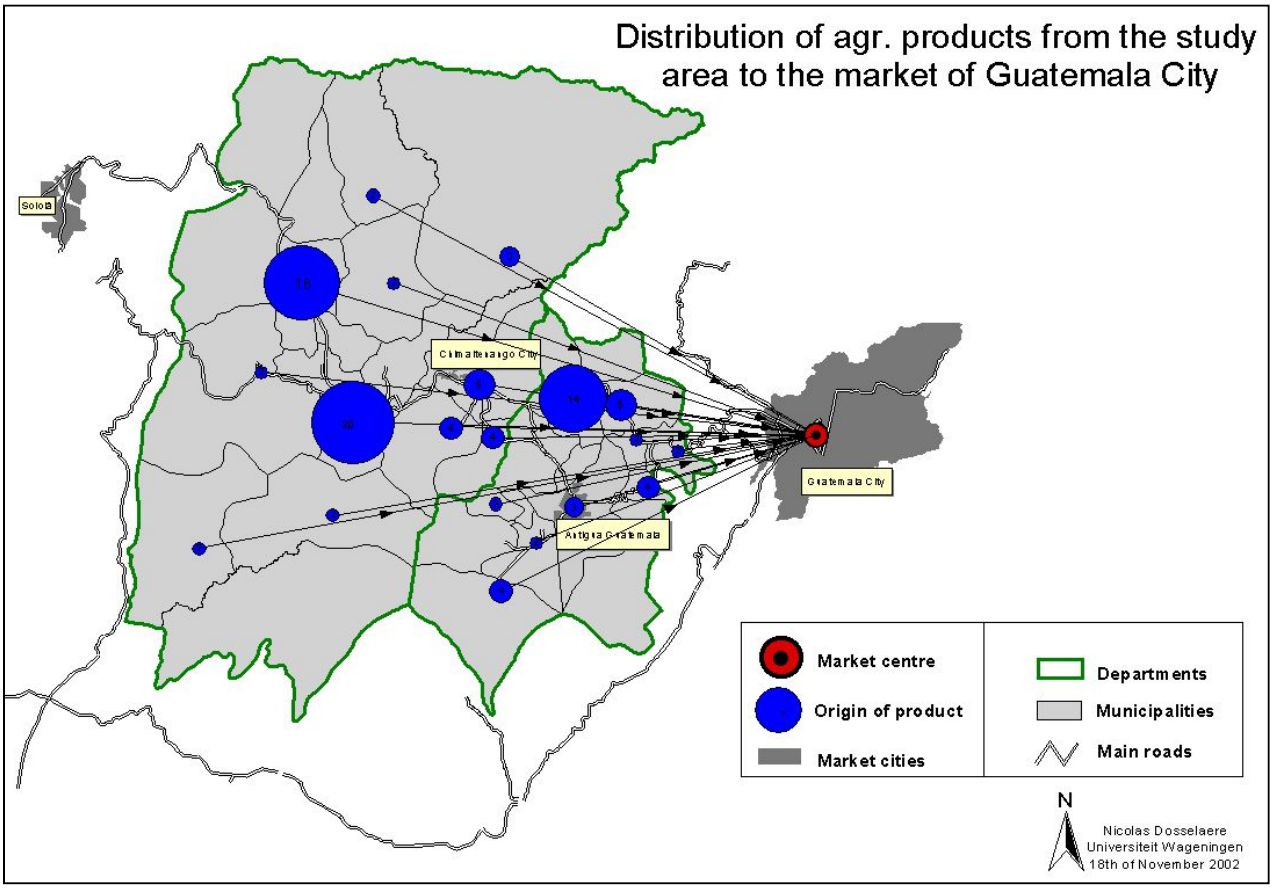


Figure 37. Map representing the distribution of agricultural products from the study area to the market of Guatemala City.

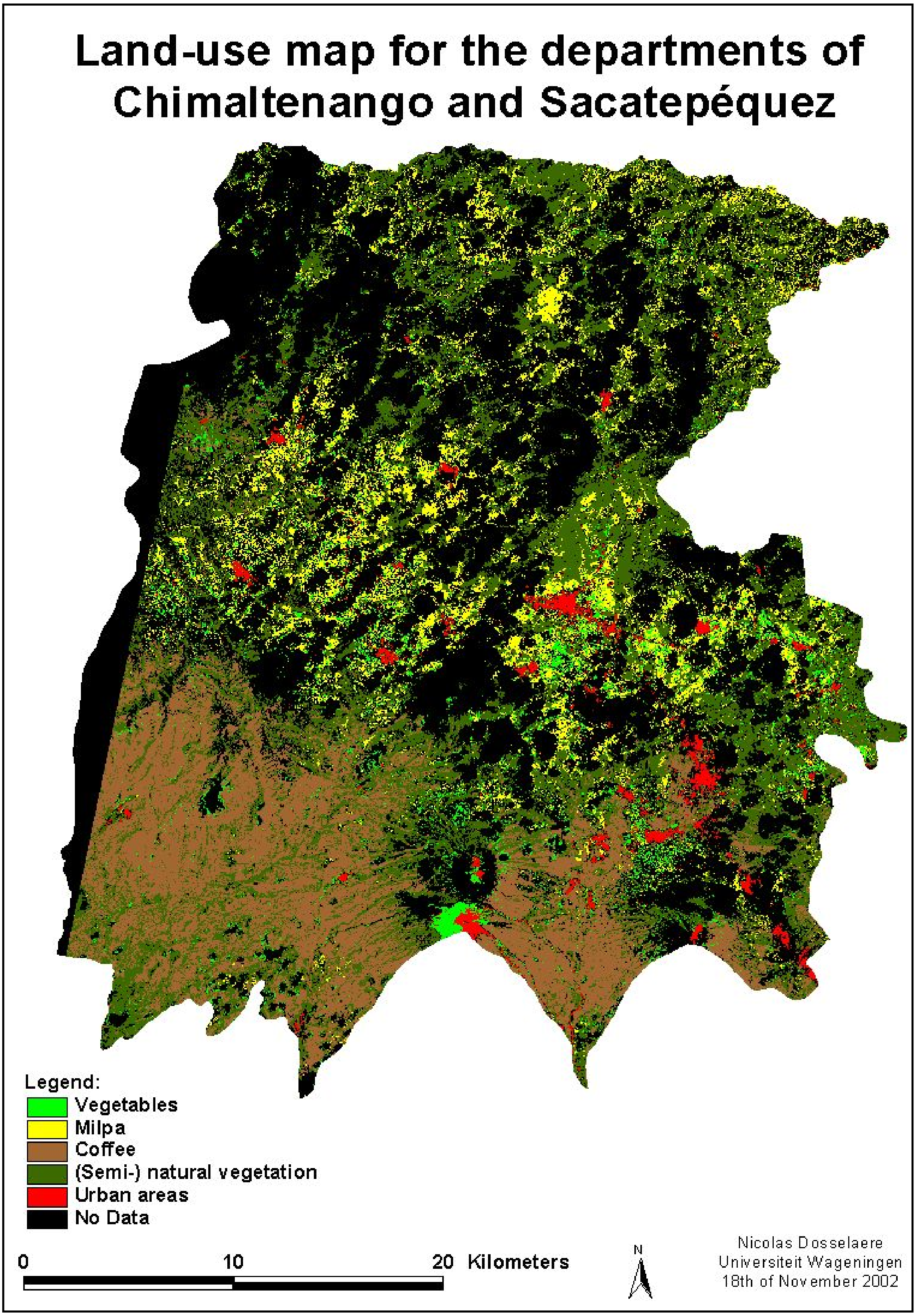


Figure 36. Land-use map for the departments of Chimaltenango and Sacatepéquez.

5.2.3 Poverty in the study area

A description of the poverty situation in the study area and an overall discussion of the poverty problem were given in respectively 3.1.2.3 and 3.1.1.3.

5.2.4 Accessibility in the study area

The different types of accessibility in the study area are represented in the figures 38 and A20-A26. While the quality of the accessibility values of the different villages to the targets was quite satisfactory, local variations were represented insufficiently. This is a pity as the previous case studies have proven the importance of the local road network in the accessibility problem.

In both the relations with land-use and poverty, the most important accessibility type was this one considering transport on foot to the village, followed by a motorised transport to Guatemala City (figure 38). The case studies and other interviews had shown its relevance for small-scale farmers and their choice between subsistence and cash crops. However, for big-scale farmers direct transport to the capital was more appropriate. As big and small-scale farming could not be separated at this level of detail and the latter were more important for the region and this study, the village as an intermediate target was taken in consideration. Moreover, the importance of the village as a source of working power and its central role in the transport network justified also its use for the big-scale farmers. The biggest drawback encountered for the relation between accessibility and crop choice using this accessibility type was the different market functioning of coffee. For reasons of simplicity and lack of information about the local situation of this crop, the same accessibility as for the vegetables was taken. Concerning the relation with poverty, the dominance of Guatemala City as a selling and working centre in the study area and its central role in the spatial perspective of the poverty problem (see 3.1.1.3 and 3.2.1), justified the use of accessibility to the capital.

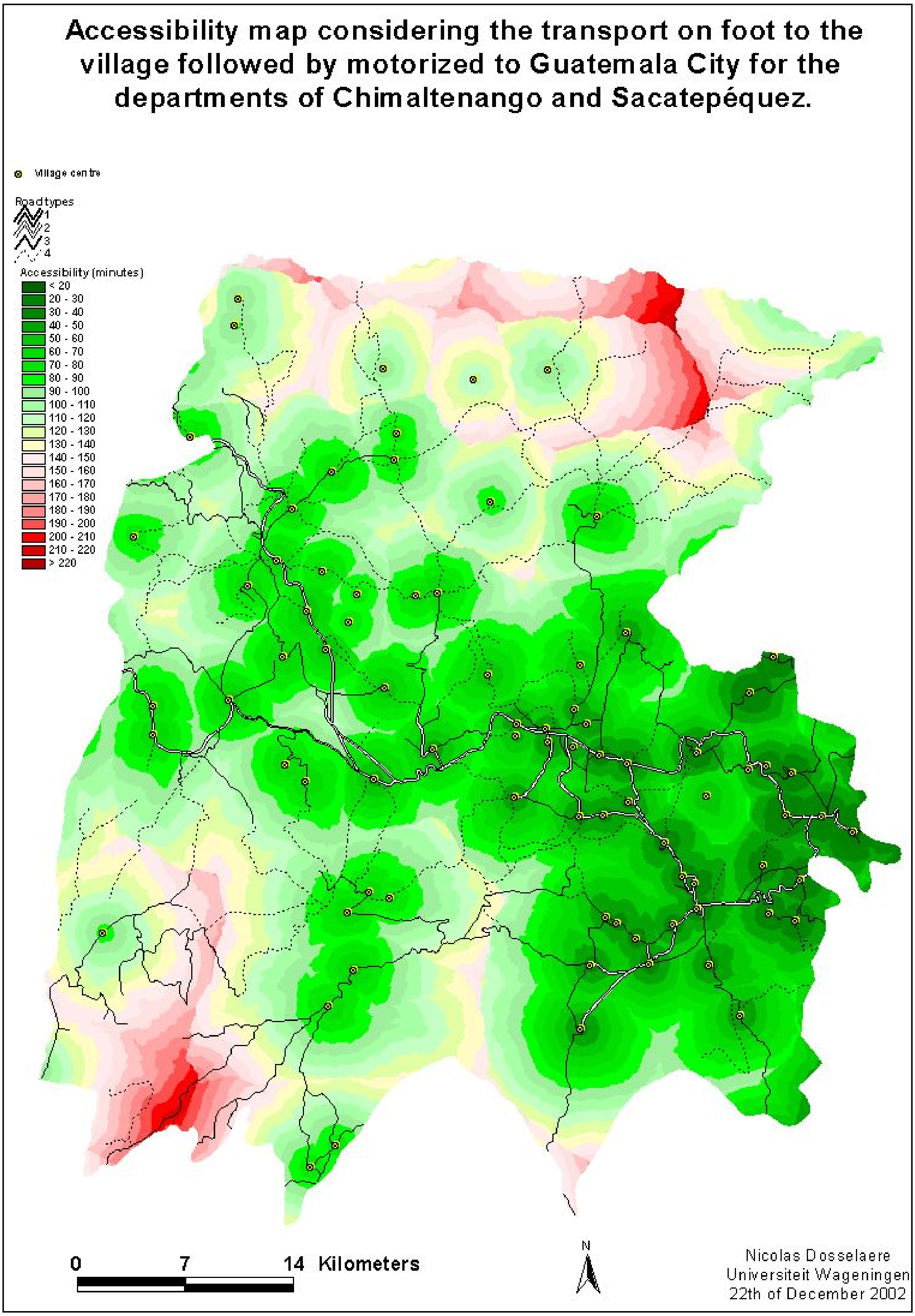


Figure 38. Accessibility map considering transport on foot to the village followed by motorized transport to Guatemala City for the departments of Chimaltenango and Sacatepéquez.

5.2.5 The relation between accessibility and crop choice in the whole study area

The figure 39A represents the relation between accessibility and crop choice in the departments of Chimaltenango and Sacatepéquez. While high valuable vegetables were spatially distributed according von Thünen's model, milpa 'behaved' extremely odd with a positive correlation between accessibility and this crop. As the major cause, the strange distribution and high (over-) representation (see 4.2.2.3) of coffee can be assigned. Although the accessibility topic for coffee was investigated too scarcely, the interviews did not confirm the negative correlation of coffee with access. Some reasons can be appointed. Nonetheless the weighted users accuracy (see 4.2.2.3) was quite high (83 %), the traditionally difficult distinction between coffee and forests can be assigned as one of the major reasons. As in local remote areas agriculture and forest are respectively scarcely and abundantly represented (see e.g. figure 33), even relative low misclassifications can result in huge over-estimations of the % of coffee in these remote agricultural areas. Moreover, the 'coffee municipalities' were situated in the more distant zones of the study area (figures 37 and 38), consequently increasing the percentage of coffee in higher accessibility classes. As already mentioned in the previous sections, accessibility for coffee should be approached in a different way. Other targets and the degradation of the importance of the villages as coffee is largely a big-scale agricultural activity in this region, would alter the distribution of coffee. Nevertheless, as coffee transport is less 'urgent' (less perishable and lower mass density), and other factors like tradition and environmental factors (e.g. temperature) are more prevailing, accessibility probably is a less influencing factor in the positioning of the coffee plantations. More investigation on this subject is recommended. In order to analyse the influence of access on the other crops, the study area was split up in two. While the municipalities, in which more than 50 % of the agricultural area was classified as coffee, were grouped, the rest of the municipalities formed the 'non-coffee region'.

The farmer's choice between agriculture for subsistence and for monetary reasons was strongly intertwined with accessibility in the study area. In both the complete study area as the non-coffee region (figures 39B and C), the choice between vegetables and

milpa was strongly correlated with accessibility (both respectively 0.85 and 0.89). While the high-value transport-sensible vegetables were positioned closer to Guatemala City, subsistence crops became the dominating choice in the more distant areas. For the former, this strong relation still stood when also coffee was considered (even in the coffee municipalities, see figure 39D). The reasons for the relation between access and the choice of vegetables/milpa were already discussed thoroughly in 5.1.1.5 and 5.1.2.5.
Nonetheless the rather poor quality of the local road network, figures 39E and F confirmed the importance of the local accessibility and the proximity of good roads in the non-coffee municipalities of the study area. The former is especially crucial for the small farmers as the village plays a central role in the transport functioning (see 5.1.1.1). Although for big-scale farming the village is also important as a source of working power, access to good roads seems more important (see 5.1.2.5).

More attention to other crop choice influencing factors, accessibility for coffee, the use of more crop types, the distinction between big and small-scale agriculture and a better land-use map are recommended for further research.

In figure 40, the choice of milpa/vegetables and accessibility to the capital were spatially combined. While in the east of the study area good access and a high amount of cash crops (green colours) went hand in hand, in the north the combination of bad access and high occurrence of subsistence agriculture (purple colours) was dominating. It nicely illustrated once more the potential selective character of accessibility on crop choice. However, 'purple colours' do not automatically mean that the improvement of the road infrastructure would introduce a boom of cash crops. As seen in the case study of San Andrés Itzapa, also possible other constraining factors (e.g. lack of financial inputs and land-ownership) should be considered. The more bluish colours (better access but still relative low cash-crop production) in the middle and eastern side of the study area illustrated this statement. It should, however, be noted that the factors directing farmers in cultivating subsistence crops do not necessary have a constraining character. Factors, like the proximity of a fabric (e.g. Tecpán Guatemala), can make the farmers choose to diminish their traditional agricultural activity and cultivate exclusively milpa in order to reduce labour input and to have something up one's sleeve in case the job would be lost. Moreover, the

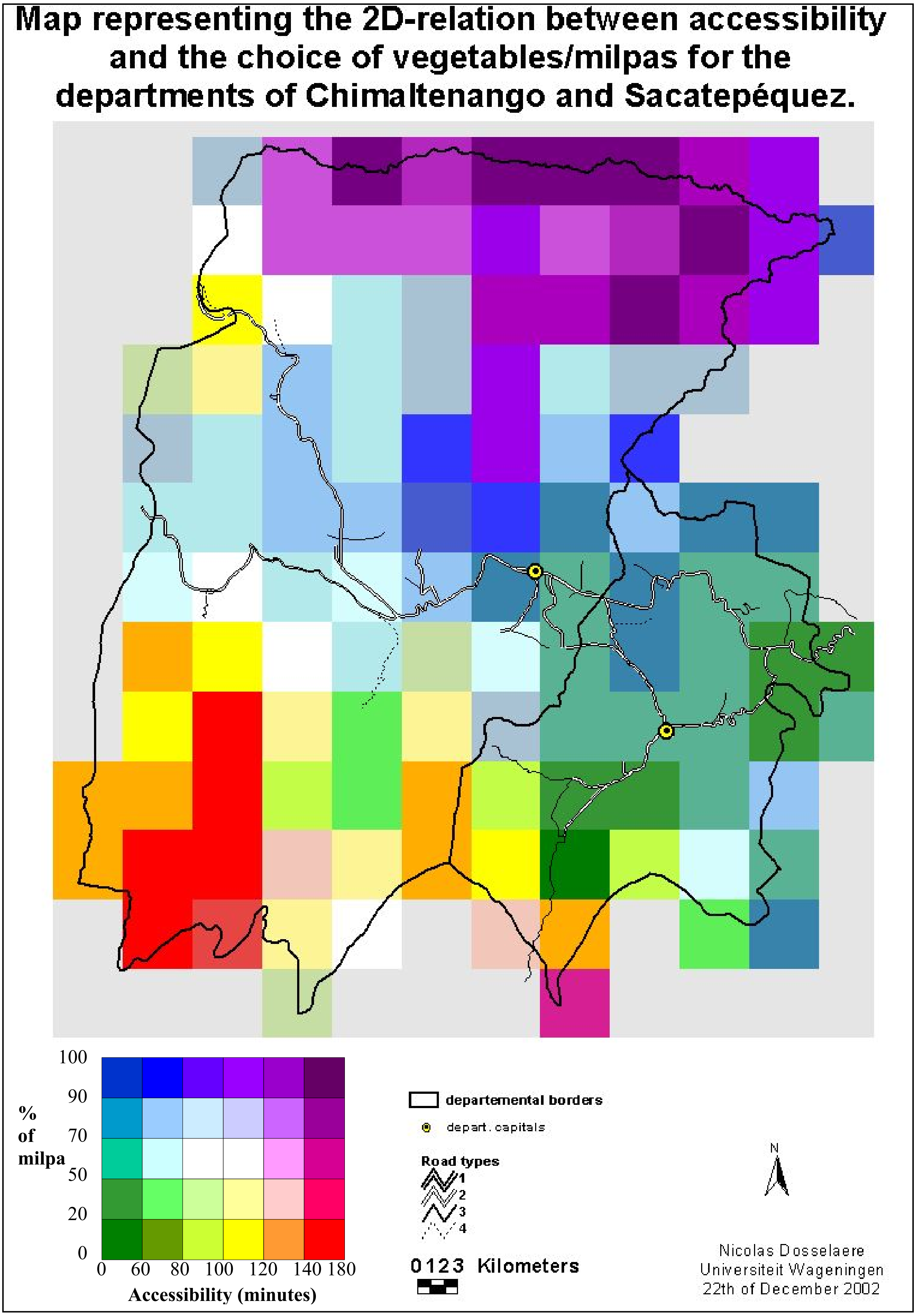
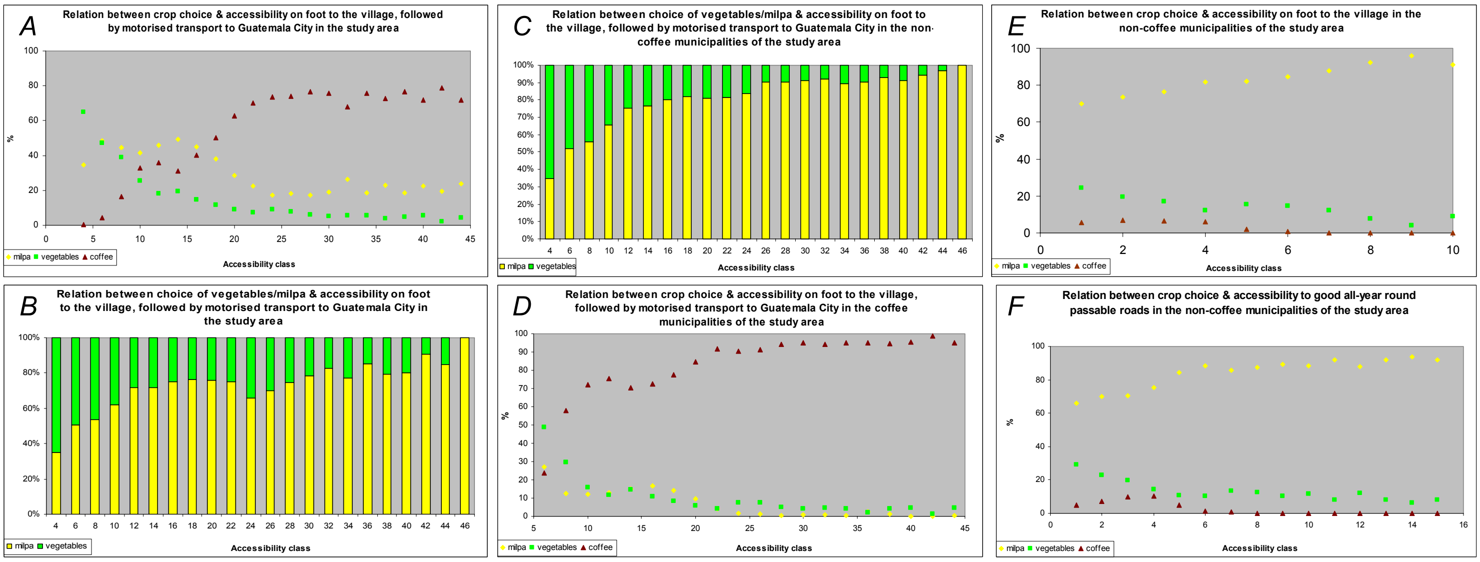


Figure 40. Map representing the 2D-relation between accessibility and the choice of vegetables/milpa for the departments of Chimaltenango and Sacatepéquez.

Relation between crop choice & accessibility in the departments of



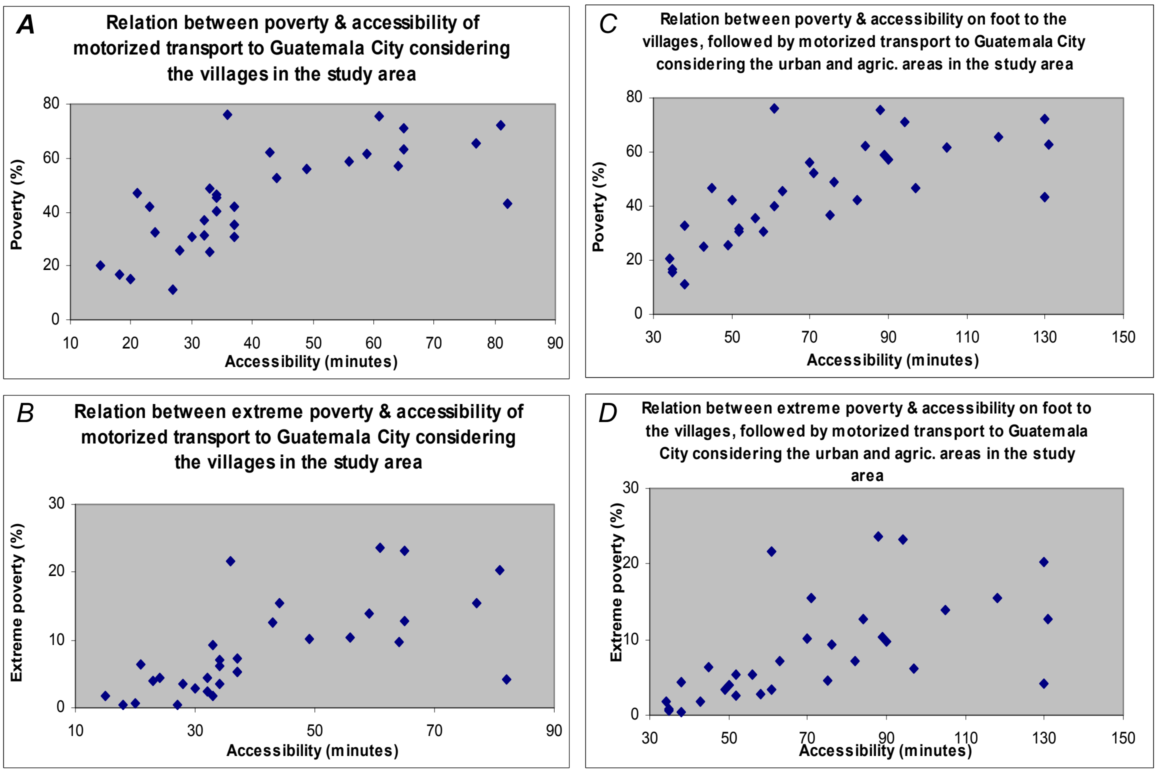
igure 39. Relation between crop choice & accessibility in the whole study area. The accessibility classes are classes of 5 minutes, with class 1: 0-5 min; class 2: 5-10 min; etc.

relative higher accessibility in these regions does not mean that accessibility was already sufficient. Especially the local accessibility in these regions was still grave, introducing big inequalities amongst farmers of the same community (see e.g. Santiago Sacatepéquez). In the south-west of the study area a remarkable combination of low accessibility and still a high vegetable/milpa proportion was found. Although too little fieldwork was performed in this area, some reasons can be given. In the first place the amount of classified milpa and vegetables in this region was very low. This low number and the knowledge that this part of the study area was more big-scale oriented, made the amount of big-scale vegetables in the overall vegetable production more pronounced and as a consequence, the percentage of milpa decreased considerably. A detailed study, also considering land-ownership and the local road infrastructure, should be executed to be decisive in this part of the study area.

It may be clear that accessibility in the study area played a dominant role in the small farmer's choice between subsistence and cash crop agriculture on the one hand and the constant battle between big and small-scale agriculture on the other hand. In order to lower the fundamental inequalities amongst farmers of the former, it is crucial to improve the road network. However, this should be done in an object-oriented approach, considering contextual circumstances of accessibility, agriculture and other crop choice influencing factors. The 2D-analysis proved to be a useful indicating tool. It can help locating the areas where 'aid' should be focused on and can point out the occurrence of other important constraining crop choice factors.

5.2.6 The role of accessibility on poverty in the whole study area

As can be seen in figure 41, accessibility to the capital was strongly related to poverty in the study area. This was confirmed by the positive correlations of 0.72 and 0.73 for access considering respectively the urban areas and the 'living environment' (see 4.5.2). As the study area was particularly agricultural oriented, the small difference between these two different approaches was not surprisingly. Nonetheless, more research about the degree in which accessibility in the different land-use types influences poverty is recommended (see 4.5.2). Also extreme poverty, although in lesser extent, was positively correlated with both types of accessibility (0.66 and 0.60).



1. The relation between poverty and accessibility in the study area.

The results of this detailed study nicely illustrated the effectiveness of accessibility as a poverty trap and its crucial role in breaking down the dualism of society. The improvement and maintenance of the overall and local road network is an indispensable step to a sustainable development of the study area (see 3.2.1). Besides the social dimensions (equality), also the economic/financial (continuation) and environmental/ecological ('quality of life') sustainability should be taken in granted (Worldbank, 2003).

The 2D-analysis shows the spatial distribution of poverty and its relation with accessibility (figure 42 en 43). The least accessible areas in the north and the south of the study area corresponded in general with a high degree of poverty (purple colours). In the east, good access was intertwined with relative high prosperity. In the middle and the west, where lighter blue and white colours dominated, an intermediate situation was found. It may be clear that these types of maps are an excellent indicating tool in order to decrease poverty by means of accessibility improvement.

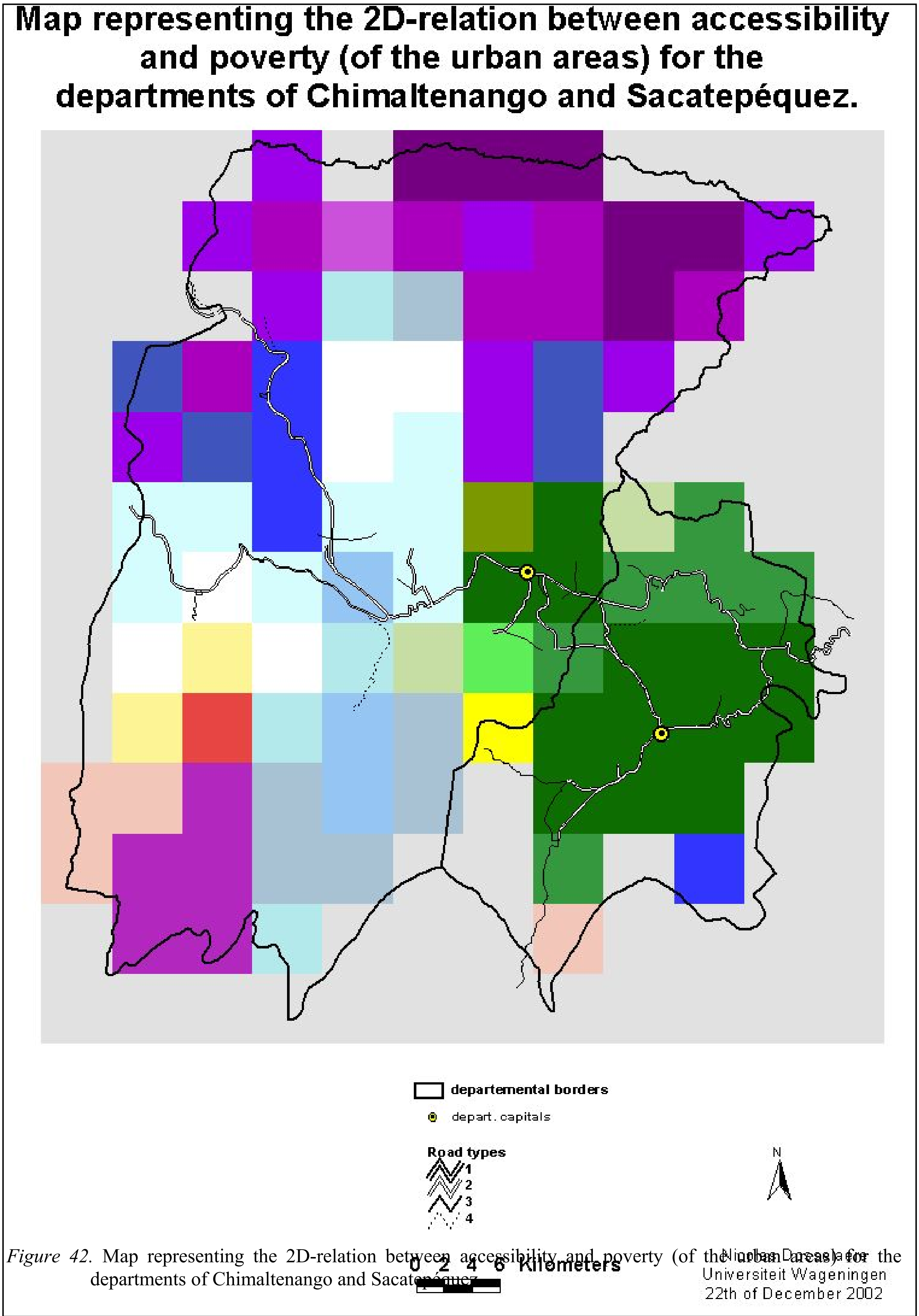


Figure 42. Map representing the 2D-relation between accessibility and poverty (of the urban areas) for the departments of Chimaltenango and Sacatepéquez.

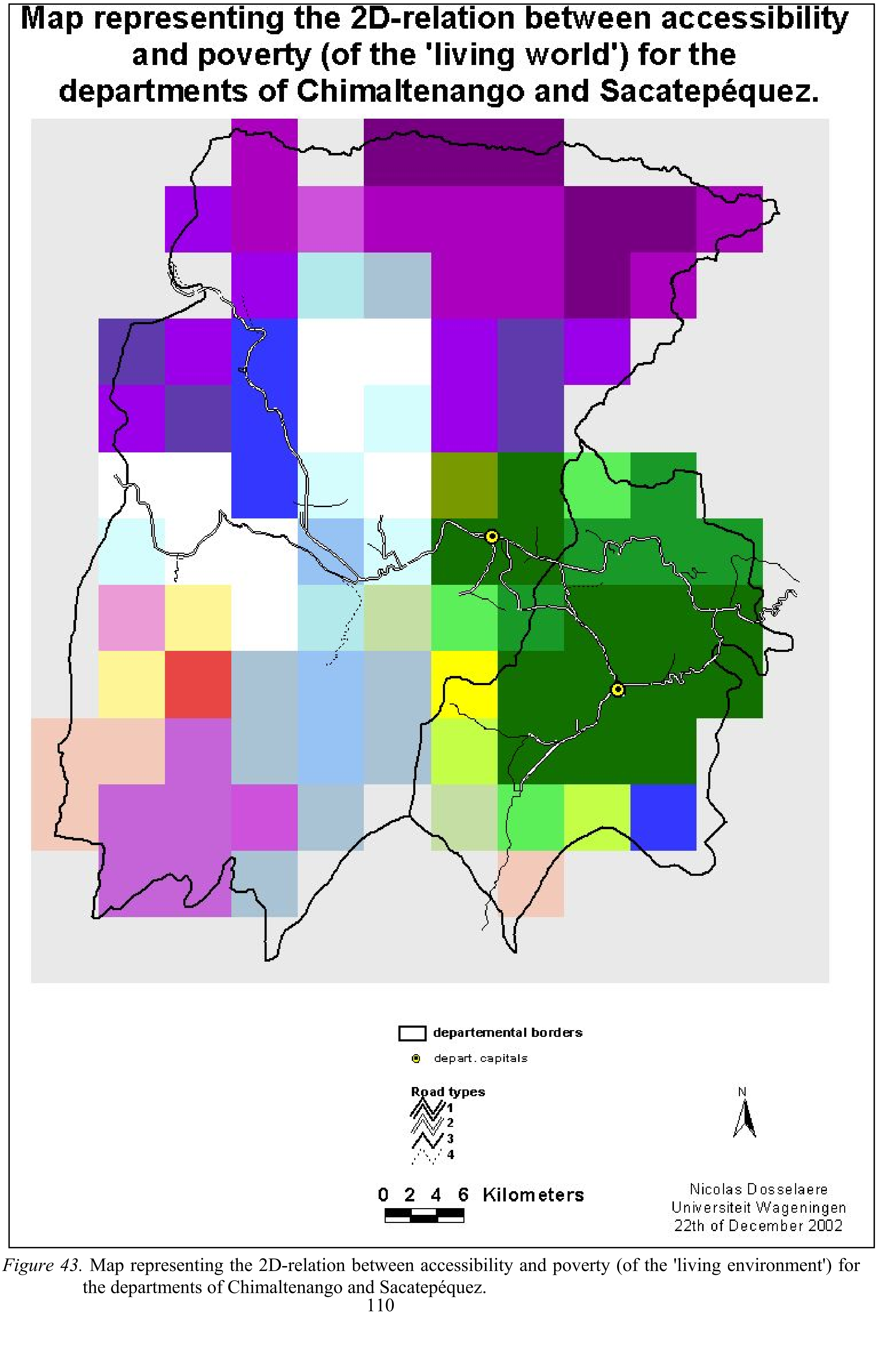


Figure 43. Map representing the 2D-relation between accessibility and poverty (of the 'living environment') for the departments of Chimaltenango and Sacatepéquez.

Moreover, it also locates areas where accessibility is less related with poverty. In the dark blue colours for example other fundamental problems were more responsible for the high poverty rate. In contrast, in the red pixels, bad accessibility did not seem to hamper development in the same amount as it did in other areas. Nevertheless, it should be remembered that even in the richer municipalities of this study area, the percentage of pover people was substantial and that a better accessibility also there would stimulate the welfare.

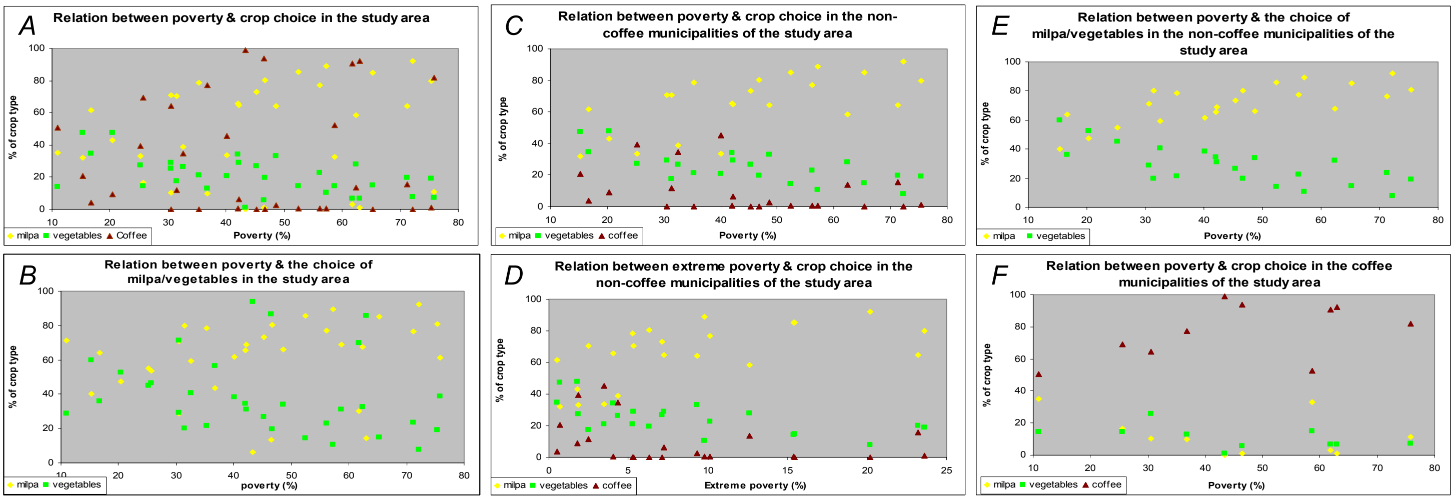
5.2.7 The relation between poverty and crop choice in the whole study area

Although coffee is a cash crop, its representation was un-correlated with poverty in the study area (figure 44A). Besides the rather low return rates of coffee in recent years, the strong amount of big-scale coffee plantations in the study area can be assigned as the major cause. As big-scale farmers seldom life and consume in the municipality and wages in the coffee plantations were modest, revenues of big-scale farming only flow for a small part into the community. This is nicely illustrated when the study area was split up in a coffee and a non-coffee area. In the latter, in which coffee was more small-scale oriented (e.g. San Martin Jilotepequez), the amount of cultivated coffee was negatively correlated with poverty (figure 44C), showing the possible positive effect of this cash crop on the community. In contrast, in the coffee municipalities, where big plantations were dominating, high representations of coffee corresponded with higher poverty (figure 44F).
For vegetables and milpa the same reasoning can be followed. While the percentage of vegetables and milpa was only slightly correlated with the percentage of pover people when the complete study area was considered (figure 44A), a relative strong correlation (-0.64 and 0.70) was found for respectively milpa and vegetables in the non-coffee municipalities (figure 44C). The same applied to the extreme poverty (figure 44D). The high influence of the un-correlated coffee on the percentages of the other two crop types and the higher proportion of big-scale vegetable farming in the coffee municipalities can be assigned as the two major reasons for the lower correlation in the whole study area. When the choice of milpa/vegetables in the non-coffee municipalities (figure 44E) was considered, a strong correlation (0.73) was

found. This is logic, as agriculture is for many people the only source of income. It can be concluded that, in general, poverty and the degree in which small farmers cultivate cash crops were clearly related in the study area. The effect of big-scale cash crop farming on poverty seemed more negative but more research, focusing on the land-ownership topic, is recommended. It should also be noticed that the relation between crop choice and the poverty distribution can work in both ways, leaving the question of cause and consequence open (see 3.3.3).

The 2D-analysis (figure 45) was again a useful visualisation tool as it showed how poverty and crop choice were spatially related. The trends discussed in the non-spatial analysis were confirmed. While in the non-coffee municipalities the relation was quite straightforward and according to a positive correlation between poverty and percentage of milpa (purple and green colours), in the coffee municipalities, located in the south of the study area, this was less the case. The blue colours and even the green colours can be questioned for the same reasons mentioned in the previous paragraph. More research is needed. Especially an analysis of the role of big-scale farming on poverty and the other way around could point out some crucial elements in the debate of the relation between poverty and crop choice in this region. The high degree of subsistence agriculture combined with a relative low poverty around Chimaltenango City can be explained by a ‘highly rewarding’ labour attraction of the departmental capital. However, as the farmers’ proportion of the overall rather rich non-agricultural citizens was rather limited, more fieldwork is needed to point out if this low poverty also applies to its farmers' community and that the choice of subsistence agriculture was indeed a ‘luxury choice’.

Relation between poverty & crop choice in the departments of



igure 44. Relation between crop choice & poverty in the whole study area

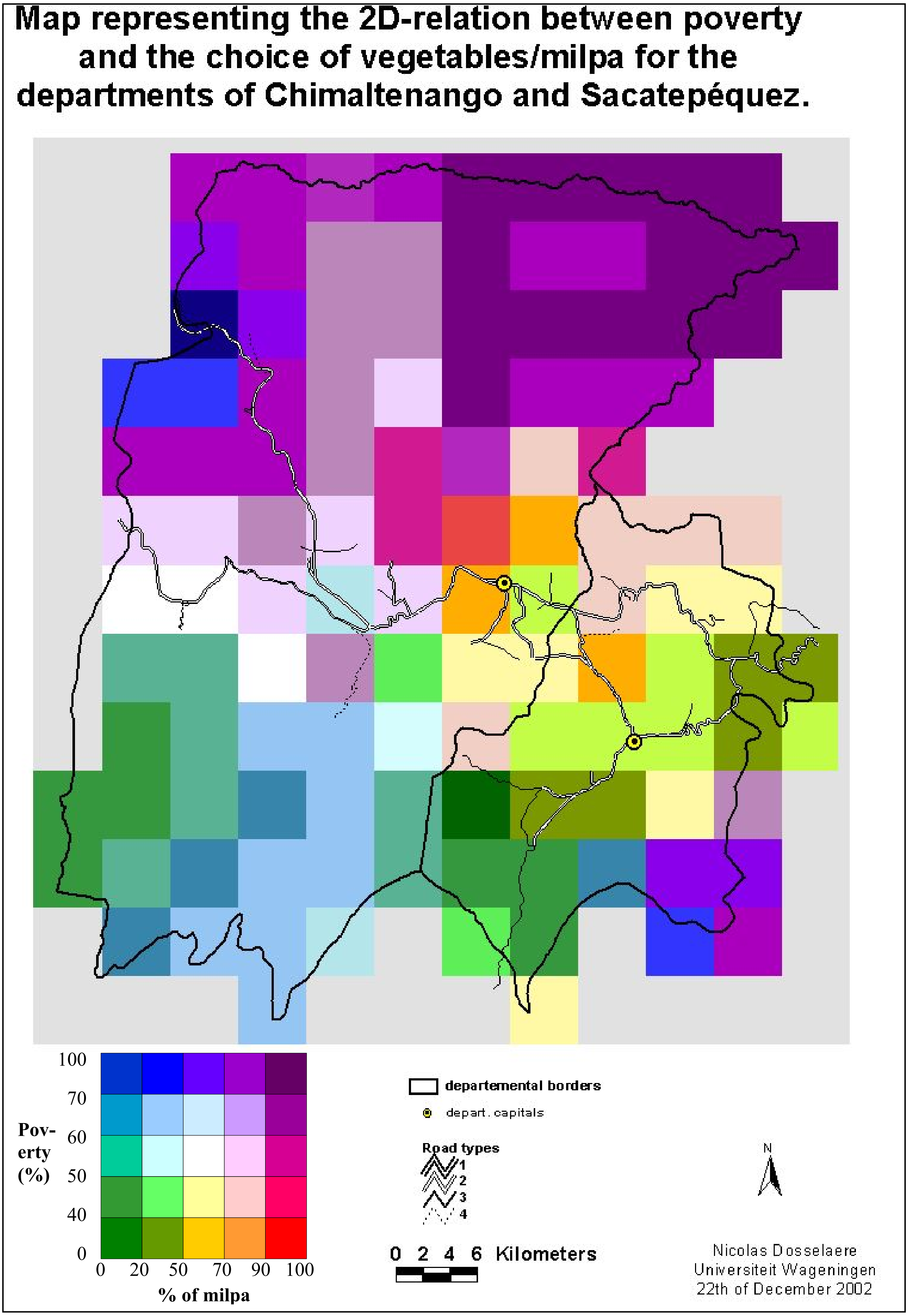


Figure 45. Map representing the 2D-relation between poverty and the choice of vegetables/milpa for the departments of Chimaltenango and Sacatepéquez.

Conclusion and recommendations

Development economists usually ignore spatial variability and are more concerned with general production inputs and outputs. This detailed study that related accessibility with crop choice and poverty in a contextual manner, counteracted this reasoning by underlining the importance of the spatial dimensions in the development problem. In the following section, the research questions are answered and some suggestions for further research are outlined.

1) Does accessibility influence the crop choice in the study area?

Although the study area did hold some strong trumps concerning the agricultural commercialisation, cash crop production was still modest. Accessibility, undoubtedly, played a central role in the difficult and uneven distribution of these crops in the study area. However, as accessibility is not a standard notion and its relation with crop choice depends on the crop type, on the local situation and on the type of farmer (small or big-scale), different combinations of crop type and accessibility were considered.

Throughout this work, accessibility was strongly correlated with the small farmer's choice between agriculture for subsistence (milpa) and for monetary reasons (e.g. vegetables). Bad access, unarguably, could be assigned as the most hampering factor in fertile agricultural areas. However, the opposite was not true. A good access did not necessary mean that the farmer's choice was inexhaustible and that cash crops were dominating the agricultural scene. As long as other factors, like financial means, impeded a full crop choice, the effect of accessibility was less visible. Its role became especially distinctive under the form of spatial unequal distribution of the different crops, when the impact of the other factors started to reduce.
While for small farmers transport on foot to the village, followed by motorised means to the market, was the most important accessibility to consider, big-scale farming was more sensible for the proximity of good, all year-round passable roads. This access and the minimalisation of other input costs, like price of the ground and wages, were more determinative factors for the localisation of big-scale farming than the overall access to the capital.

In order to diminish the fundamental inequalities amongst farmers, this work clearly demonstrated the must to improve the road network. However, aid should not be focused solely on a global access (high mobility) to the urban centres. As the local road network (basic accessibility) proved to be crucial in the small farmer's crop choice, the accessibility problem will never be solved without attention for the latter. Moreover, as high amounts of people do not make optimised use of the available roads and as motorised transport is exclusive for poor people, the effect of accessibility improvements would be rather limited for a considerable part of society, unless it is accompanied by attention to e.g. improvement of the non-motorized transport or the public transport.

2) *Is there a relation between accessibility and poverty in the departments of Chimaltenango and Sacatepéquez?*

The answer is affirmative as poverty and accessibility were strongly correlated in this study area. These results nicely illustrated the effectiveness of accessibility as a poverty trap and its crucial role in the development process. Notwithstanding, governments and development specialists usually ignore the spatial variability of poverty. However, internal diversification and growth in the poor rural regions by taking away constraining factors like lack of accessibility, should result in possibilities for the local economy and, as a consequence for the whole development of the country. Sustainable investment in the road infrastructure and its maintenance is an excellent development strategy, as it reaches better the target group than e.g. the traditional economical support.

3) *Is there a relation between crop choice and poverty in the study area?*

In general, poverty and the degree in which small farmers cultivate cash crops were clearly related in the study area. The effect of big-scale cash crop farming on poverty seemed more negative. More research, focusing on the land-ownership topic, is recommended.

The ILO (1998) have proposed that 'integrated rural accessibility planning provides a solid starting point for local realities and understanding what is happening from the point of view of socio-economic development in many critical areas of rural life'. This research confirmed this statement. An accessibility map can directly point out some problem areas and suggest priorities for further action and investments. It is an excellent and rather cheap tool to obtain an idea of the crop marketing and poverty situation. However, accessibility and its relations with crop choice and poverty should be approached in an object-oriented way, considering contextual circumstances by means of fieldwork. Moreover, also the 2D-analysis (a spatial visualisation of the relations) proved to be a useful and rather cheap indicating tool. It can help locating the areas where 'aid' should be focused on and can point out the occurrence of other important constraining factors.

It may be clear that the use of better input-data (e.g. a high qualitative DEM and land-use map) would considerably increase the quality of the analysis. Moreover, more attention at other crop types and, more in particular the accessibility of coffee is recommended. The same applies to the distinction between big and small-scale farming. An analysis of the role of big-scale farming on poverty and the other way around could point out some crucial elements in the debate of the relation between poverty and crop choice in this region. In the methodology to relate poverty with accessibility, the major bottleneck was the calculation method of the mean accessibility in a certain area. As accessibility is not equally influencing poverty over a whole area, the knowledge about the degree in which accessibility in the different land-use types influences poverty is crucial for further research.

In order to get a full understanding of the impact of accessibility, crop choice and poverty on each other, it is crucial to consider also the other influencing factors. As these could only be touched briefly in this work, more emphasis on these factors is strongly recommended. Moreover, the analyses in this work did not consider the time factor. However, it should always be remembered that accessibility could change quickly in time, but little is known about its dynamic link with poverty (Gannon and Liu, 1997) and crop choice. A thorough study about the impact of accessibility changes on the spatial variation of poverty and crop choice over time is needed. In order to evaluate the applicability of the results encountered in this work in other regions, the study area should also be extended to other parts of the world.

Poverty is in the beginning of the third millennium a true anachronism. In order to reduce the gap between rich and poor, it is fundamental to tackle the accessibility problem. Its efficiency as a poverty trap and its ability to degrade 'crop choice' into an insignificant term, converts it into a central issue in the development problematic.

References

Agexpront. (2002). Exportaciones: la experiencia de una década; Análisis de las exportaciones período 1990-1999. http://www.agexpront.org.gt.

ASTER. (2002). http://asterweb.jpl.nasa.gov.

Barwell, I. (1996). Transport and the Village: Findings from African village-level travel and transport surveys and related studies. World Bank Technical Paper N° 344, Washington D.C., World Bank. 66 p.

Carletto, C. (2000). Non-traditional crops and land accumulation among Guatemalan smallholders: Is the impact sustainable? FCND discussion paper No. 80. International Food Policy Research Institute, Washington, D. C., USA.

CATIE. (1984). Characterización ambiental y de los principales sistemas de cultivo en fincas pequenñas in Chimaltenango, Guatemala. Informe Téchnico No. 37. CATIE, departemento de Producción Vegetal, Turrialba, Costa Rica. 141 p.

CBS. (2002). http://www.cbs.nl.

Christaller, W. (1933). Central places in Southern Germany (trans. Baskin C. W. in 1966). Englewood Cliffs: Prentice-Hall.

Congulton, R. C. (1991). A review of assessing the accuracy of classifications of remotely sensed data. Remote Sensing of environment.

Consuelo, R. P., Aju, M. E. & Jiménez, L. T. (2001). Monografía diagnostica del municipio de San Andrés Itzapa. Unpublished report of the ‘Universidad Rafael Landivar’.

Deaton, B. J. & Nelson, G. L. (1992). “Conceptual Underpinnings of Policy Analysis for Rural Development”. Southern J. Agric. Econ., 24: 97-99.

Deaton, B. J. & Weber, B. A. (1988). “The Economics of Rural Areas.” In: Agriculture and Rural Areas Approaching the Twenty-first Century. Hildreth, R. J., Lipton, K. L., Clayton, K. C. & O’Connor, C. C. (eds.). Iowa State Univ. Press, Ames.

Deckers, J. A., Nachtergaele, F O. & Spaargaren, O. C. (1998). World Reference Base for Soil Resources. Introduction. First Edition. International Society of Soil Science (ISSS), International Soil Reference and Information Centre (ISRIC) and Food and Agriculture Organisation of the United Nations (FAO). Acco Leuven. 165 p.

Deichmann, U. (1997). Accessibility indicators in GIS. Department for Economic and Social Information and Policy Analysis. United Nations Statistics Division. 146 p.

DPE, Dirección General de Caminos & Ministerio de Comunicaciones, Infraestructura y Vivienda. (2001). Longitud de la red vial de Guatemala. http://www.segeplan.gob.gt.

Driessen, P. M. & Dudal, R. (1991). The major soils in the world. Lecture notes on their geography, formation, properties and use. Agriculturale University Wageningen , and Katholieke Universiteit Leuven.

ERSDAC. (1998). ASTER Level 1 Data Products specification. Version 1.2. http://asterweb.jpl.nasa.gov.

ESRI (2001). ArcDoc Version 8.1 ARC/INFO Help. Environmental Systems Research Institute, Inc.

FAO. (2002). http:\www. fao.org.

Ganon, C. A. & Liu, Z. (1997). ''Poverty and transport'', Discussion Paper No. TWU-30. http://www.worldbank.org/transport.

Goodall, B. (1987). The Facts on File Dictionary of Human Geography, Facts on File Publication, New York.

Hentschel *et al.* (1998). Combining census and survey data to study spatial dimensions of poverty. World Bank Policy Research Working Paper 1928.

Hite, J. (1999). The Thünen model as a paradigm for rural development. http://www.strom.clemson.edu/opinion/hite/thunen.html.

Horst, O. H. (1989). The persistence of *milpa* Agriculture in highland Guatemala. Journal of Cultural Geography, 9(2): 13-31.

IGN. (1983). Diccionario Geográfico de Guatemala. Francis Gall. Guatemala, C. A.

ILO. (1998). Accessibility planning and Local Development. Technical report.

INE. (1994). Tenth Population Census / Fifth Housing Census http://www.segeplan.gob.gt.

INE. (1999). Encuesta Nacional de Ingresos y Gastos Familiares 1998-1999. INE, Guatemala. p. 228.

INE. (2002). http://www.ine.gob.gt.

Johnson, E. A. J. (1970). The organisation of space in developing countries. Camebridge, Mass.: Harvard Univ. Press.

Krueger, C. & Enge, K. (1985). Security and development conditions in the Guatemalan highlands. Washington, DC: WOLA.

Leclerc, G. (2001). The Accessibility Wizard, a computer application that evaluates and maps "accessibility" and allows to define a new, flexible, ecoregional areal unit, the Econoshed. http://gisweb.ciat.cgiar.org.

Lillesand, T. M. & Kiefer, R. W. (2000). Remote sensing and image interpretation. 4th ed. John Wiley & Sons, New York. 724 p.

ME. (2001). Censos de Talla Escolar 2001; http://www.segeplan.gob.gt. (DESNUTRICIÓN CRÓNICA DE ESCOLARES DE PRIMER GRADO DE PRIMARIA.)

MAGA & Plan de Acción para la Modernización y Fomento de la Agricultura Bajo Riego (PLAMAR). (1999a). Caracterización del departemento de Sacatepéquez. Segeplan, Guatemala.

MAGA & Plan de Acción para la Modernización y Fomento de la Agricultura Bajo Riego (PLAMAR). (1999b). Caracterización del departemento de Chimaltenango. Segeplan, Guatemala.

MAGA. (2001). El Estadística de Precios de Productos & Insumnos Agro-pecuarios. Sistema de informacion de mercados. 119 p.

MAGA. (2002). http://www.maga.gob.gt.

MPHSAS. (2000). Indicadores de mortatilidad. http://www.segeplan.gob.gt.

NASA. (2002). http://ltpwww.gsfc.nasa.gov.

Nations, J. & Nigh, R. B. (1980). The evolutionary potential of Lacandon Maya sustained-yield tropical forest agriculture. Journal of Anthropological Research, 36(1).

Nelson, G. (1984). “Elements of a paradigm for Rural Development”. Amer. J. Agric. Econ., 66: 694-700.

Nelson, A. (2000). Accessibility, transport and travel time information. http://gisweb.ciat.cgiar.org

Nyron, R. F. (1983). Guatemala: A country study. Foreign Area Studies. Washington, D.C.: American University.

Pearson, F. II. (1990). Map Projections: Theory and Applications. Boca Raton, Florida: CRC Press.

Ravallion, M., 1996, "Issues in measuring and modeling poverty", Economic Journal, 106: 1328-1343.

SEGEPLAN. (2001). Mapa de pobreza de Guatemala (Instrumentos para entender el flagelo de la pobreza en el país). SEGEPLAN, Guatemala. 37 p.

SEGEPLAN. (2002). http://www.segeplan.gob.gt.

Smith, C.A. (1972). The domestic marketing system in Western Guatemala: an economic, location and cultural analysis. Stanford university, PhD. University Microfilms, A XEROX company, Am. Arbor, Michigan, USA.

Smith, C.A. (1975). Examining stratification systems through peasants marketing arrangements: an application of some models from economic geography. Man (N.S.), 10: 95-122.

Smith, C A. (1976). Regional Analysis. Two Vol. 1 Vol.: Economic Systems. 2 Vol.: Social Systems. New York, Academic Press.

Smith, C. A. (1984a). Local history in global context: Social and economic transitions in western Guatemala. Comparative Studies of Society and History 26(2): 193-227.

Smith, C. A. (1984b). Labour and international capital in the making of a peripheral social formation: economic transformations of Guatemala, 1850-1980. In: Seventh Annual political Economy of the world System Conference, Duke University, Durham, North Carolina, April 1983. Castro-Klarén, S. (Ed.).

Smith, C.A. (1990). The militarisation of civil society in Guatemala. Latin American Perspectives, 67(17): 8-41.

Snyder, J. P. (1994). Map Projections: A Working Manual. USGS Professional Paper 1395. Third Printing.

Talbot, J. M. (1997). “Where does your coffee dollar go in?”. Tea and Coffee Journal.

USGS (2002). http://edcdaac.usgs.gov

Watanabe, J. (1981). Cambios económicos en Santiago Chimaltenango, Guatemala. Mesoamérica 2(2): 20-41.

WOLA. (1988). Who pays the price? The cost of war in the Guatemalan highlands. Washington, DC: WOLA.

Worldbank. (2003). Sustainable transport: The role of transport. http://web.worldbank.org.

Appendix

Appendix 1:Poverty in Guatemala

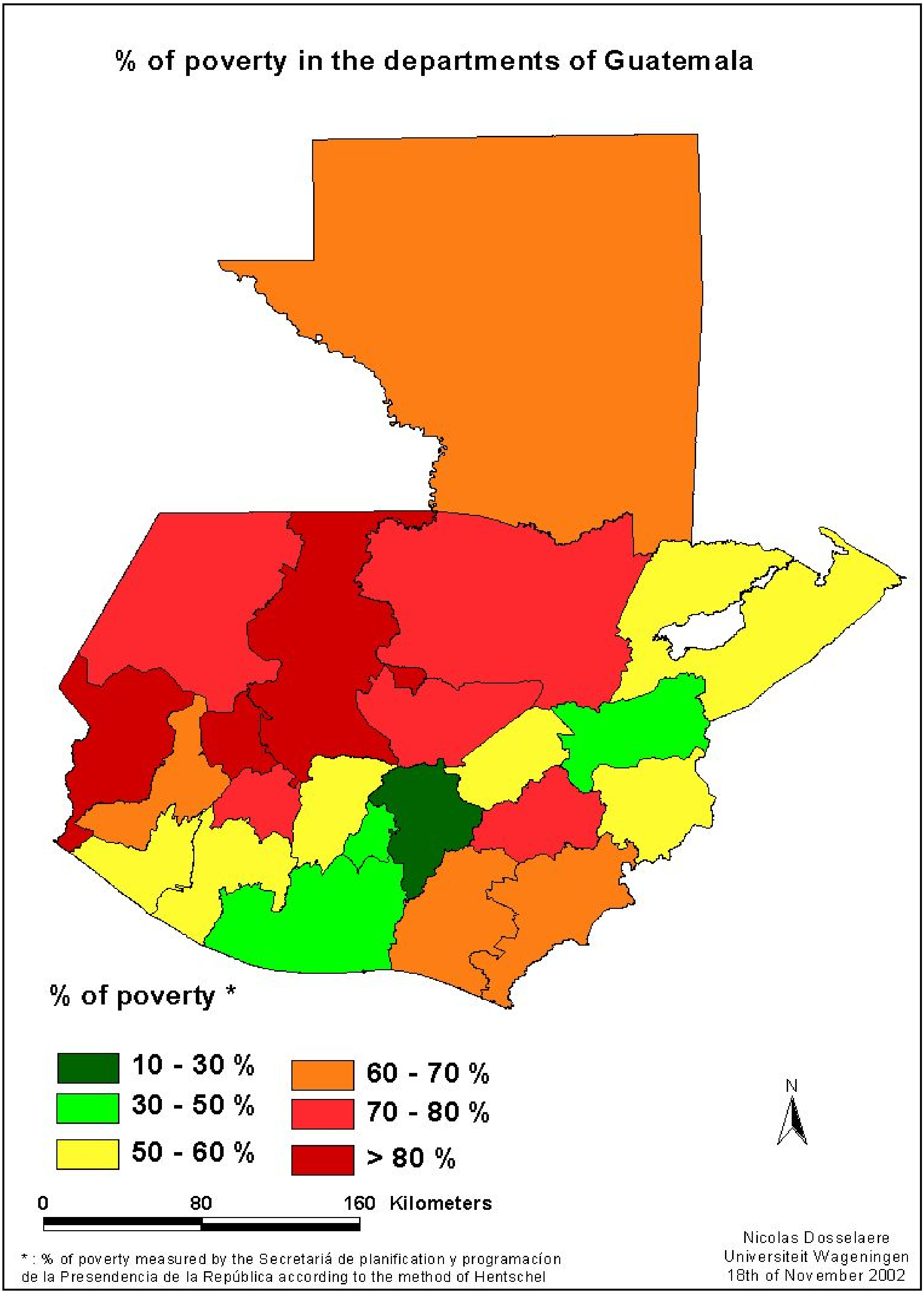


Figure A1. Map representing % of poverty in the departments of Guatemala.

Appendix 2:Poverty in the study area

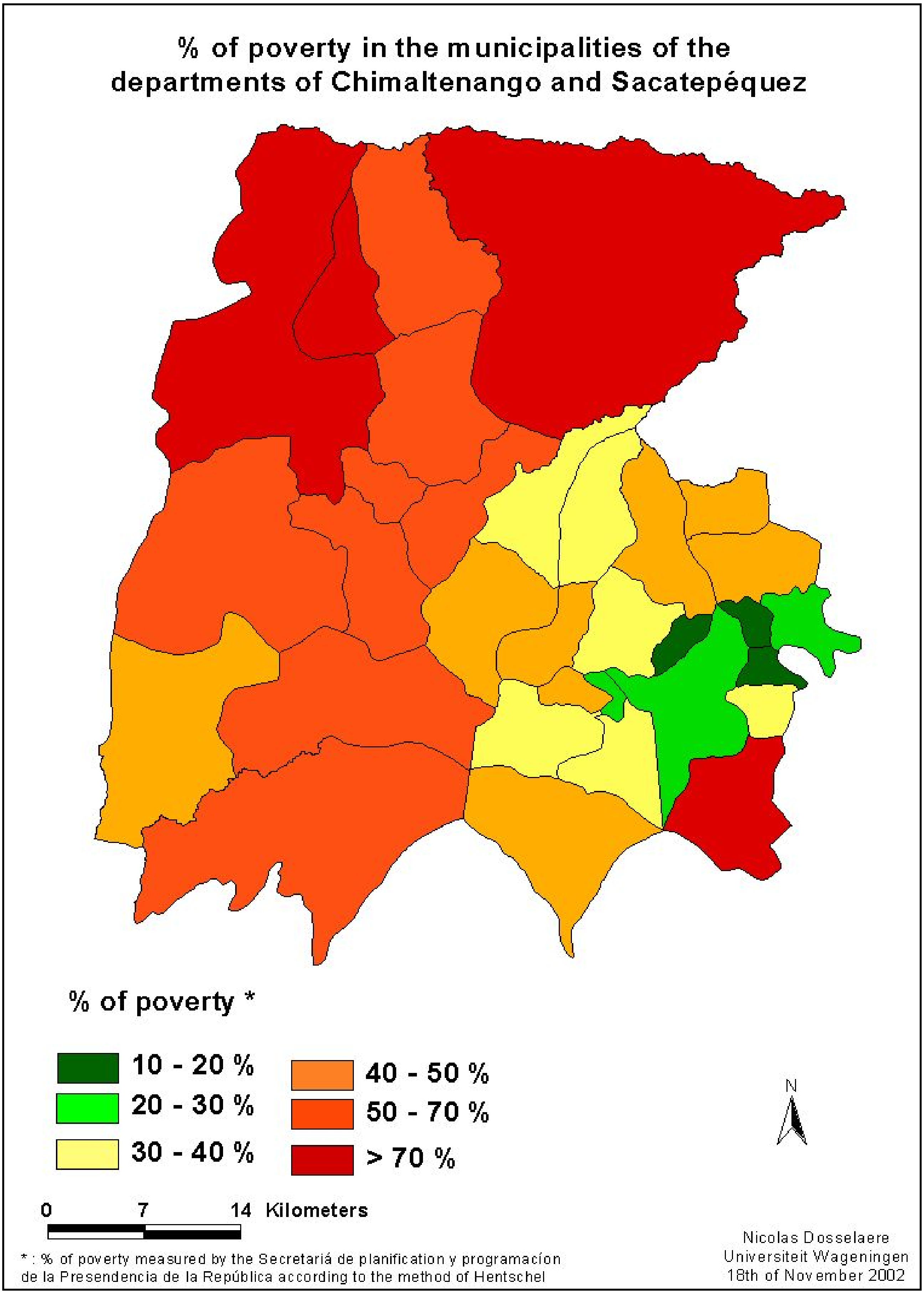


Figure A2. Map representing % of poverty in the municipalities of the departments of Chimaltenango and Sacatepéquez.

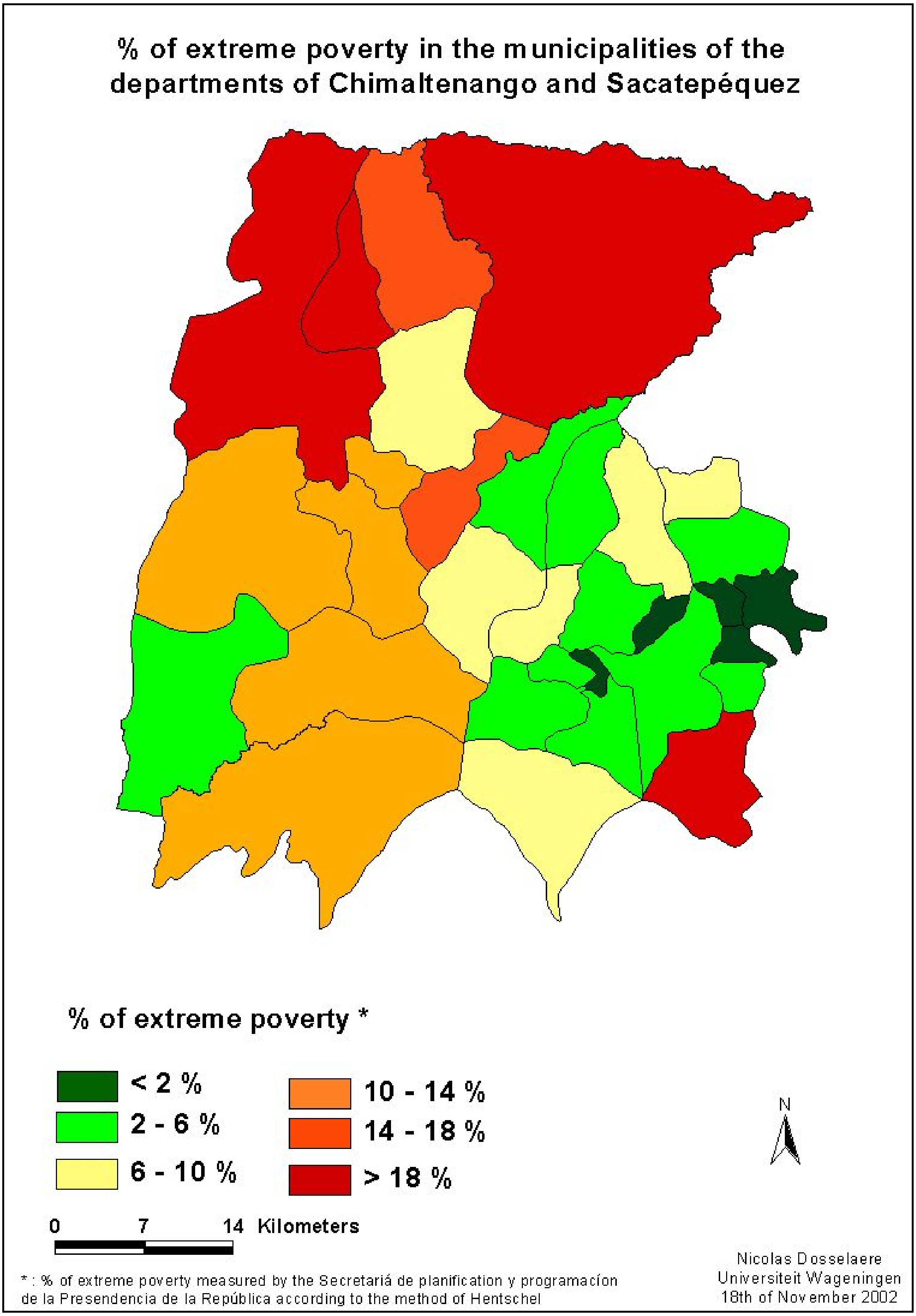


Figure A3. Map representing % of extreme poverty in the municipalities of the departments of Chimaltenango and Sacatepéquez.

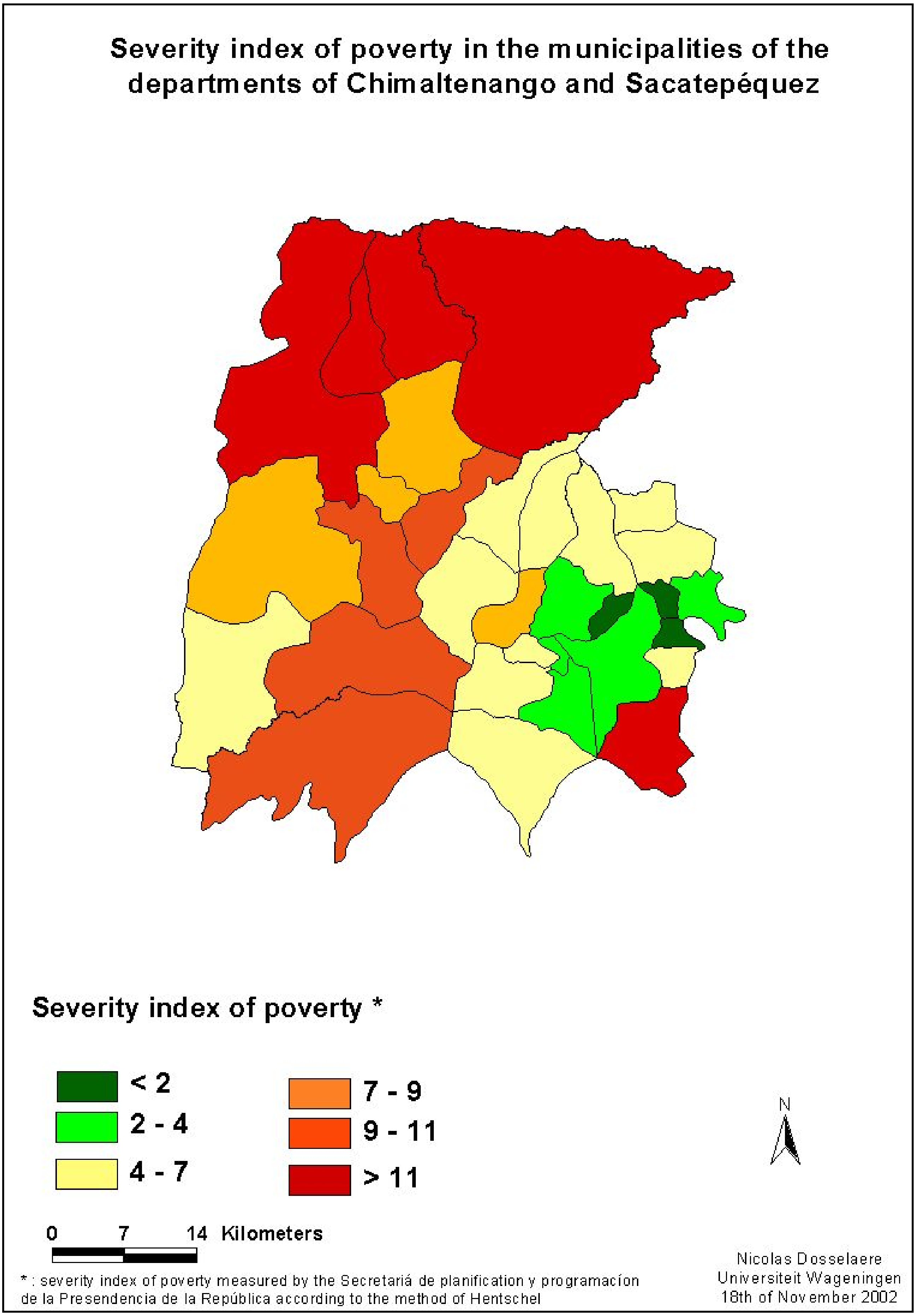


Figure A4. Map representing the severity index of poverty in the municipalities of the departments of Chimaltenango and Sacatepéquez.

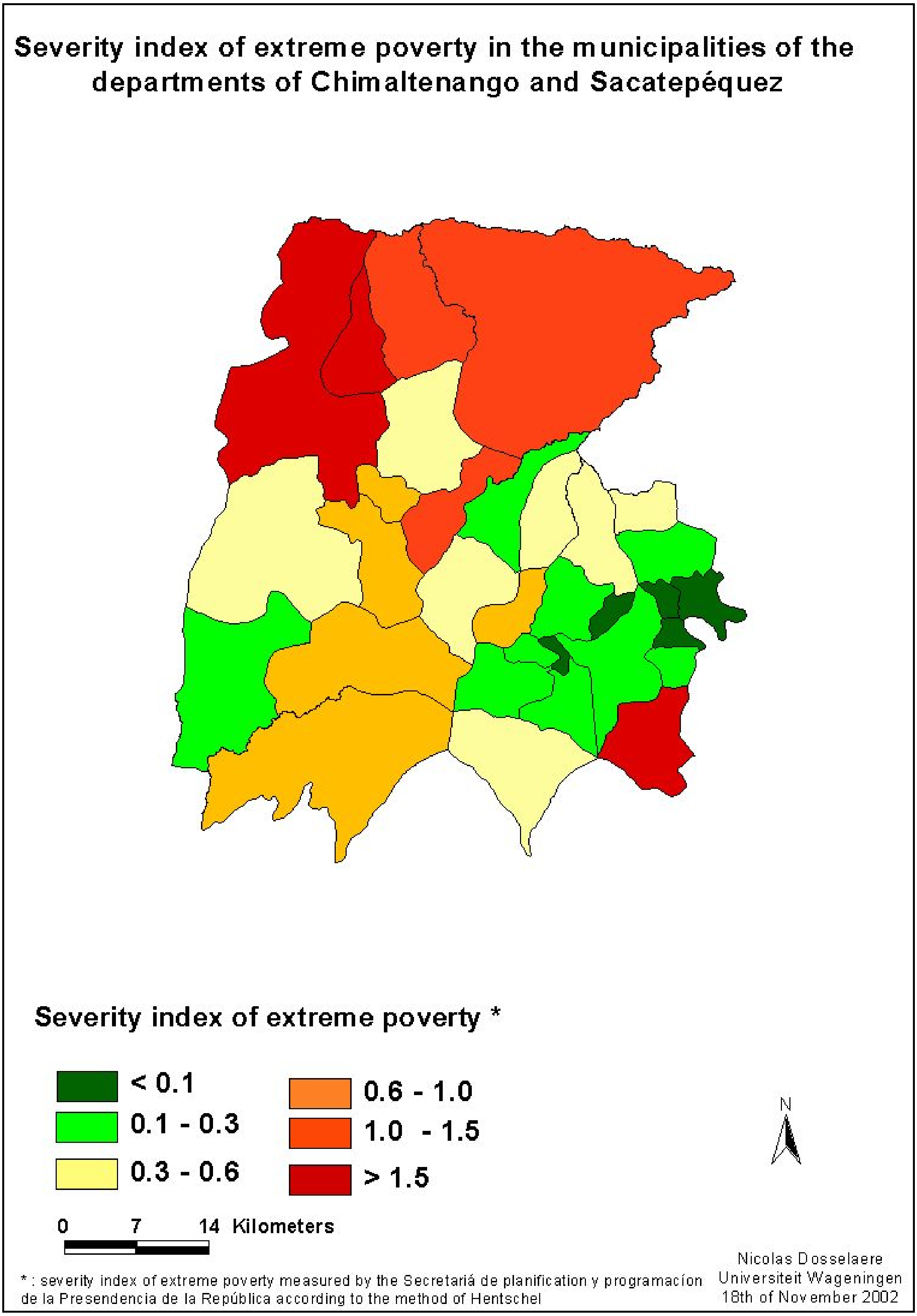


Figure A5. Map representing the severity index of extreme poverty in the municipalities of the departments of Chimaltenango and Sacatepéquez.

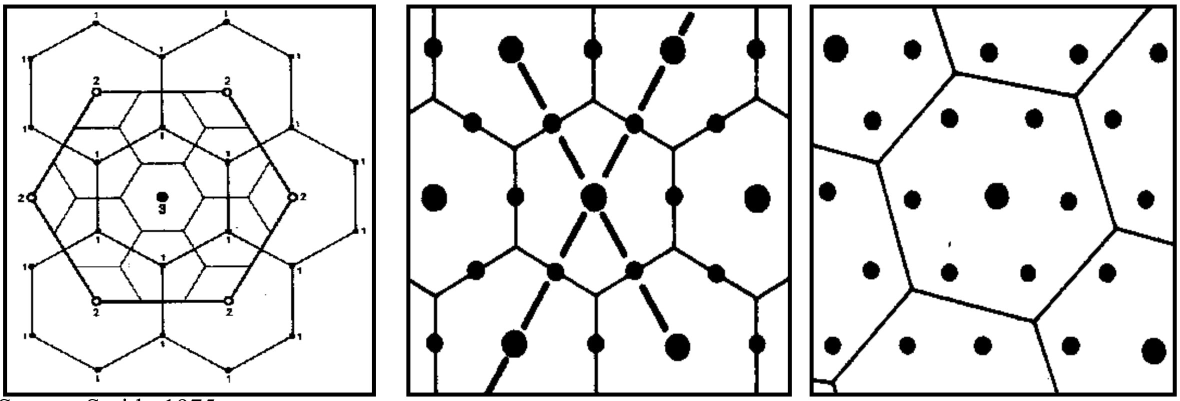
Appendix 3: The central place theory

The {PRIVATE}Central Place concept is an economic theory, which explains patterns of urbanisation and establishment of market areas for different goods and services. It offers insight into why specific goods and services are or are not present in a particular community. It specifically recognises that no community's trade sector can be viewed in isolation. The German geographer Walter Christaller originally published the theory in 1933.

Just like in the model of von Thünen, important assumptions are made: first of all, an isotropic landscape with equal transport facility and even distribution of purchasing power in all directions; secondly, a rationality regarding the minimisation of distance-cost and finally, a perfect competition among the suppliers. It may be clear that this assumptionous-world is rarely the case. Nevertheless, it allows us to abstract the basic economic and locational principles of marketing systems (Smith, 1975).
In the central place theory, different levels (hierarchies) of market centres exist. These centres are evenly distributed in each level of hierarchy. The smaller centres nest regularly in the hinterland of the progressively bigger market centres. As some goods and services are purchased less frequently, suppliers of higher order goods will require a larger market. Therefore suppliers of higher order goods will have a larger sphere of influence.

Christaller (1933) noted three different arrangements of central places:

The marketing principle (K=3 system);
The transportation principle (K=4 system);
The administrative principle (K=7 system).



Source: Smith, 1975.

Figure A6. The central place theory; K=3, 4 and 7 respectively.

In a k=3 system, there are for each of the largest settlements in the hierarchy on average 3 proximal settlements of the next size down in the hierarchy; for each of these again there will be on average 3 proximal settlements of the next size down in the hierarchy and so on down the hierarchy to the smallest sized settlement (see figure A6). Christaller noted that this type of hierarchy prevailed where it was most important for society to ensure equal provision of goods and services. This is the case for areas where a significant portion of the consuming and producing population is dispersed in rural settlements, and when transport is both costly and primitive. It is the most efficient system for pre-dominantly rural landscapes.

If transportation costs are to be minimised, Christaller (1933) found that by rotating and enlarging the hexagon that central places emerged where there are 4 proximal settlement of a given size (K=4). The transportation principle (figure A6) maximises the position of centres on a limited number of roads by locating lower-level centres between two higher-level centres, thus along already established roads. This system is especially prevailing in areas where a big number of the consuming population is located in the central places themselves.

Finally, for administration purposes, Christaller believed the need for 7 proximal settlements of the highest order to drive the creation of the central one into the next order in the hierarchy (K=7). Thus, each lower-level centre orient to only one higher-level centre (see figure A6). This administration system, highly resembling the ‘solar’ marketing systems, almost always suggests imposition of the economic system of rulers (e.g. colonial).

The central-place theory in the study area during the seventies.

Carol Smith (1975) performed a detailed study in the western highlands and concluded that all three of Cristoffers' central place systems (K=3, 4 and 7) and even a fourth one (see further) occured together in the area.

Investigating the marketing system of western Guatemala, Smith (1975) focused on the market centres that fell within the maximal hinterland of the large market town of Quezaltenango. This town was then the second city of Guatemala and is located approximately 175 km west of Guatemala City. The department of Chimaltenango was only a small part in the outer region of the hinterland of Quetzaltenango. The department of Sacatepéquez was not considered.

Smith made notice of three levels of large Ladinos-controlled market towns (LMT's). Quetzaltenango, which is the administrative and industrial centre of the region, was the highest level. Six intermediate LMT's, including Sololá, formed the second level. Near the periphery of the regional market system, twelve minor LMT's were found. One of them was the town Chimaltenango. It was the biggest market place in the department of Chimaltenango and it also harboured some administrative functions.

All these LMT's mentioned above were associated with many large permanent commercial establishments and were the major transport centres in the region. Moreover, these towns had relative large urban populations, which were heavily depended on the town marketplaces for their food requirements. The Ladinos, who controlled the major businesses as well as the administrative apparatus, made up the largest group of this urban population. The LMT's were the critical supply centres for all sectors of the population, since permanent commercial establishments and trucks controlled the distributions of imports in the region.

Next to this network of LMT's, Smith (1975) also described a network of rural bulking centres (RBC's). These centres were marketplaces for goods produced primarily by Indian peasants in rural areas. Smith (1975) estimated that the Indian peasants produce most of the marketed foodstuffs (some 80%). About the half of this were destined for urban markets; the rest were sold and consumed locally. The RBC's contrasted with the LMT's in the fact that they had fewer permanent establishments and that they were oriented towards rural peasants' production and consumption rather than urban Ladino provisioning. Another important characteristic of the RBC network was that it did not show any pattern of hierarchical interrelationship except through LMT's.

A distinction between town- and marketplace goods had to be made to explain the exchange of goods. Town goods were primarily produced outside the region and imported to it, whereas marketplace goods were primarily produced in the rural areas of the region. The town goods flew from the LMT's to small town centres. In contrast, marketplace goods flew from minor marketplace to the RBC's. From this RBC's, they were distributed to both other minor markets in the system and the LMT's, who had to supply the town people with marketplace goods. Thus, the LMT's were critical in the movement of town goods, whereas the RBC's were critical in the transfer of market goods.

Twelve out of the eighteen lower-level LMT's were located along roads between two higher-level centres. In this case these roads were the six main roads that radiate out of Quetzaltenango to for example Guatemala City. This strongly suggested the existence of Christaller's transportation principle. Since the main commercial functions of LMT's were to move export commodities out of the region and to supply their urban populations with goods imported into the region, this K=4 principle was a logical determinant of their spatial pattern (Smith, 1975).
As the consuming population was dispersed in rural hamlets and small villages in the western highlands of Guatemala, also the 'marketing' principle was efficient in this region. The RBC's, the collecting points for rural goods, were related each time to three LMT's. This K=3 system was only valid in the fact that the lower-level centres (the RBC's) provided the higher-level centres (the LMT's) with goods produced in the rural hinterland. The delivery of specialised goods in the other direction was not the case. The rural centres did not require many town goods (Smith, 1975).
The administrative principle was also significant in the region. This could be seen by the dominance of the major LMT's over the region as a whole and the poor articulation of these LMT's with one another in domestic trade. The simple presence of concentrated numbers of political-military-administrative bureaucrats in a very few

urban centres, who had relative very high purchasing power in the region, would draw commercial productivity to them. This was particularly the case here where these centres were surrounded by a mass of poor, dispersed and semi-self-sufficient peasants, who had very low purchasing power (Smith, 1975).

Next to the three central place principles of Christaller, Carol Smith also added a fourth type, termed the 'dendritic' market system by Johnson (1970). In this principle all economic networks converge on a single centre (figure A7). The consequence is that there does not exist any competition among equivalent centres for the commerce of smaller centres. The dependent centres become progressively smaller with distance from the major centre. In this 'dendritic' system, the market economy is controlled by outside economic interests. It is very common in third world countries where primary goods (e.g. plantation crops) are moved out of the country. Also in western Guatemala some aspects of the dendritic system now were a major force in the marketing arrangements (Smith, 1975). Plantation or import-export trade flew directly from production points to a national port or commercial centre (e.g. Guatemala City). In other words, it was first collected in the minor LMT's, then in the major ones and flew from there to Guatemala City.

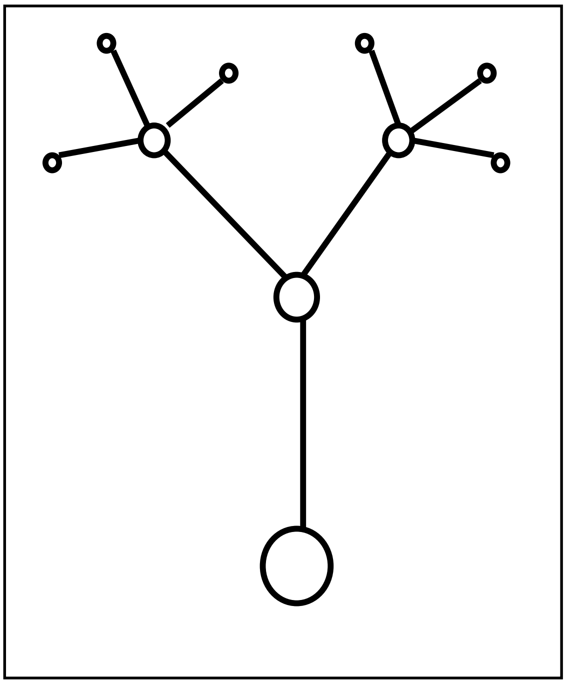


Figure A7. Dendritic market pattern.

Appendix 4:The mapping-out procedure

The case study areas of San Andrés Itzapa and Santiago Sacatepéquez were mapped out completely. Intensive fieldwork was performed in these regions in September and October 2002. With a pencil, land use (and roads) was drawn in detail onto transparent paper. Aerial photographs of 1:40000 (NIMA/Guatemala) and two of 1:20000 (JICA-IGN) respectively were used as a basis for this mapping out. This resulted for both case studies in a land-use and a road type 'paper'. Local people were enlisted to help on the determination of some crops or to give some information about the road and its quality. 17 and 19 well spread GPS points of respectively San Andrés Itzapa and Santiago Sacatepéquez were taken with a GPS of type Garmin 45 XL. In most cases, these points were road intersections or other structural 'marks' needed for the transformation of the different 'papers' to the Universal Transverse Mercator Projection. All the GPS points were 'measured' in this projection (Zone 15 N) with a WGS 84 datum and spheroid and the map units in meters. The GPS points were downloaded with PCX5 and after some editing were imported in ARC/INFO as a text-file.

The four 'transparent papers' were scanned as windows bitmap files and were converted to grids in ARC/INFO version 8.1. The stripes resulting from the scanning of the relative 'broad' pencil lines were converted to 'single' arcs using the gridline vectorisation command GRIDLINE. In total two processes were performed to transform these scanned 'images' into a correct two-dimensional projection, in this case UTM: an affine transformation and a rubber sheeting. Rubber sheeting is the process, which corrects flaws through the geometric adjustment of co-ordinates (ESRI, 2001). During this process, the surface is literally stretched, moving other features using a piecewise transformation that preserves straight lines. This was necessary to perform a 3D spatial rectification's of the airborne photos. A normal two-dimensional transformation, like the affine one, could not completely fulfil this. Nevertheless, before rubber sheeting could be performed, the reference points had to be already quite close to their actual map position. It is in this perspective that the affine transformation was executed first.

The affine transformation scales, skews, rotates, and translates all co-ordinates in the coverage using the same equation. Based on a minimum of three control points, this transformation can scale the x co-ordinates differently than the y co-ordinates. In the

43.2 km^2 case study area of San Andrés Itzapa 17 of these GPS control points could be used for the transformation process. For Santiago Sacatepéquez, 19 points in the 18.3 km^2 area were used. In both cases the different reference points were spread quite equally over the terrain. In a next step the resulting coverages were edited and the topology was build. The editing process was executed in edit tools of ARC/INFO in which errors like over- and undershooting were corrected and the correct information of the different arcs and polygons could be assigned. In a last step the already discussed rubber sheeting could finally be performed. Again ARC/INFO was used here and the same control points as in the affine transformation were taken.

Appendix 5: Importing and pre-processing of the RS-images

The ASTER images (product number 1B) were downloaded from the Earth Observing System Data Gateway. These 1B products were already geometrically and radiometrically corrected. For specific algorithm specifications, see ERSDAC (1998). The Aster EOS HDF format could be imported in the latest version ERDAS Imagine 8.5. The images had a geographic (Lat./Lon.) projection with a WGS84 spheroid and a WGS84 datum. For reasons of uniformity with other data and the GPS measurements, these projections were transformed into the UTM (zone 15 North) projection type of the same datum and spheroid. The LANDSAT image was re-projected in the same way. The quality of the projections was checked by means of GPS measurements (characteristic places as intersection of rivers and big roads). They proved to be satisfactory for the LANDSAT image, while for the ASTER images there was a constant shift. This was corrected in ERDAS imagine.

In a next step, the two ASTER images were 'mosaicked' to one image. Mosaicking is the process of joining geo-referenced images together to form a larger image. Matching between the different input-images was not necessary because the images were taken with a very short time interval and as a consequence had almost the same solar azimuth angle, solar elevation angle and other determining conditions. In the parts were the two images were overlapping, the image with the least cloud cover was preferred. This ´mosaicking´ resulted in one image, covering almost the complete study area.

Digital imagery from mountainous regions, like the department of Chimaltenango, often also contains a radiometric distortion known as the topographic effect. This effect results from the differences in illumination due to the azimuth/elevation angle of the sun and aspect/slope of the terrain. It causes a variation in the image brightness values, which should be corrected by means of a topographic normalisation. In this research the correction of this topographic effect was nevertheless rather difficult and at the end was not executed for the image of the 21st of June 2002.
Validation of the quality of the topographic normalisation happened by using the NDVI and the NIR/RED ratio. Spectral rationing conveys the spectral characteristics

of image features, regardless of variations in scene illumination conditions. A rationed image effectively compensates for the brightness variation caused by the varying topography (Lillesand & Kiefer, 2000). Pixels with more or less the same ratios but with different aspects and slopes were used to compare the radiances and as a consequence to validate the quality of the normalisation.

The available Digital Elevation Map (DTED of Central America created by the USGS), needed as input for topographic normalisation, was of a rather bad quality. It had a spatial resolution of only 60 meter (compared to 15 and 30 meter for respectively ASTER and LANDSAT) and a striped pattern in north and south direction. It was especially this last factor that made its direct use for topographic correction impossible. The resulting normalised map had an alternating over- and under-correction of ± 60 m thick horizontal and vertical 'lines'. The striping pattern was especially visible in the Fourier spectrum of the DEM in which clearly horizontally and vertically components were appearing. A spatial low pass or high frequency blocking filter on the Fourier spectrum resulted in a DEM lacking the striping pattern. The resulting topographic normalised product using this corrected DEM, was considerably better but was still over-correcting areas with an aspect-angle opposite to the in the metadata given solar azimuth angle. There are several possible reasons for this bad topographic normalisation. It is possible that the DEM still contained errors or that the Lambertian Reflectance Model of ERDAS Imagine 8.5 was the cause for this over-correction. More likely, the reason has to be found in wrong information about the solar azimuth and elevation angle of the ASTER images. Strange and impossible combinations of elevation and azimuth angle were found. That is why at the end the original, non-topographic-normalised image (of the 21st of June 2002) was used for classification. Like could be seen from spectral rationing and from fieldwork in which no big misclassification due to aspect and slope were detected, the original image seemed already quite satisfactory. That is why it can be suggested that the image maybe was already geometrically normalised, although nothing was mentioned about this in the metadata or other information about the ASTER 1B products.

Appendix 6: Conversion of the coordinate system

Road maps for the whole study area were obtained in an Arc View format (shape files) from the ‘Ministerio de Agricultura, Ganadería y Alimentación (MAGA)’ of Guatemala (2001). Before these maps could be used, the coordinate system had to be converted to fit with the one used for the other geographical data sets in this thesis (UTM projection zone 15N; datum and spheroid WGS84). The ‘MAGA’ data had this projection but a different datum and spheroid (respectively US State Plane –NAD27 and Clarke 1866). The conversion was executed in ARC/INFO in a two-step method, being a primer conversion of NAD27 into NAD83 followed by the conversion of the resulting NAD83 into the final WGS84. This method takes advantage of the fact that the most accurate way to convert between NAD83 and NAD27 is the NADCON method (Pearson, 1990; Snyder, 1994). It's possible to convert directly between NAD27 and WGS84 but not as accurate (ESRI, 2001). The same conversion procedure was used for other MAGA data, like maps of the municipalities and the departments.

In a next step the study area was clipped and the different roads were assigned values according to their quality. The same quality classes as described above were assigned with this difference that here only roads until quality class 4 were represented. These four classes were assigned based on a reclassification of existing road quality information of MAGA. This reclassification process and the quality of the roads were evaluated and updated if necessary during the fieldwork.

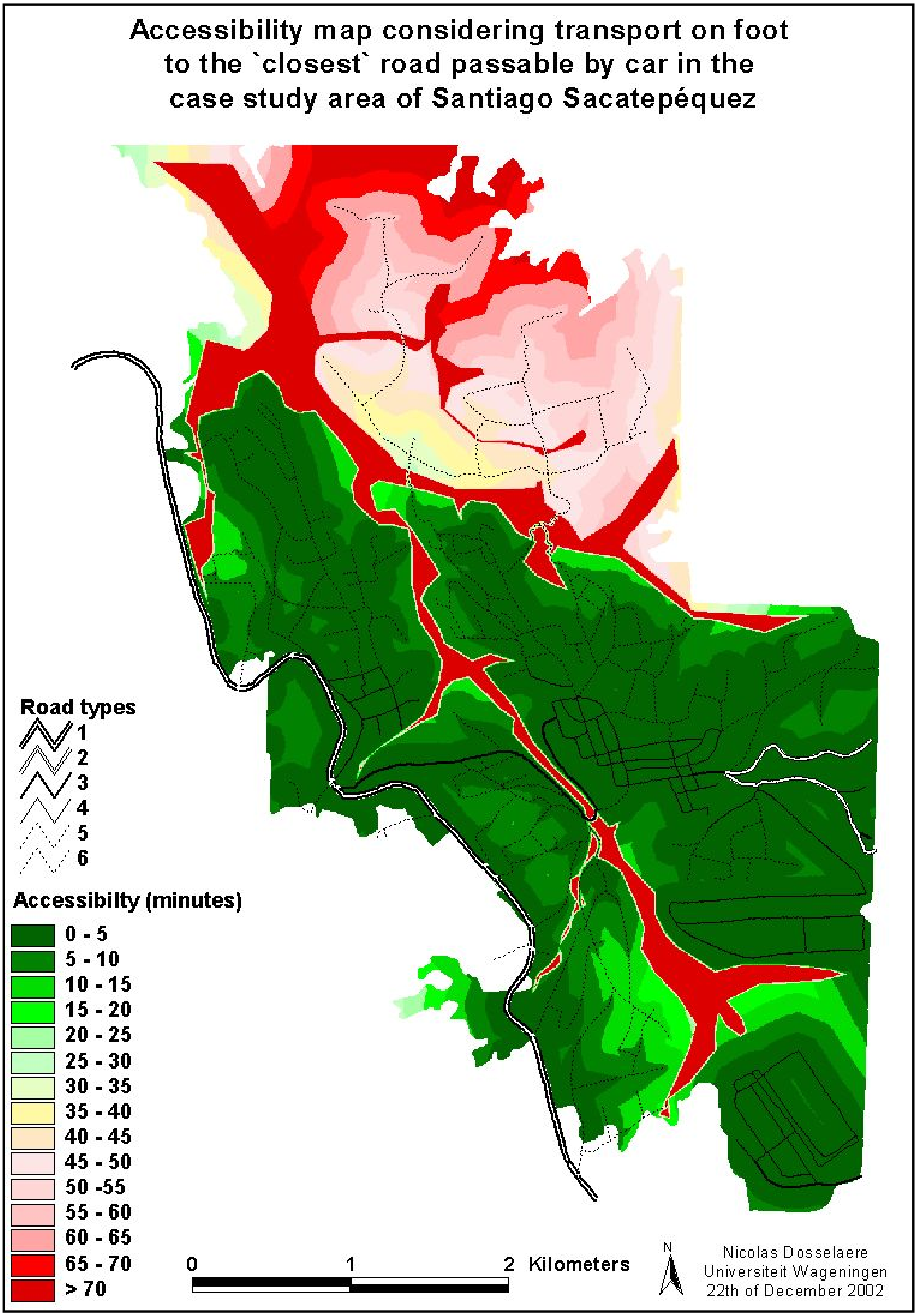


Figure A9. Accessibility map considering transport on foot to the `closest` road passable by car in the case study area of Santiago Sacatepéquez.

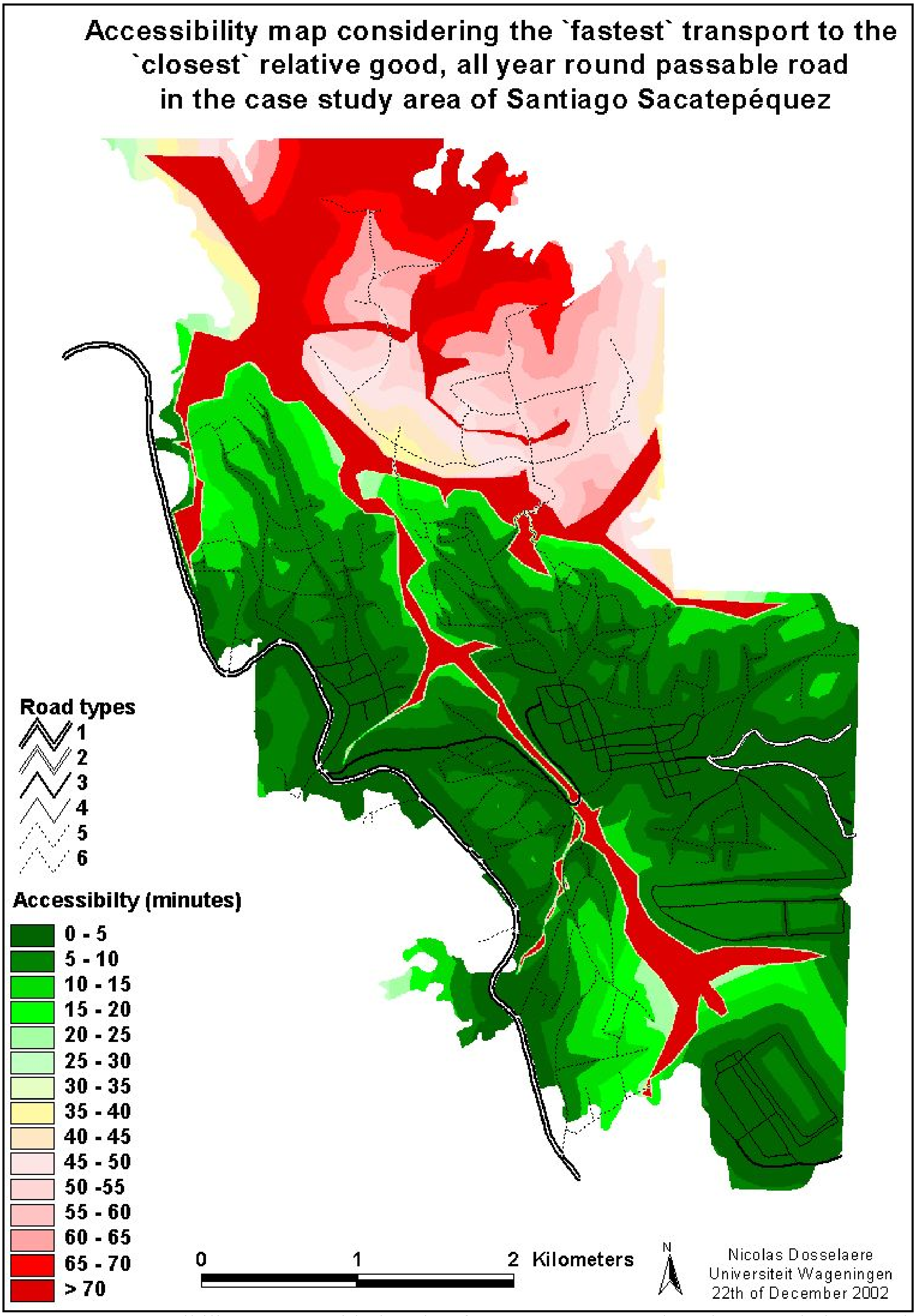


Figure A10. Accessibility map considering the `fastest` transport to the `closest` relative good, all year-round passable road in the case study area of Santiago Sacatepéquez.

Appendix 8: Accessibility maps of San Andrés Itzapa

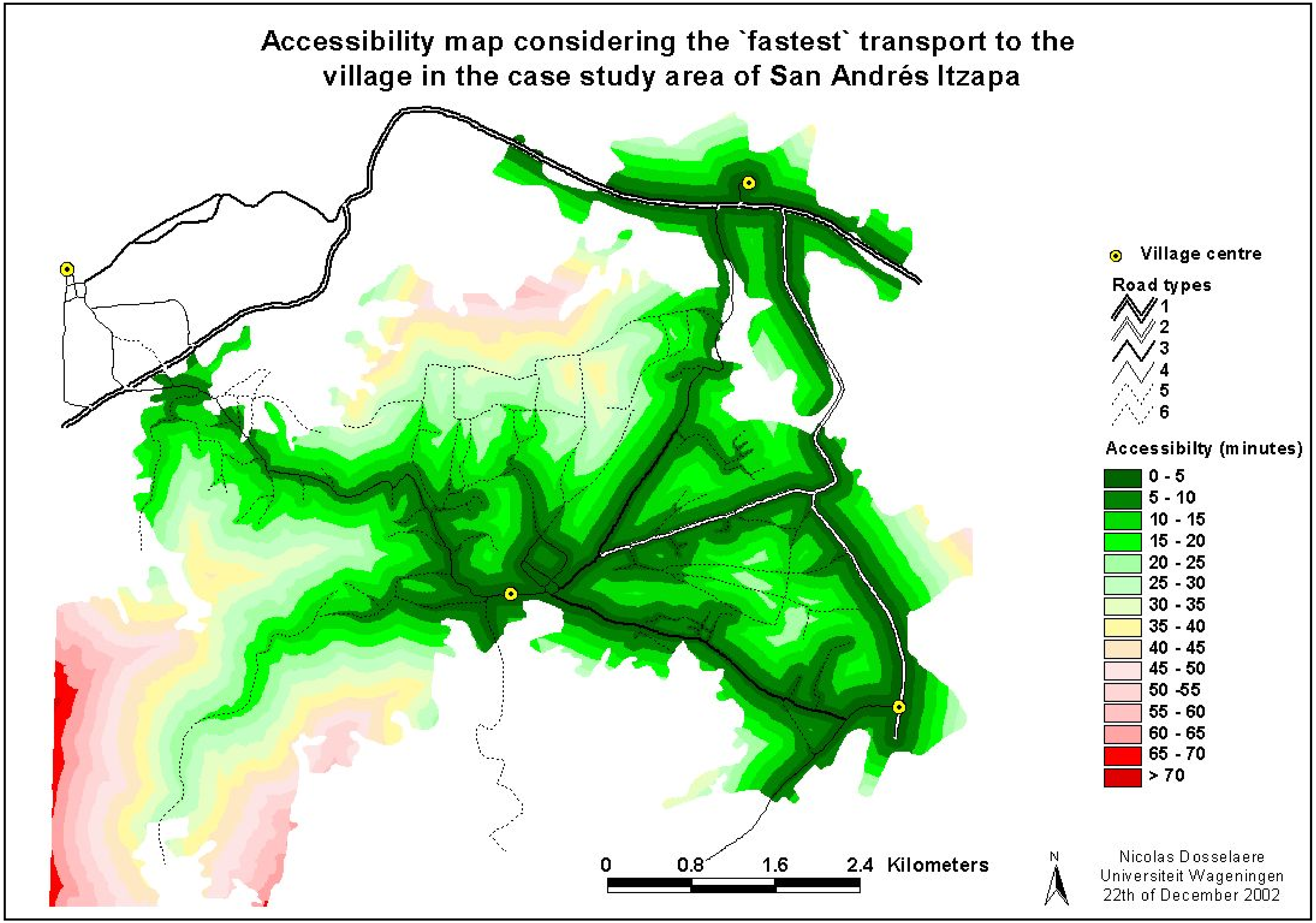


Figure A11. Accessibility map considering the `fastest` transport to the village in the case study area of San Andrés Itzapa.

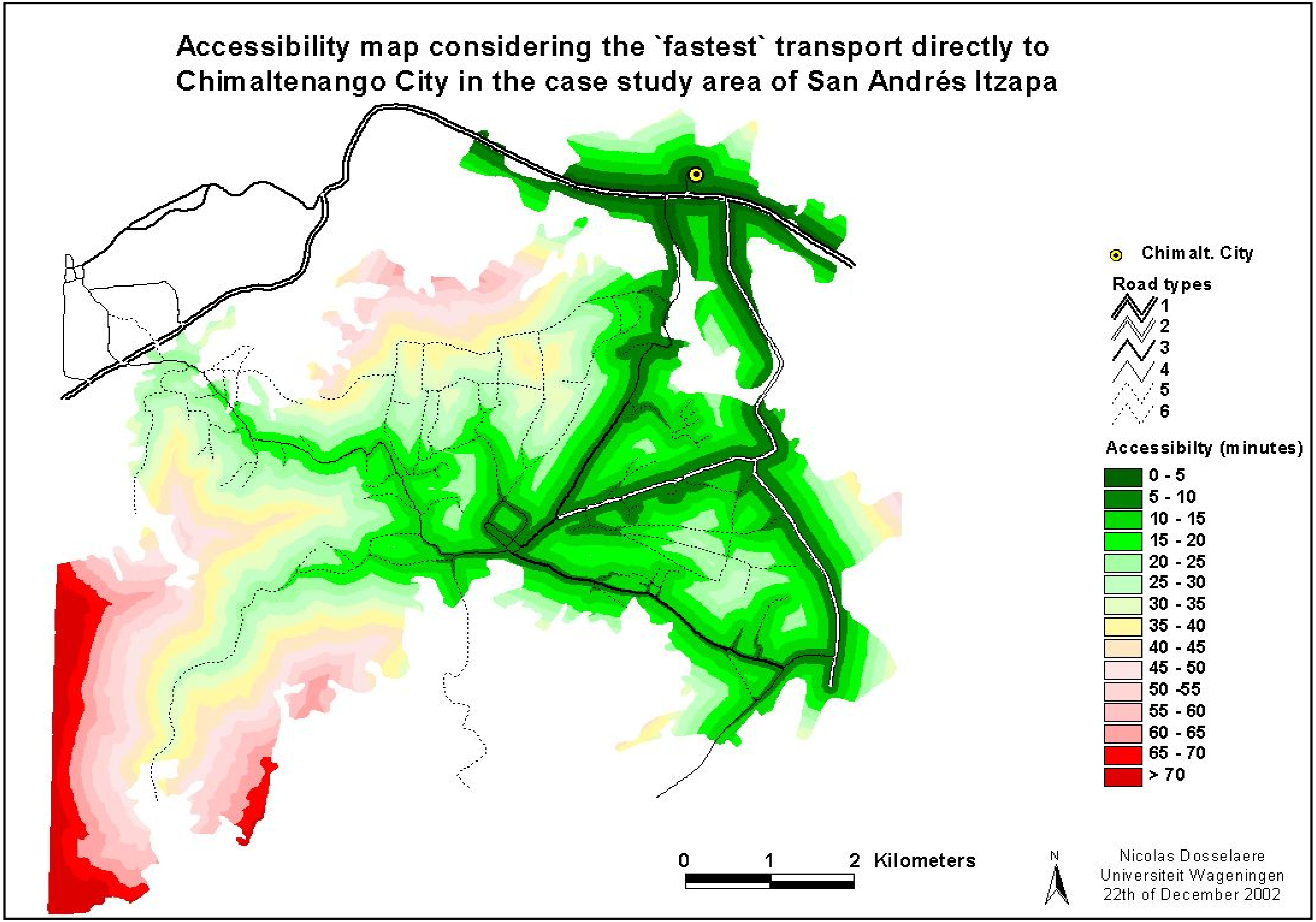


Figure A12. Accessibility map considering the `fastest` transport directly to Chimaltenango City in the case study area of San Andrés Itzapa.

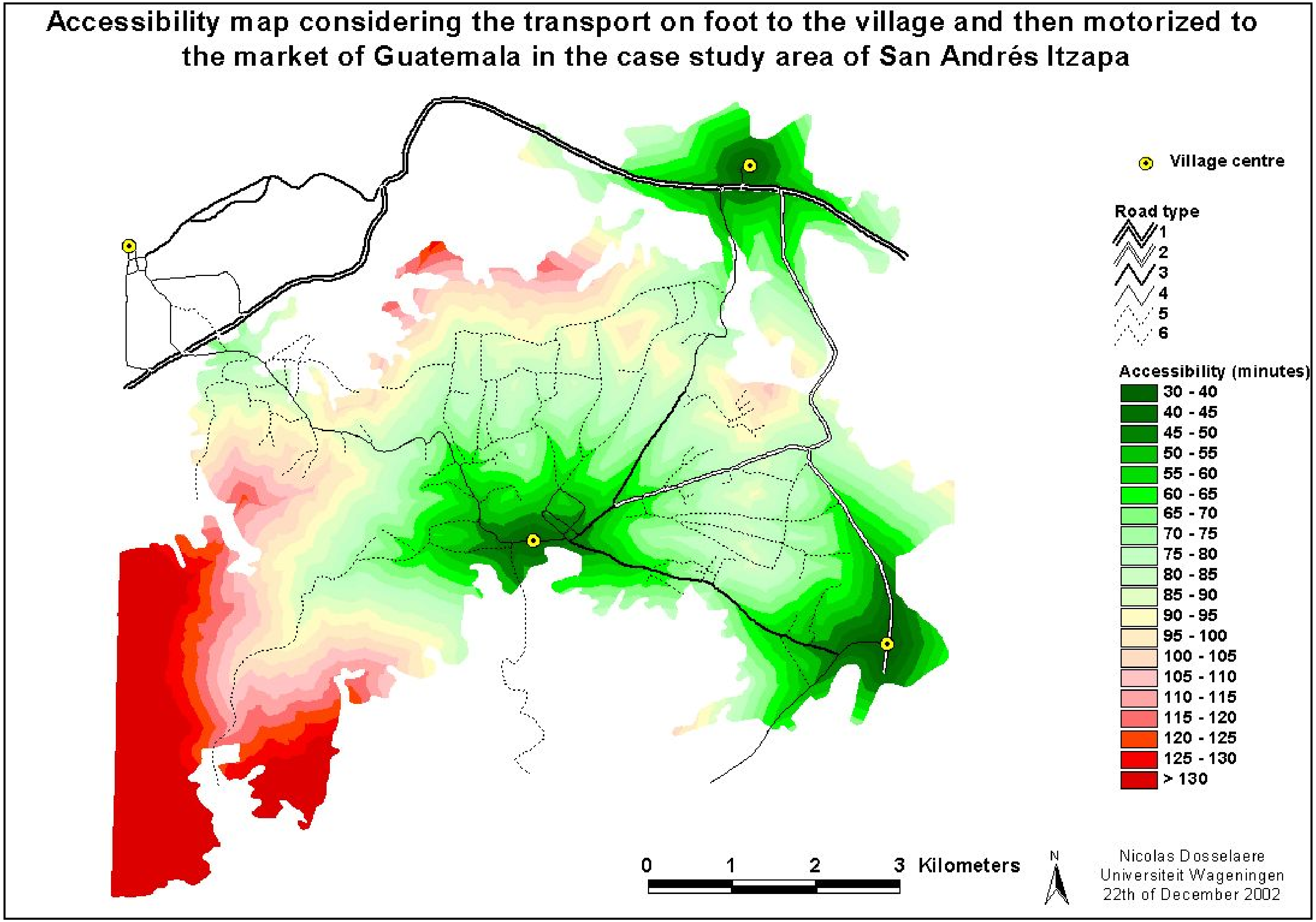


Figure A13. Accessibility map considering the transport on foot to the village and then motorized to the market of Guatemala in the case study area of San Andrés Itzapa.

c

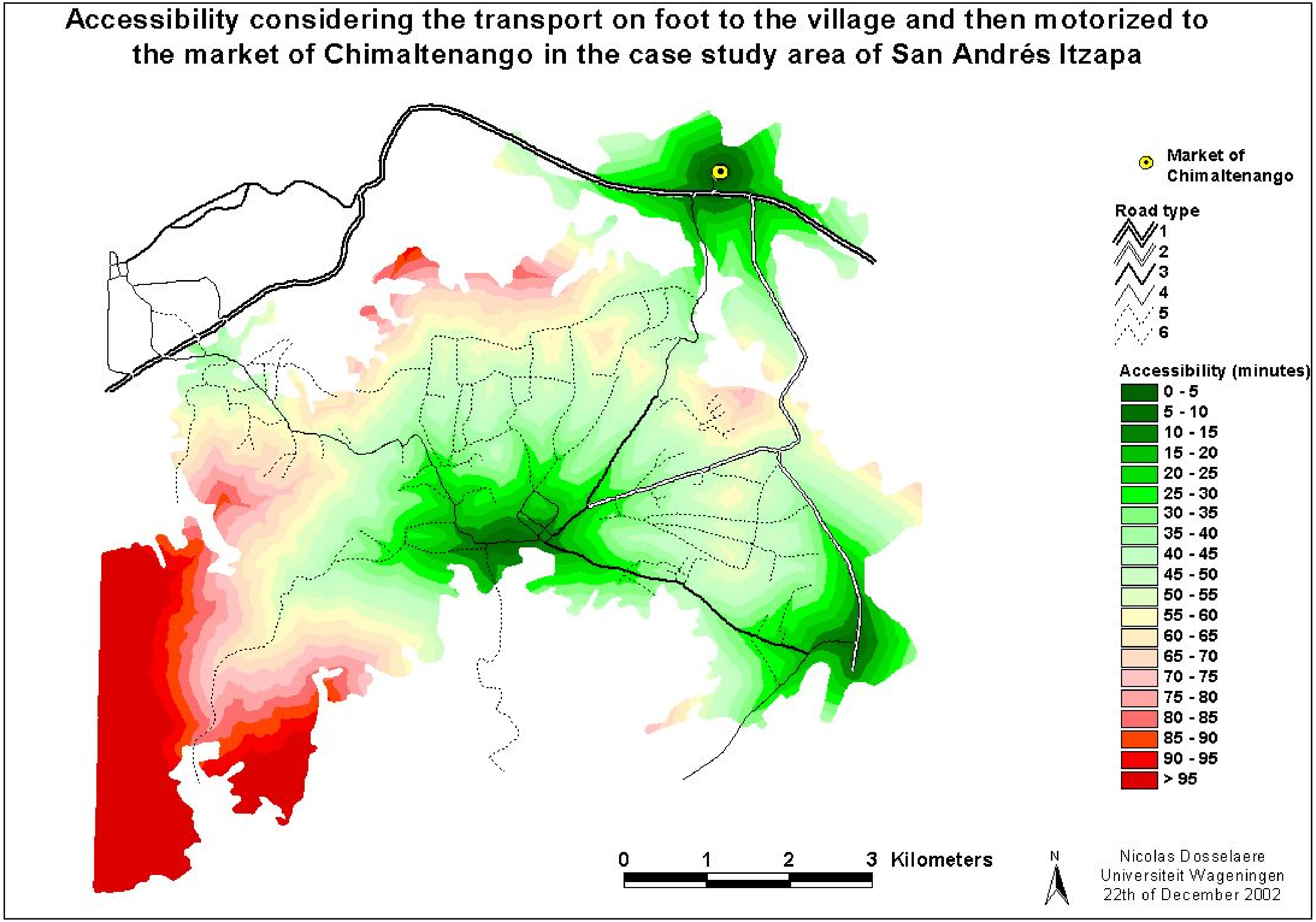


Figure A14. Accessibility map considering the transport on foot to the village and then motorized to the market of Chimaltenango City in the case study area of San Andrés Itzapa.

d

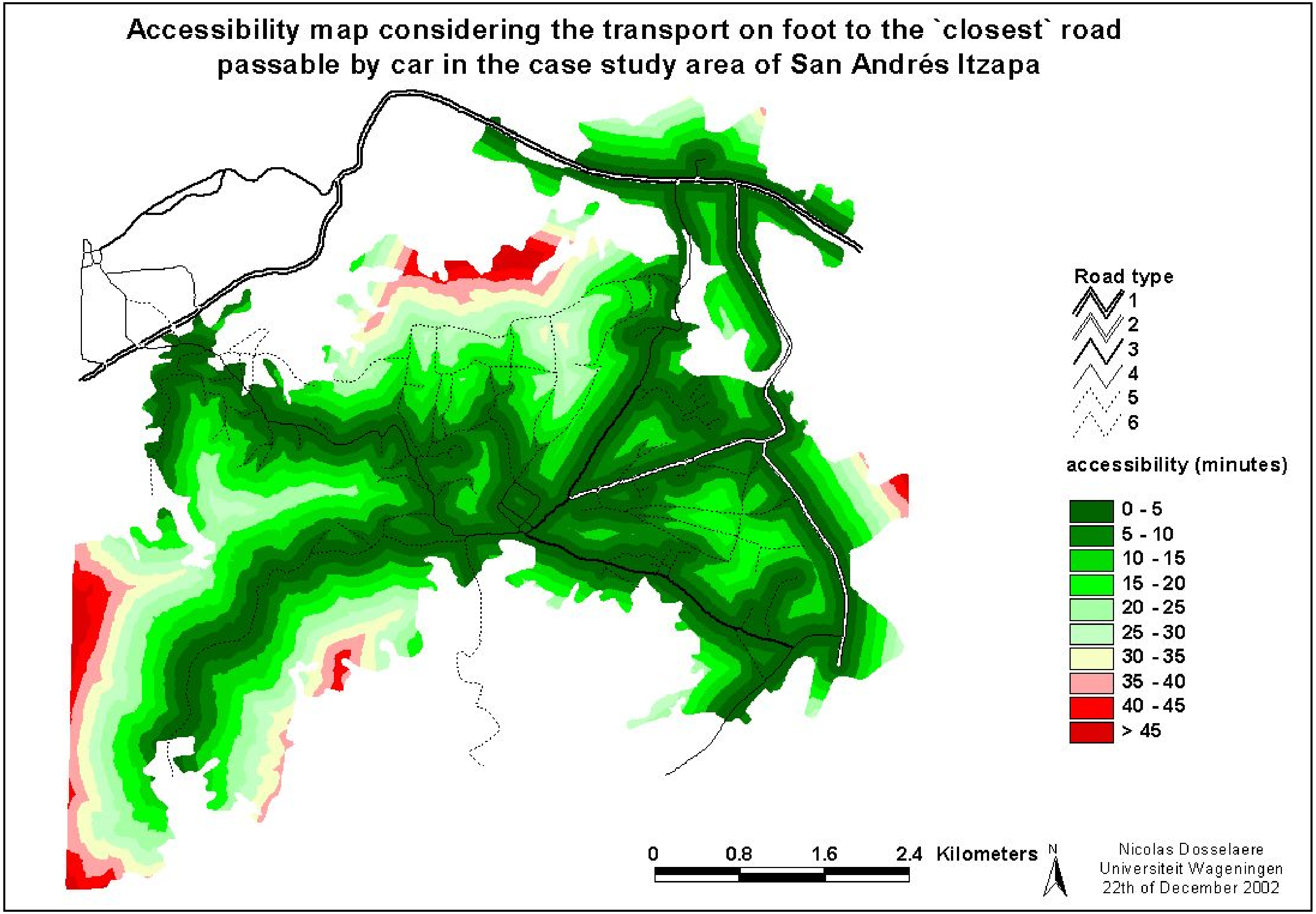


Figure A15. Accessibility map considering the transport on foot to the `closest` road passable by car in the case study area of San Andrés Itzapa.
e

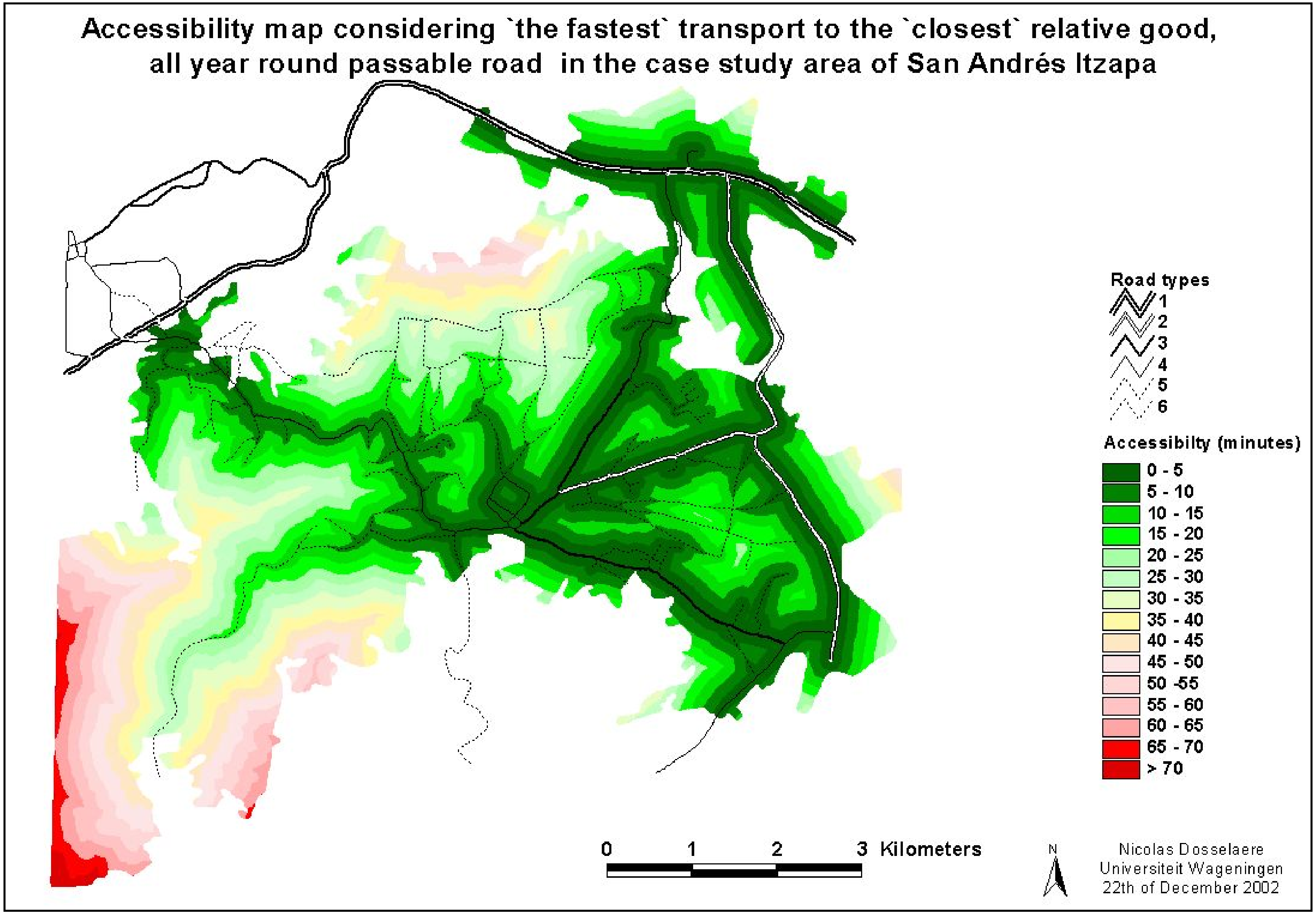


Figure A16. Accessibility map considering `the fastest` transport to the `closest` relative good, all year round passable road in the case study area of San Andrés Itzapa.

f

Appendix 9: Distribution of agr. products in the study area

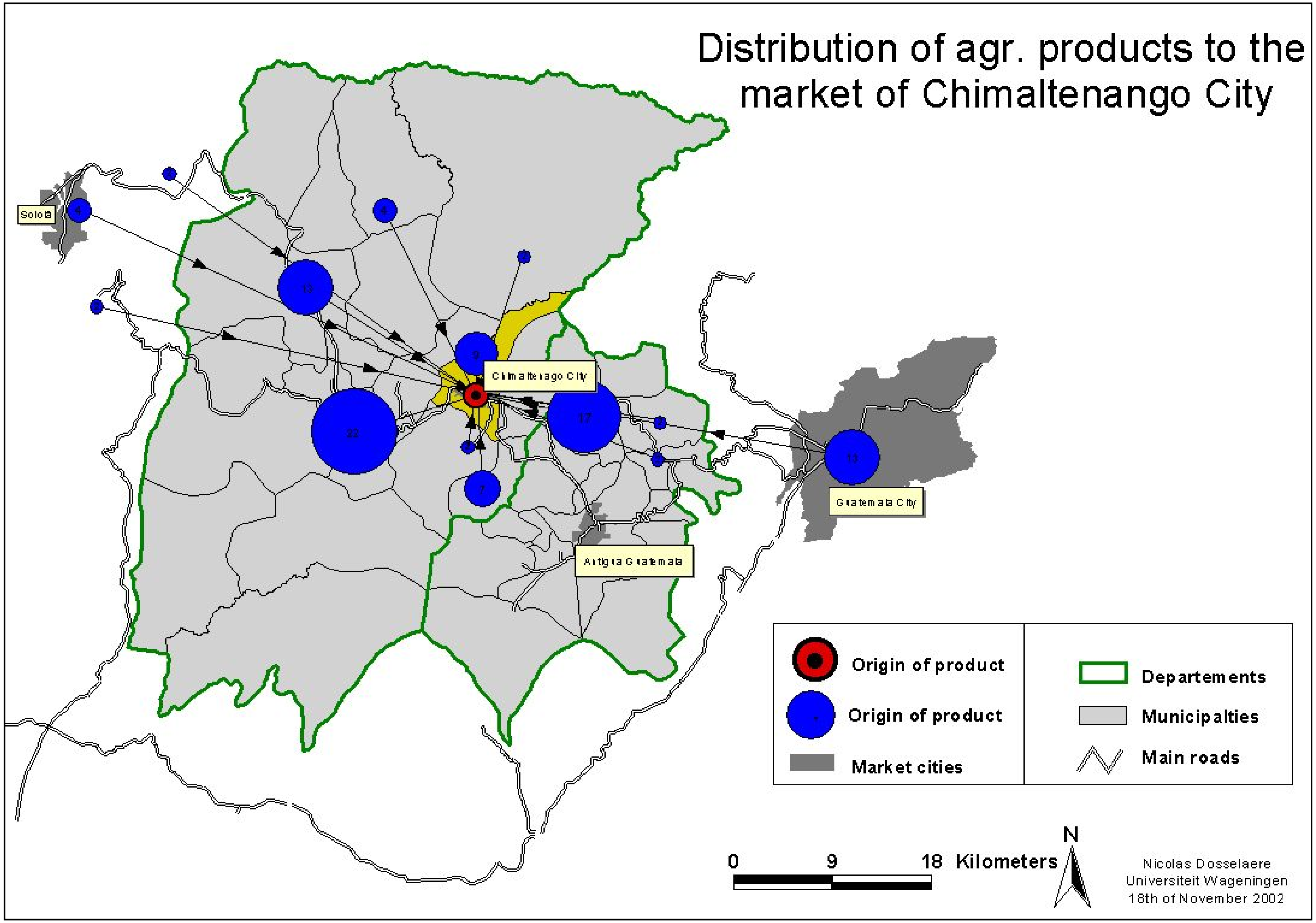


Figure A17. Distribution of agricultural products to the market of Chimaltenango City.

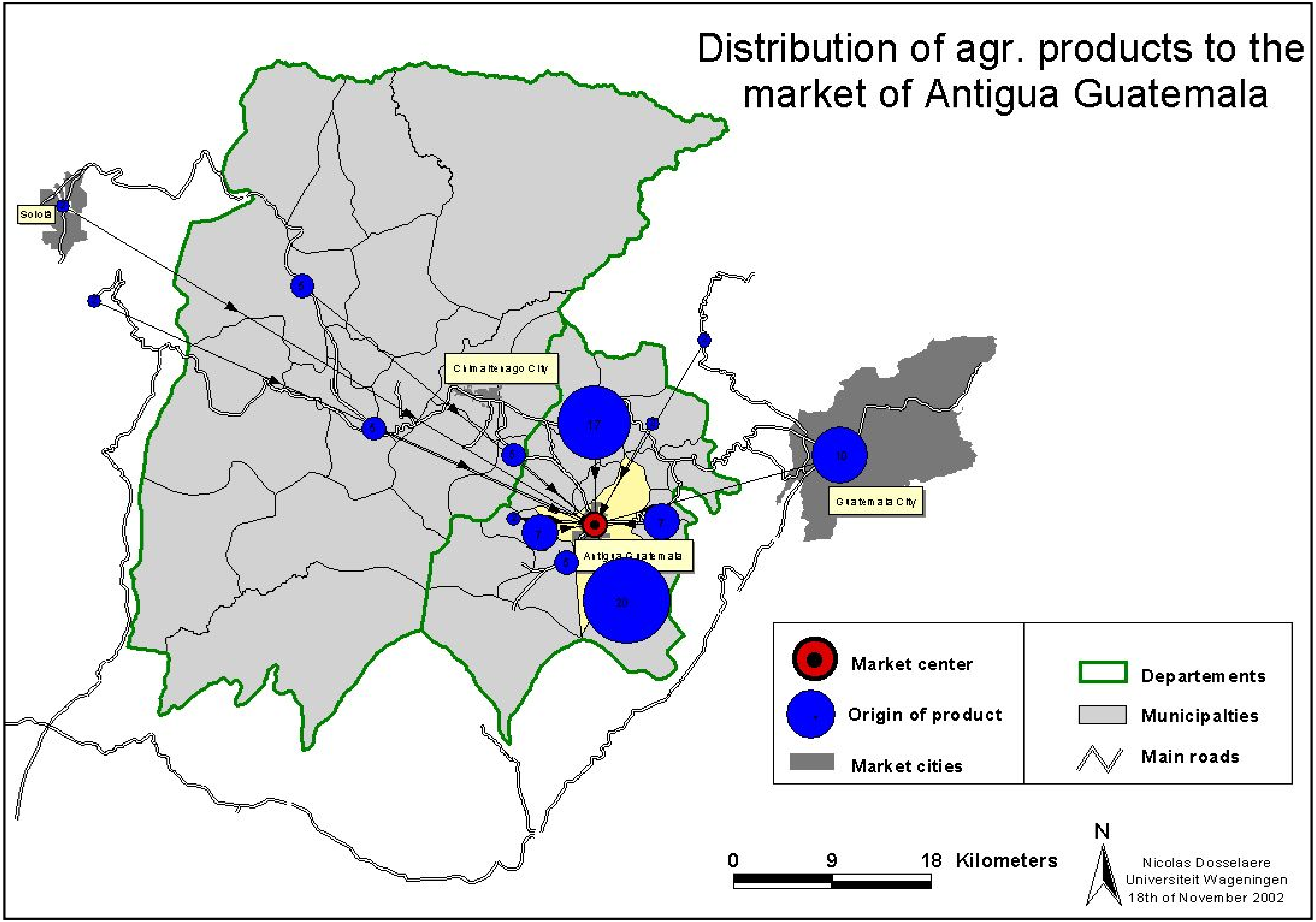


Figure A18. Distribution of agricultural products to the market of Antigua Guatemala.

h

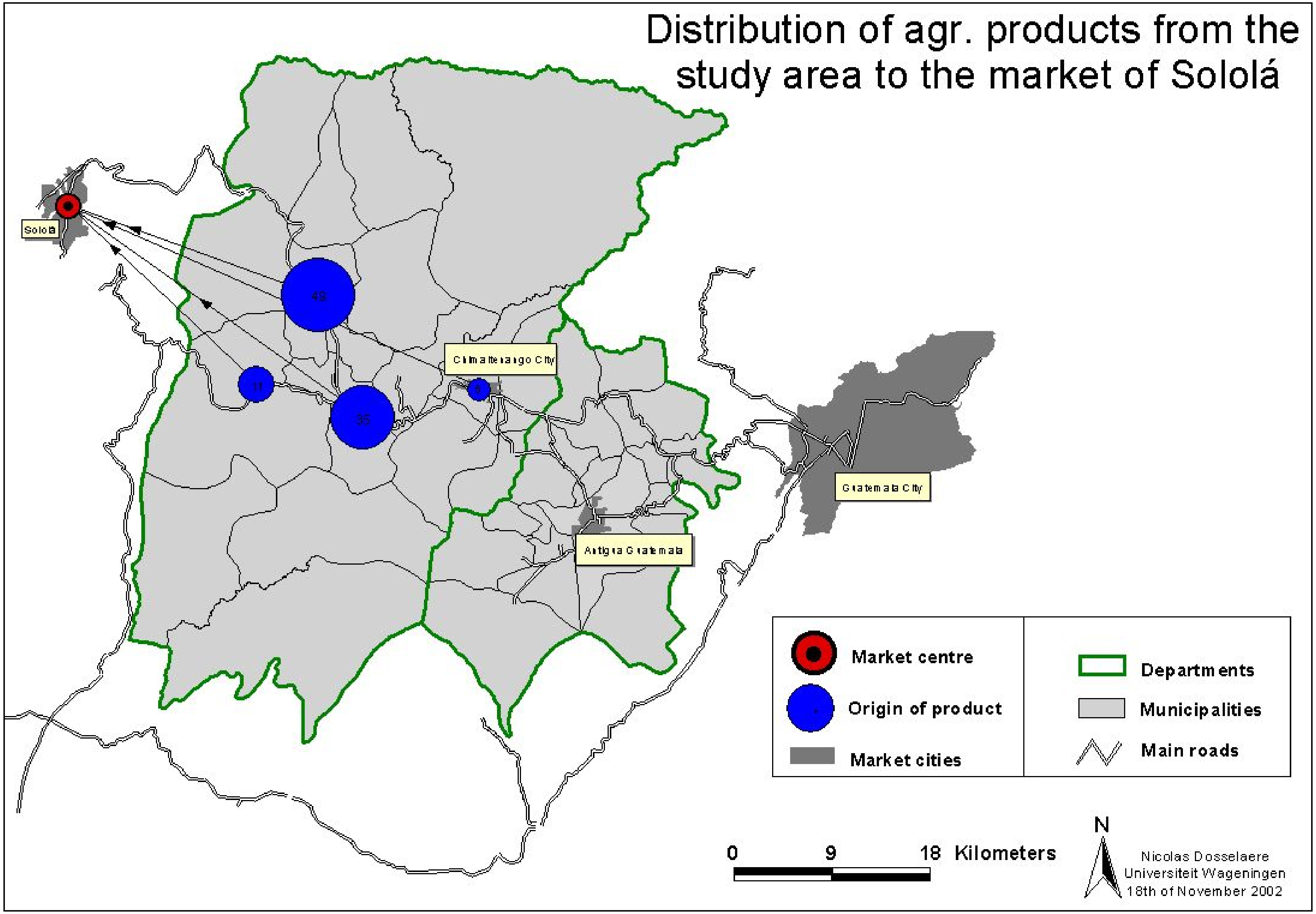


Figure A19. Distribution of agricultural products from the study area to the market of Sololá.

Appendix 10: Accessibility maps of the study area

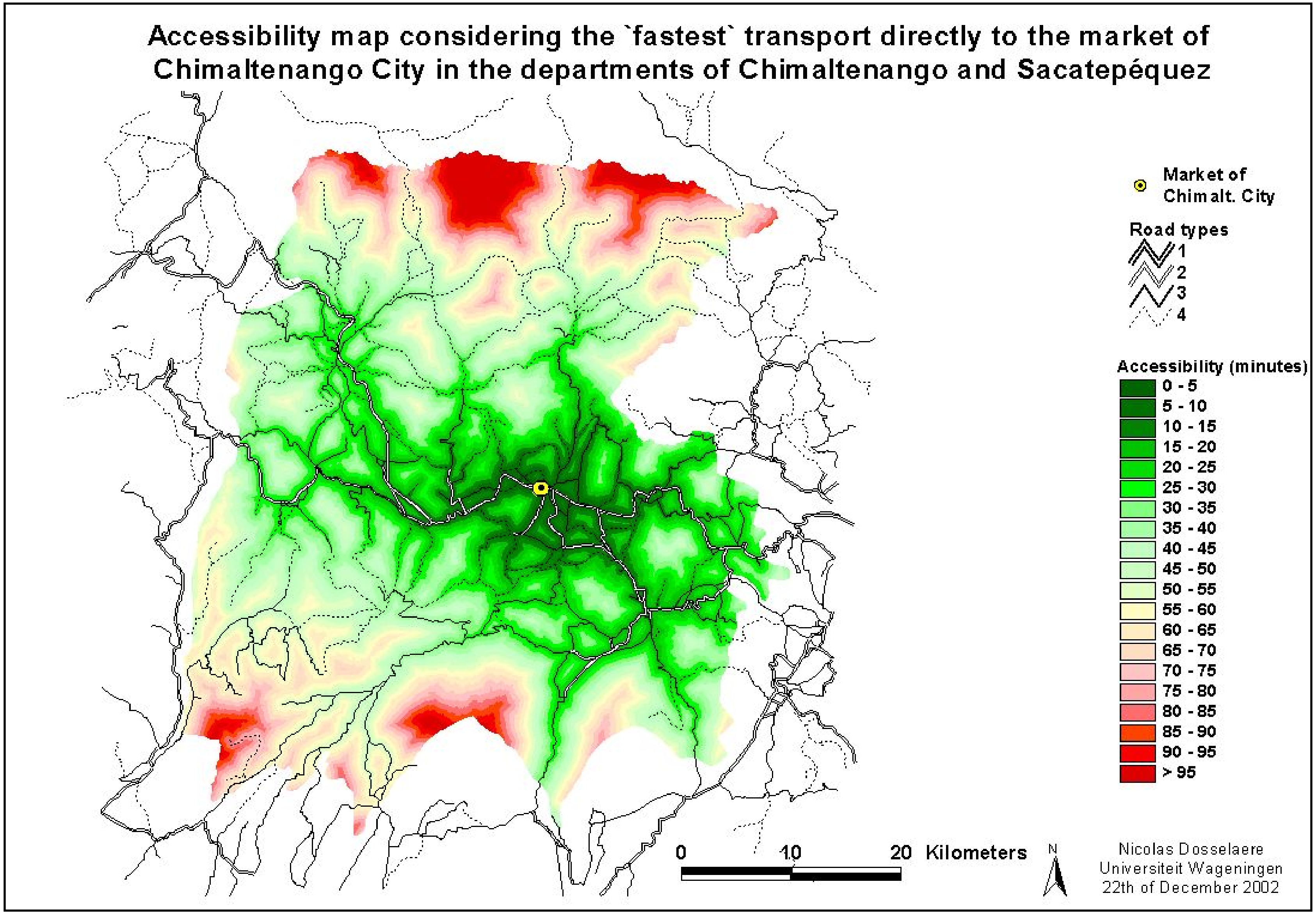


Figure A20. Accessibility map considering the `fastest` transport directly to the market of Chimaltenango City in the departments of Chimaltenango and Sacatepéquez.

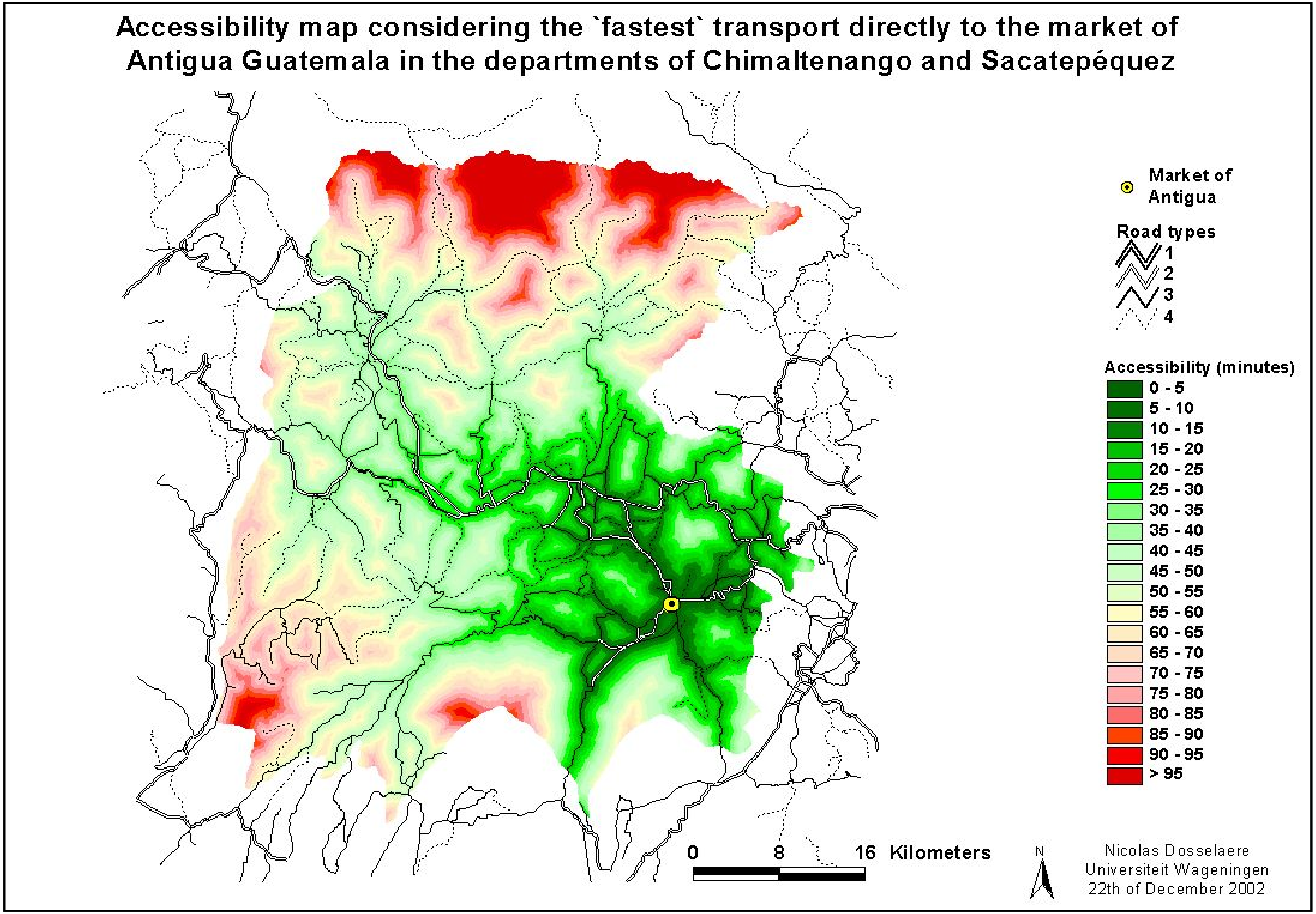


Figure A21. Accessibility map considering the `fastest` transport directly to the market of Antigua Guatemala in the departments of Chimaltenango and Sacatepéquez.

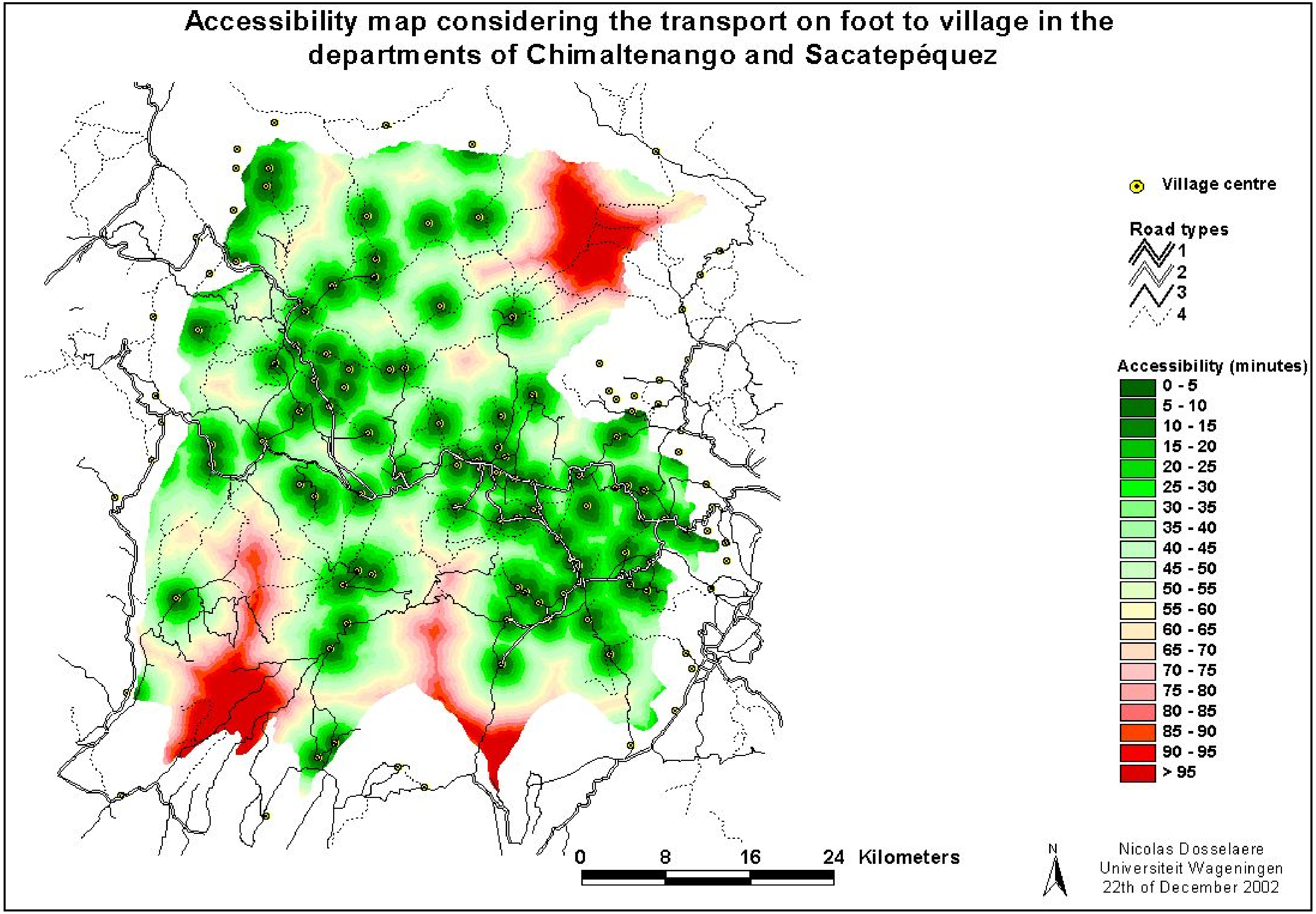


Figure A22. Accessibility map considering the transport on foot to village in the departments of Chimaltenango and Sacatepéquez.

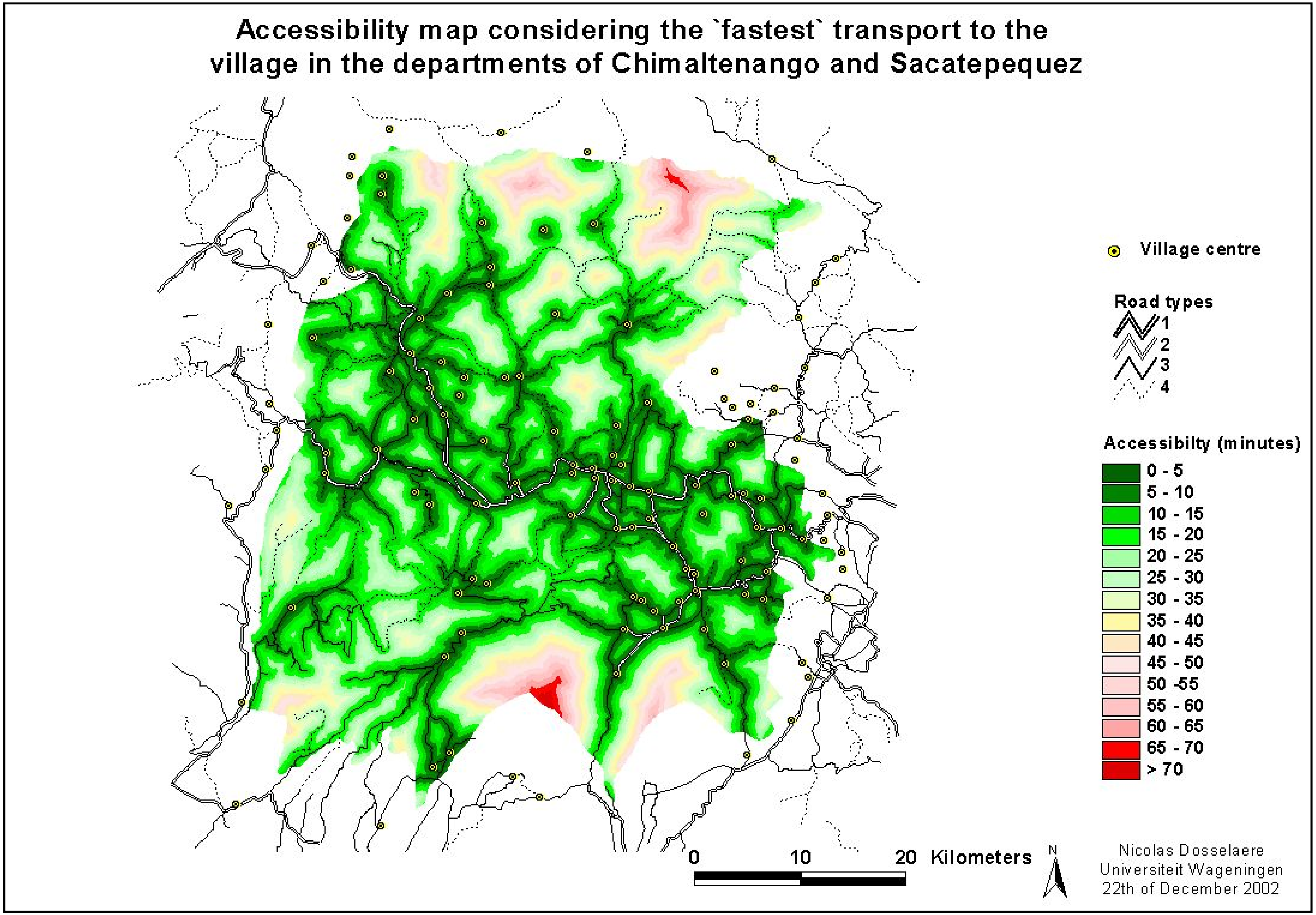


Figure A23. Accessibility map considering the `fastest` transport to the villages in the departments of Chimaltenango and Sacatepéquez.

m

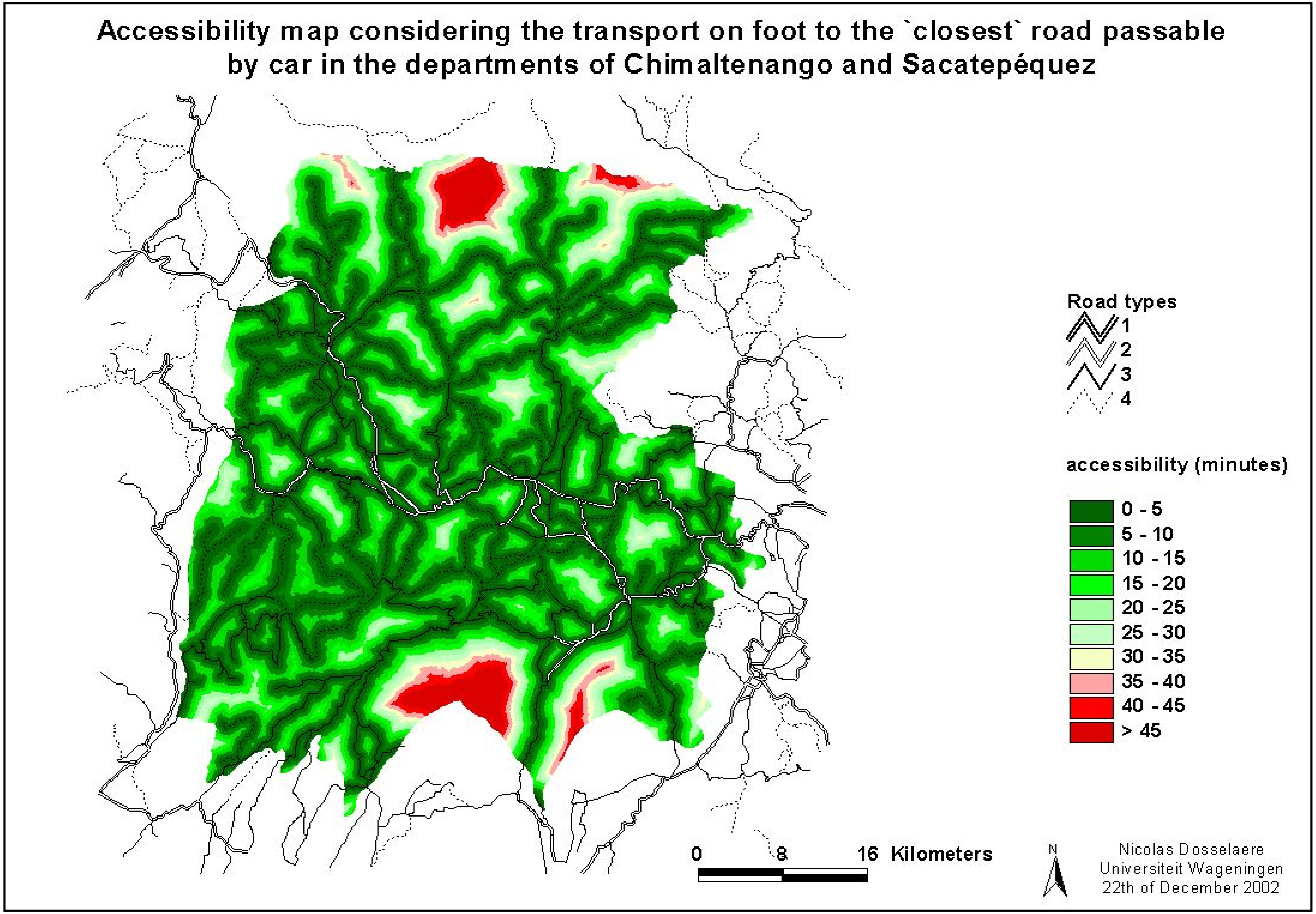


Figure A24. Accessibility map considering the transport on foot to the `closest` road passable by car in the departments of Chimaltenango and Sacatepéquez.

n