Environment and Natural Resources

Working Paper No. 10

Towards a GIS-based analysis of mountain environments and populations

POVERTY MAPPING

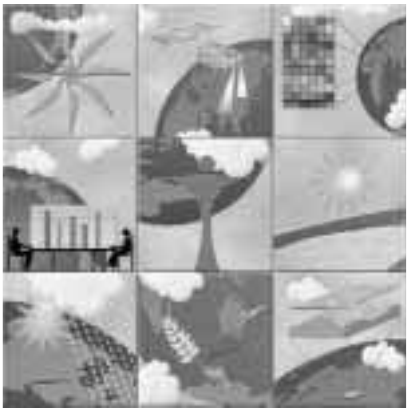
International Year of MOUNTAINS 2002

FAO FIAT PANIS

Environment and Natural Resources Service
Sustainable Development Department

in collaboration with
Food Security and Agricultural Projects Analysis Service
Economic and Social Department
and
Istituto Nazionale per la Ricerca Scientifica e Tecnologica sulla Montagna

Environment and Natural Resources



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Towards a GIS-based analysis of mountain environments and populations

by

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An FAO contribution to the follow-up activities of the International Year of Mountains, prepared with the support of members of the FAO Inter-Departmental Working Group on Mountains and partial funding from the Norwegian-funded Poverty and Food Insecurity Mapping Project, a joint initiative of FAO, the United Nations Environment Programme-GRID-Arendal and the Consultative Group on International Agricultural Research (CGIAR).

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2003

Preface

The value of spatial information for understanding development issues and improving decision-making is increasingly recognized. With this publication, FAO seeks to apply GIS-based analysis techniques to deepen understanding of conditions underlying poverty and hunger in the world, with special reference to mountain environments and populations. This focus is especially appropriate in 2003, as we begin the follow-up activities to the International Year of Mountains 2002 and consider ways in which the international community can respond more effectively to the special needs and concerns of mountain people.

Environmental constraints limit the prospects for agricultural development in many mountain areas, yet about 70 percent of the world's mountain population of 719 million remain rural and continue to depend on the natural resource base of land, water and forests for their livelihood. The spatial information about mountain environments and livelihood systems presented in this report provides new specificity about important aspects of the conditions that determine their sustainability.

The techniques used to prepare this report are applicable on a global scale, and will be extended later to other environments where poverty affects significant numbers of people. The work is being developed as a contribution to international initiatives for reducing poverty and hunger and achieving sustainable development. It is expected that the results will aid, *inter alia*, in the formulation and implementation of poverty reduction, food security and sustainable development strategies, and in the monitoring of progress towards the achievement of various international commitments and goals within the framework of Food Insecurity and Vulnerability Information and Mapping Systems (FIVIMS) and the Millennium Assessment Programme.

FAO is grateful to the Government of Norway for the encouragement and funding it has provided for this work, and to its collaborating partners for the constructive dialogue on substantive issues of common interest that has begun to emerge. We are committed to our common task and confident that this first set of preliminary results will not only demonstrate the potential usefulness of the method, but also prove to be of immediate use to those concerned with improving living conditions in mountain environments in a sustainable manner.

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Abstract

Towards a GIS-based analysis of mountain environments and populations

by Barbara Huddleston, ESAF; Ergin Ataman, SDRN with FAO GIS specialists Paola de Salvo, SDRN, Marina Zanetti, AGLL, Mario Bloise, SDRN, Judith Bel, SDRN and Gianluca Franceschini, SDRN; and Luca Fè d'Ostiani, INRM

32 pages, 6 maps, 9 tables, 8 graphs; Environment and Natural Resources Working Paper No. 10, FAO, Rome 2003

This report presents the results of work in progress. It applies GIS techniques and newly available geo-referenced data to understand conditions underlying poverty and hunger in the world, with special reference to mountain environments and populations. Following the system developed by the United Nations Environment Programme – World Conservation Monitoring Centre (UNEP-WCMC) in 2000 for classifying mountain areas, hilly as well as high mountain areas are covered by the analysis. New data about global population density from the LandScan 2000 map has made it possible to estimate population figures for each mountain area class, as well as for other parameters about agricultural land use, farming systems, environmental constraints and yields per person that contribute to the estimation of the number of vulnerable rural mountain people. The report notes that, although vulnerable people represent a far greater proportion of the total population in high mountain areas, their absolute numbers are far greater at lower elevations. In all, around 245 million rural mountain people in developing and transition countries are estimated to be vulnerable to food insecurity. Of these, 87 percent live below 2 500 m where population pressure and increasing demand for grazing land are creating serious sustainability problems for mountain environments and the livelihood systems of the inhabitants. This report concludes with a brief summary of five areas of opportunity for developing more sustainable livelihood options for mountain people, namely, water, agriculture, conservation and tourism, forests and rangelands, and mountain industry and services.

Keywords: mountains, poverty, hunger, food security, environments, populations, GIS, mapping

The Environment and Natural Resources Series replaces the following series:

- Environment and Energy Series
- Remote Sensing Centre Series
- Agrometeorological Working Papers

Acknowledgements

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Contents

LIST OF MAPS, TABLES, GRAPHS AND BOXES

Section one

INTRODUCTION

Mountain water, forests, flora and fauna constitute a rich global resource. Yet, in many places, the people living in mountain environments are exposed to harsh climatic conditions and soil and terrain constraints that make sustainable agricultural production difficult. In many locations, their relative isolation also limits non-agricultural options.

This report uses newly available geo-referenced data to explore the distribution and characteristics of mountain populations by region, type of mountain environment, and for rural mountain people, the type of farming system practised. The results contained in this report represent a first set of findings from work in progress. In subsequent work it is proposed to deepen the analysis for mountain areas by considering a larger number of variables that might help explain the extent of livelihood vulnerability, and its causes. At the same time, because much of the analysis is based on global GIS data, it is also envisaged to extend the work to non-mountain areas, eventually encompassing other locations where the nexus between environment, poverty and food insecurity is of particular concern.

The analysis in this report has been developed from GIS databases produced by FAO's Environment and Natural Resources Service from sources cited at the end of the paper. The reference map for all the analysis contained in this report has been the mountain map produced in 2000 by the United Nations Environment Programme-World Conservation Monitoring Centre (UNEP-WCMC). At that time, UNEP-WCMC defined six mountain area classes on the basis of slope and elevation. The UNEP-WCMC has recently added a seventh mountain area class, referring to isolated inner basins and plateaus and using a 7 km instead of 5 km radius for local elevation range, but the significance of these changes has yet to be fully investigated.

The procedure used for this report was first to create a geo-referenced map showing the six mountain area classes, as defined by UNEP-WCMC in 2000, and then to overlay the boundaries for the mountain area classes onto geo-referenced maps for each of the other pertinent variables. In this way the values for each of the other variables within the boundaries of each mountain area class, or other defined zone, could be obtained.

With the exception of the information on prevalence of malnutrition in mountainous countries, which was provided by the multi-donor-supported Micronutrient Initiative, all the data analysed here have been derived from maps developed by FAO's GIS Unit. The objective was to investigate the usefulness of GIS to generate data that would permit insights into location-specific characteristics of mountain environments and livelihood systems considered pertinent to guide action.

Variables examined in this study include the distribution of mountain area across regions and mountain area classes, distribution of mountain people across regions and mountain area classes, population density and extent of urbanization in mountain areas, rural land cover and agricultural land use in mountain areas, main farming systems, incidence of environmental constraints, degree of isolation as measured by distance of mountain areas and people from roads, productivity of rainfed agriculture based on estimates of livestock density and amount of cereals produced per person per year, and prevalence of selected micronutrient deficiencies.

The data were calculated using the best global maps available. Although most maps used as sources for this report were prepared with a 30 arc-second grid of the world, in one or two instances it has been necessary to use maps that were prepared with a 5-minute grid. Adjustments in the data have been made to bring the results obtained from these lower-resolution maps into line with those obtained at the 30 arc-second resolution. Due to the rather small-scale resolution of these maps, some variables such as area and population in some small and/or island countries could not be calculated with sufficient accuracy. Furthermore, for a few countries, there may be up to a 10 percent difference in the variables compared to other available international statistical data, as some of the maps originated from different sources and have slightly different topographic features, such as coast lines and/or water bodies. When overlayed, that is, when analysed together, such differences can cause small errors. However, the magnitude of these errors was deemed acceptable for the purposes of this document.

The results reported here differ in some respects from those in the *Special feature* in *The state of food insecurity in the world 2002*, *(SOFI),* mainly in the calculation of population data and urban and rural shares in total mountain population, for which more accurate data were obtained after SOFI went to print.

In general, this first set of results highlights a number of features of mountain environments that differ markedly from one part of the globe to another. It also provides some initial insights into the livelihood systems of mountain people.

We look forward to continuing the collaboration with other partners in efforts to further improve the knowledge and understanding of vulnerable environments and livelihood systems. For further information, or to comment on the method or preliminary results, please consult the Web site of the FAO GIS Unit at www.fao.org/sd/eidirect/gis/Elgis000.htm, or send an e-mail to GIS-Manager@fao.org.

Section two

MOUNTAIN AREA

2.1 What is a mountain?

In the year 2000 the United Nations Environment Programme – World Conservation Monitoring Centre (UNEP-WCMC) developed an approach for classifying mountains that defines a mountain area as a land mass with slope and/or elevation. In many cultures, mountains are differentiated from hills by their higher elevations, steeper slopes and cooler temperatures. However, mountain area, as defined by UNEP-WCMC, includes both mountains and hills.

The UNEP-WCMC initially defined six mountain area classes (Map 1). Land located at elevations higher than 2 500 m is always classified as mountain area, irrespective of slope (classes 4, 5 and 6). Below 2 500 m, high plateaus and large intermountain valleys are not classified as mountain area, even though they may exhibit many of the characteristics of a mountain ecology and are often closely linked with mountain ecosystems. But land with slope or sharp changes in elevation within a small radius is classified as mountain area, even at elevations as low as 300 m above sea level (classes 1, 2 and 3) .

2.2 Mountain area in developing and transition countries

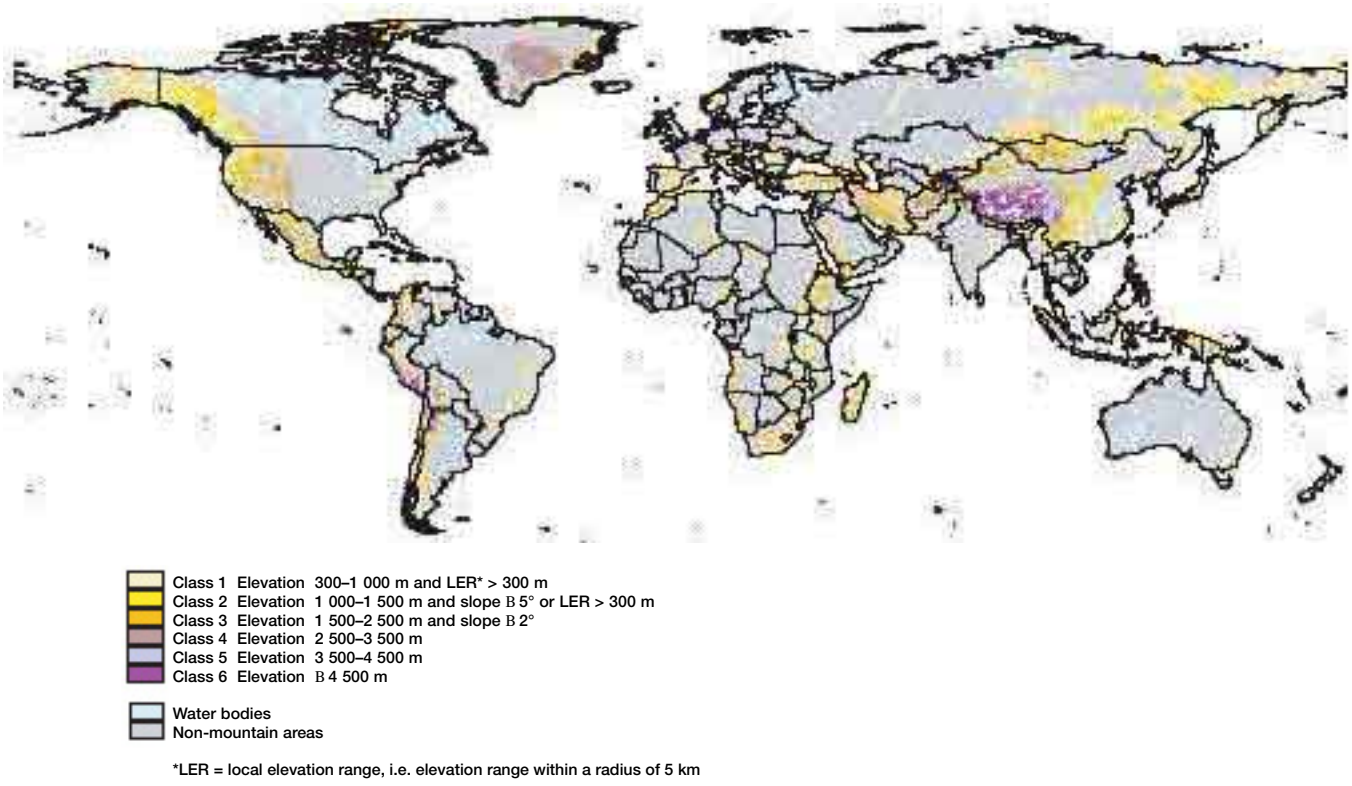
The original UNEP-WCMC classification scheme puts mountain area at 29 million km^2, or 22 percent of the total land area of the earth. Of this, 22 million km^2 is in developing countries and 5 million km^2 in transition countries.

Mountains are not equally important in all parts of the world. Asia and the Pacific (28%), developed countries (23%) and countries in transition (18%) have the highest shares of total mountain area (Graph 1). Subregions in developing and transition countries where mountain area exceeds one million km^2 include, in order of importance, East Asia, the Commonwealth of Independent States (CIS), South America, the Near East, Southeast Asia and Oceania, South Asia and East Africa (Table 1). Altogether, mountain area in these seven sub-regions accounts for almost 90 percent of the developing and transition country total.

When mountain area is viewed as a percent of total land area in a sub-region, the picture changes. From this perspective, sub-regions in developing and transition countries where mountain area is important include East Asia (50%), North America (Mexico) (45%), Central America (41%), Southeast Asia and Oceania (35%) and the Near East (34%) (Table 4).

Eighty percent of the world's mountain area is found below 2 500 m, and almost 50 percent below 1 000 m (Graph 2). Among developing and transition countries, this low-elevation mountain area is relatively evenly distributed. By contrast, high-elevation mountain area is geographically concentrated in the

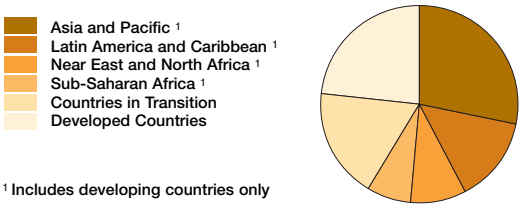
MAP 1 Mountains of the world



Himalayan and Andean mountain ranges and, above 4 500 m, on the vast semi-arid Chinese Tibetan plateau and the Andean altiplano. Because of their uniqueness and visibility, the high mountain areas have attracted considerable public interest and attention.

However, it is argued here that the greater size of the land mass, the higher population densities, and the growing threats to sustainable mountain development at lower elevations constitute a more widespread and equally pressing problem.

GRAPH 1
Distribution of mountain area by region



1 Includes developing countries only

GRAPH 2
Distribution of mountain area by mountain area class

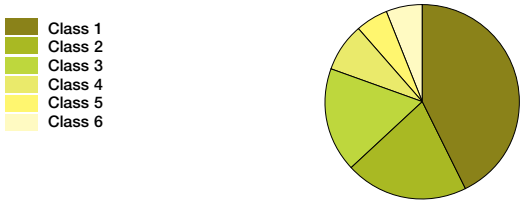


TABLE 1 Mountain area, by region and mountain area class

region/sub-region 1	mountain area (thousand km²)						
	class 1	class 2	class 3	class 4	class 5	class 6	total
ASIA AND PACIFIC	2 731	1 151	1 219	759	853	1 581	8 294
East Asia	1 189	662	887	627	740	1 409	5 514
Southeast Asia and Oceania	1 175	336	168	42	7	1	1 729
South Asia	367	153	164	90	106	171	1 051
LATIN AMERICA AND CARIBBEAN	1 412	730	812	443	585	155	4 136
Caribbean	38	6	3	–	0	0	46
North America	275	217	327	62	1	–	881
Central America	137	43	28	5	–	0	213
South America	962	464	455	375	584	155	2 996
NEAR EAST AND NORTH AFRICA	857	752	798	223	37	13	2 681
Near East	587	611	739	216	37	13	2 202
North Africa	271	141	59	7	–	0	478
SUB-SAHARAN AFRICA	921	668	438	94	5	–	2 125
Central Africa	138	109	55	6	–	–	308
East Africa	307	319	308	78	5	–	1 016
Southern Africa	373	225	74	9	0	0	681
West Africa	103	15	2	-	0	0	120
TOTAL DEVELOPING COUNTRIES	5 921	3 301	3 268	1 518	1 479	1 748	17 237
COUNTRIES IN TRANSITION	3 353	1 129	546	156	93	27	5 305
Commonwealth of Independent States (CIS)	3 103	1 057	529	156	93	27	4 966
Baltic States	0	0	0	0	0	0	0
Eastern Europe	250	72	18	–	0	0	340
TOTAL DEVELOPING AND TRANSITION COUNTRIES	9 275	4 430	3 815	1 674	1 573	1 776	22 542
TOTAL DEVELOPED COUNTRIES	3 263	1 573	1 296	698	12	–	6 842
TOTAL WORLD	12 538	6 003	5 110	2 372	1 585	1 776	29 384

– negligible
Some totals may not add, due to rounding.
1 Only developing countries are included in the region and sub-region totals for Asia and the Pacific, Latin America and the Caribbean, Near East and North Africa and Sub-Saharan Africa.

Section three

MOUNTAIN POPULATION

3.1 Where do mountain people live?

Data for the year 2000 put the number of mountain people in the world at around 720 million, or 12 percent of the total population of the earth. Altogether, about 90 percent, or 663 million, live in developing and transition countries (Table 2.a).

Among developing and transition country regions, the share of mountain people in total population is generally higher than for the world as a whole, and for some developing country sub-regions it is much higher (Central America, 53%; Near East, 33%; North America (Mexico), 30%; East Africa, 29%). However in Asia and the Pacific, even though mountain people make up nearly half of the world's mountain population (Graph 3), their numbers constitute only a small share (11%) of the region's total population (Table 4).

More than half of the world's mountain population live below 1 000 m (class 1), whereas less than 10 percent live above 2 500 m (classes 4, 5 and 6) (Graph 4). But population distribution by mountain area class differs significantly from one region to another.

TABLE 2.a Mountain population, total and urban share, by region and mountain area class

region/sub-region [1]	mountain population (thousand persons and percent urban)							
	class 1		class 2		class 3		class 4	
	total	% urban	total	% urban	total	% urban	total	% urban
ASIA AND PACIFIC	202 314	15	59 474	13	53 986	14	9 906	6
East Asia	131 232	12	42 026	10	42 675	13	7 194	5
Southeast Asia and Oceania	41 212	21	7 864	18	2 633	20	361	14
South Asia	29 870	20	9 584	24	8 677	20	2 351	6
LATIN AMERICA AND CARIBBEAN	42 207	50	17 921	47	24 416	42	18 516	53
Caribbean	2 552	23	176	11	50	4	–	0
North America	8 226	41	5 594	28	10 601	31	5 201	33
Central America	9 602	47	4 815	61	3 456	33	838	7
South America	21 826	58	7 336	54	10 309	56	12 477	64
NEAR EAST AND NORTH AFRICA	37 230	46	31 565	50	22 947	28	5 220	6
Near East	26 043	47	28 468	52	21 761	30	5 165	6
North Africa	11 187	45	3 097	30	1 186	5	55	0
SUB-SAHARAN AFRICA	18 423	12	22 664	19	35 045	25	11 591	0
Central Africa	2 849	12	2 990	16	2 655	15	447	14
East Africa	5 454	14	14 964	19	30 412	28	10 871	31
Southern Africa	6 480	10	4 320	21	1 961	2	273	1
West Africa	3 640	12	389	27	17	15	0	0
TOTAL DEVELOPING COUNTRIES	300 174	23	131 624	28	136 394	24	45 234	31
COUNTRIES IN TRANSITION	24 709	52	4 837	40	1 994	17	368	1
Commonwealth of Independent States (CIS)	11 016	63	3 893	49	1 827	18	368	1
Baltic States	0	0	0	0	0	0	0	0
Eastern Europe	13 693	44	944	5	167	1	–	0
TOTAL DEVELOPING AND TRANSITION COUNTRIES	324 884	26	136 461	28	138 388	24	45 602	31
TOTAL DEVELOPED COUNTRIES	43 929	39	8 722	29	3 080	22	263	3
TOTAL WORLD	368 812	27	145 183	28	141 468	24	45 865	31

– negligible
Some totals may not add, due to rounding.
[1] Only developing countries are included in the region and sub-region totals for Asia and the Pacific, Latin America and the Caribbean, Near East and North Africa and Sub-Saharan Africa.

In developed countries, countries in transition and Asia and the Pacific, the mountain population is concentrated below 1 000 m, while in Near East and North Africa and Sub-Saharan Africa it is concentrated between 1 000 and 2 500 m. Only in Latin America and the Caribbean is there a more even distribution of mountain population across mountain area classes (Table 2.b).

Countries where more than one-third of the population live in mountain areas and/or where mountain area exceeds one-third of the total land area are classified as mountainous in this report (Table 5). In total, they number 56. In the following countries, listed in rank order by region, mountain population exceeds 40 percent.

- ASIA AND PACIFIC: Bhutan, Papua New Guinea, Laos
- LATIN AMERICA: Guatemala, Costa Rica, Bolivia, El Salvador, Honduras, Colombia, Peru, Ecuador
- NEAR EAST: Yemen, Afghanistan
- SUB-SAHARANAFRICA: Rwanda, Lesotho, Swaziland, Eritrea, Ethiopia, Burundi
- COUNTRIES IN TRANSITION: Armenia, Bosnia-Herzegovina, Kyrgyzstan, Macedonia, Tajikistan, Georgia

BOX 1 Salient facts about mountain people

Elevations where mountain people are found

- more than half of mountain people live at elevations of less than 1 000 m and over 70 percent live below 1 500 m; of these, the majority live in China
- less than 10 percent of mountain people live at elevations higher than 2 500 m
- the Himalaya (Bhutan, Nepal, northern Afghanistan, northern India, northern Pakistan and the Tibetan Plateau) and the Andes (Bolivia, northern Chile, Ecuador, Peru) are virtually the only locations where mountain people are found living above 4 500 m; they represent less than one percent of the total

Farming systems that mountain people practise

- grazing predominates on 44 percent of mountain land in developing and transition countries, but 64 percent of rural mountain people occupy this land
- only 17 percent practise crop agriculture or integrated tree-crop-livestock farming, while 19 percent obtain their subsistence from sparsely vegetated barren land, protected areas and closed forests
- severe environmental problems exist for mountain rangelands and forests due to the pressure of growing population on a limited natural resource base
- on average globally, population density on grazing land at all elevations up to 3 500 m has reached or surpassed the critical point of 25 persons per km^2
- improved management of grassland and open forest is essential for the sustainability of livestock-based livelihood systems in mountain environments
- urban areas are currently home to almost 30 percent of the world's mountain population; growth of secondary mountain towns offers the possibility for balanced development in many mountain areas

class 5		class 6		total	
total	% urban	total	% urban	total	% urban
4 523	3	2 867	0	333 070	14
3 152	4	1 738	0	228 016	11
30	1	1	2	52 101	20
1 342	1	1 127	0	52 953	19
8 136	37	1 224	3	112 421	47
0	0	0	0	2 779	22
35	1	1	0	29 658	33
21	12	0	0	18 732	46
8 081	37	1 224	3	61 253	55
245	0	32	0	97 239	41
244	0	32	0	81 714	41
neg	0	0	0	15 525	39
256	28	1	0	87 980	22
2	0	neg	0	8 944	14
253	28	1	0	61 955	25
0	0	0	0	13 035	12
0	0	0	0	4 046	14
13 160	24	4 124	1	630 710	25
161	1	13	0	32 082	47
161	1	13	0	17 278	53
0	0	0	0	0	0
0	0	0	0	14 804	41
13 320	24	4 137	1	662 792	26
5	0	0	0	55 998	36
13 325	24	4 137	1	718 790	27

TABLE 2.b Share of mountain population living at different elevations, by region

	Mt. Pop	<1 000m	1 000-2 500m	2 500m-3 500m	>3 500m
	million	(%)	(%)	(%)	(%)
Asia & Pacific	333	60	35	3	2
Latin America & Caribbean	113	38	38	17	7
Near East & North Africa	97	38	57	5	neg
Sub-Saharan Africa	88	19	66	14	1
Countries in Transition	32	78	22	neg	neg
Developed Countries	56	79	21	neg	neg

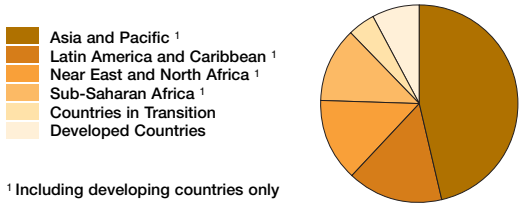
In countries such as these, mountain issues are likely to be an important national concern in their own right. Elsewhere, mountain issues are more likely to be subsumed under other policy priorities such as environmental protection, water management, sustainable agricultural development, employment creation or poverty reduction.

3.2 Population density and urbanization in mountain areas

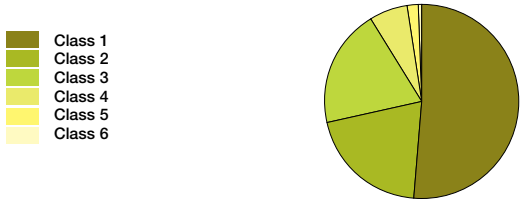
Density of mountain population can range from a few persons per km² (as in several Central Asian countries), to very high values (as in Central American and Ethiopian highlands). The extent of urbanization in mountain areas also varies markedly from one region to another (Table 2.a and Graph 5). In Latin America and the Caribbean and countries in transition nearly half of the mountain population live in urban areas, whereas in Sub-Saharan Africa and Asia and the Pacific the urban shares are only 22 percent and 14 percent, respectively. This means that the high population density figures shown in Table 3 for Sub-Saharan Africa and Asia and the Pacific reflect mainly high densities in rural mountain areas, with the consequences that this has for the mountain environments.

N - The databases developed for this report can be used to explore the specificity of conditions for mountain people in any country included in the database, recognizing that the margin of error will be greater at the national level than at the global or regional levels.

GRAPH 3
Distribution of mountain population by region



GRAPH 4
Distribution of mountain population by mountain area class



GRAPH 5
Mountain population - urban and rural shares by region

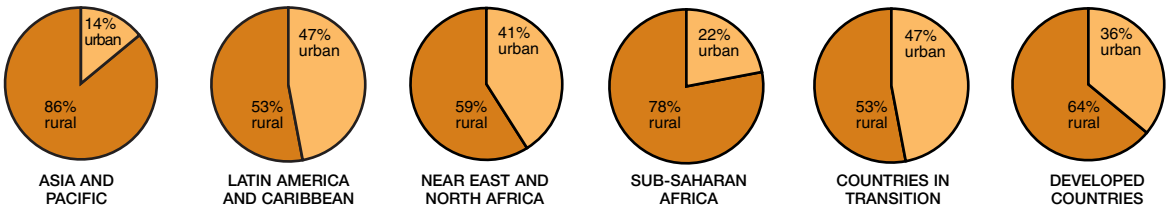
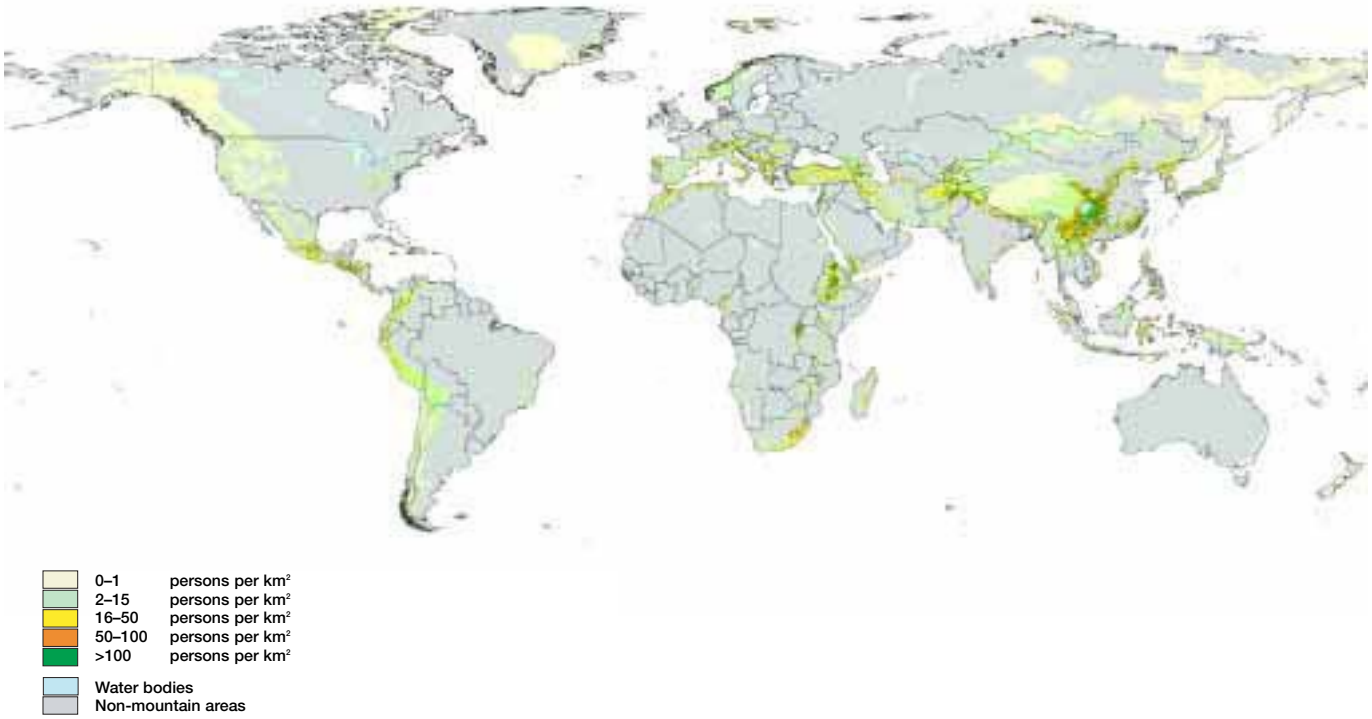


TABLE 3 Average population density in mountain areas, by region and mountain area class

region ¹	persons per km²						
	class 1	class 2	class 3	class 4	class 5	class 6	average population density
ASIA AND PACIFIC	74	52	44	13	5	2	40
LATIN AMERICA AND CARIBBEAN	30	25	30	42	14	8	27
NEAR EAST AND NORTH AFRICA	43	42	29	23	7	2	36
SUB-SAHARAN AFRICA	20	34	80	124	53	10	41
COUNTRIES IN TRANSITION	7	4	4	2	2	-	6
DEVELOPED COUNTRIES	13	6	2	-	-	-	8

¹ Only developing countries are included in the region totals for Asia and the Pacific, Latin America and the Caribbean, Near East and North Africa and Sub-Saharan Africa.

MAP 2 Population density in mountain areas of the world



MAP 3 Location of major urban centres in mountain areas of the world

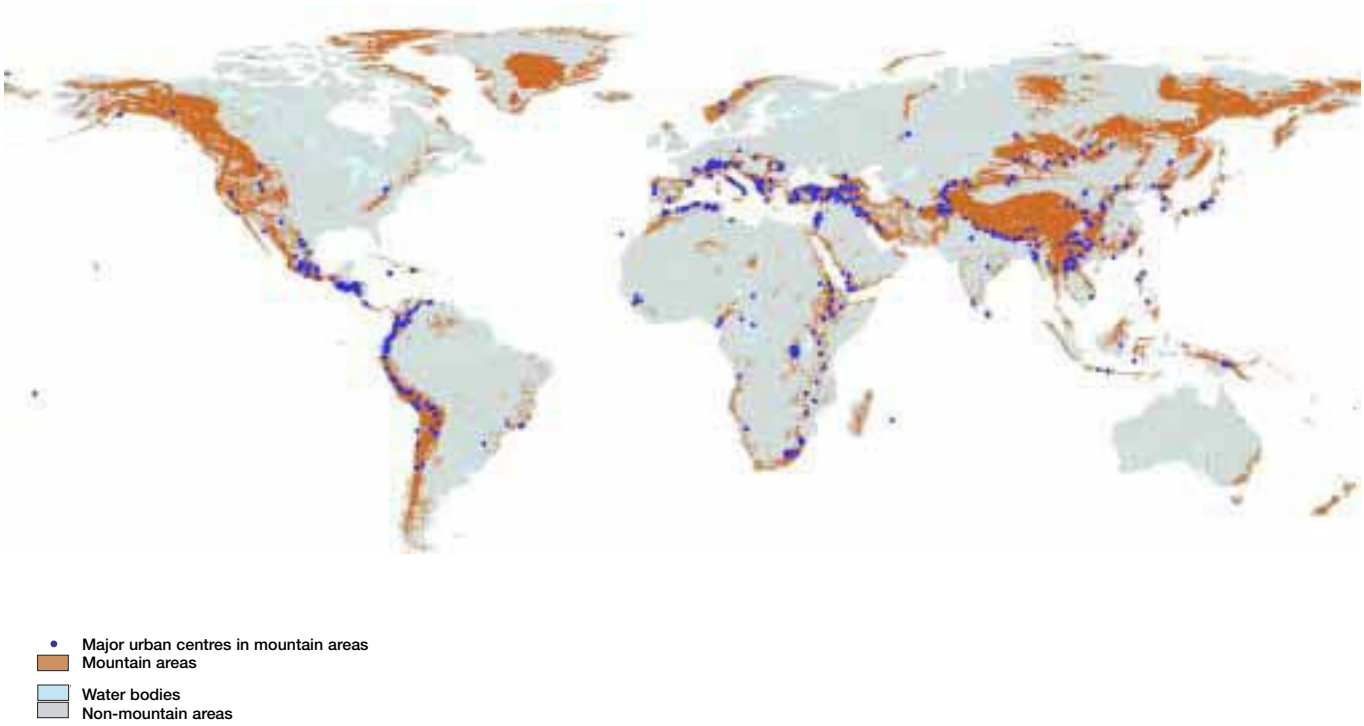


TABLE 4 Mountain area and population, regional and sub-regional totals

region/sub-region [1]	mountain area and population			
	mountain area (thousand km²)	mountain area as share of total land area (%)	mountain population (thousand persons)	mountain population as share of total population (%)
ASIA AND PACIFIC	8 294	41	333 070	11
East Asia	5 514	50	228 016	17
Southeast Asia and Oceania	1 729	35	52 101	10
South Asia	1 051	24	52 953	4
LATIN AMERICA AND CARIBBEAN	4 136	20	112 421	22
Caribbean	46	22	2 779	9
North America	881	45	29 658	30
Central America	213	41	18 732	53
South America	2 996	17	61 253	18
NEAR EAST AND NORTH AFRICA	2 681	22	97 239	25
Near East	2 202	34	81 714	33
North Africa	478	9	15 525	11
SUB-SAHARAN AFRICA	2 125	9	87 980	15
Central Africa	308	6	8 944	11
East Africa	1 016	16	61 955	29
Southern Africa	681	13	13 035	16
West Africa	120	2	4 046	2
TOTAL DEVELOPING COUNTRIES	17 237	23	630 710	14
COUNTRIES IN TRANSITION	5 305	23	32 082	8
Commonwealth of Independent States (CIS)	4 966	23	17 278	6
Baltic States	0	0	0	0
Eastern Europe	340	29	14 804	12
TOTAL DEVELOPING AND TRANSITION COUNTRIES	22 542	23	662 792	13
TOTAL DEVELOPED COUNTRIES	6 842	20	55 998	6
TOTAL WORLD	29 384	22	718 790	12

Some totals may not add, due to rounding.
[1] Only developing countries are included in the region and sub-region totals for Asia and the Pacific, Latin America and the Caribbean, Near East and North Africa and Sub-Saharan Africa.

TABLE 5 Mountainous countries and their mountain areas and populations, by region

region/country [1,2]	mountain area and population			
	mountain area (thousand km²)	mountain area as share of total land area (%)	mountain population (thousand persons)	mountain population as share of total population (%)
ASIA AND PACIFIC				
Bhutan	39	98	1 698	89
Papua New Guinea	199	44	2 127	49
Laos	167	72	2 300	42
Mongolia	528	34	1 004	38
Nepal	119	81	8 484	35
East Timor	8	60	256	33
China	4 883	52	223 346	18
Korea Dem. People's Rep.	73	61	2 953	15
Myanmar	323	49	3 571	9

TABLE 5 continued

region/country [1,2]	mountain area and population			
	mountain area (thousand km²)	mountain area as share of total land area (%)	mountain population (thousand persons)	mountain population as share of total population (%)
Philippines	103	37	5 165	7
Viet Nam	131	40	5 223	7
LATIN AMERICA AND CARIBBEAN				
Guatemala	51	46	8 012	64
Costa Rica	24	47	2 284	63
Bolivia	398	36	4 973	61
El Salvador	11	53	3 585	60
Honduras	75	67	3 530	60
Colombia	296	26	20 247	54
Peru	610	47	12 391	47
Ecuador	108	43	5 265	43
Venezuela	196	21	7 352	33
Mexico	881	45	29 658	30
Chile	471	65	3 496	24
Haiti	13	52	1 455	24
Jamaica	5	45	432	20
Dominican Republic	17	37	507	7
NEAR EAST AND NORTH AFRICA				
Yemen	155	37	10 553	61
Afghanistan	376	59	13 942	54
Iran	842	52	23 602	37
Lebanon	8	83	1 126	37
Turkey	545	70	23 147	37
Jordan	12	13	1 778	36
Morocco	188	46	6 911	24
Cyprus	3	37	46	6
SUB-SAHARAN AFRICA				
Rwanda	17	70	5 488	75
Lesotho	28	91	1 430	73
Swaziland	12	65	675	62
Eritrea	65	53	2 408	59
Ethiopia	471	42	35 244	55
Burundi	13	47	2 963	48
Djibouti	9	39	62	18
COUNTRIES IN TRANSITION				
Armenia	26	86	2 339	70
Bosnia-Herzegovina	38	73	1 874	50
Kyrgyzstan	180	91	2 182	46
Macedonia	22	85	930	46
Tajikistan	131	92	2 914	45
Georgia	55	79	2 053	41
Albania	20	72	1 251	39
Yugoslavia Federal Republic of	55	54	2 757	26
Bulgaria	45	41	1 801	24
Slovenia	13	67	434	24
Slovak Republic	25	52	1 155	22
Azerbaijan	39	46	1 145	15

[1] Only developing countries are included in the region and sub-region totals for Asia and the Pacific, Latin America and the Caribbean, Near East and North Africa and Sub-Saharan Africa.
[2] Mountainous country: country in which over one-third of the population live in mountain areas and/or over one-third of the total land area is classified as mountainous. Countries are listed in rank order by region, from highest to lowest in terms of share of the population living in mountain areas. Among developed countries, all of Andorra and Liechtenstein, and more than two-thirds of Austria and Switzerland are covered by mountain area; in these four countries the share of mountain population is 40 to 100 percent. In Norway, Greece, New Zealand, Italy, Japan, Iceland, Spain & the Canaries and Greenland, mountain area is 40 to 60 percent of total area, but the share of mountain population never exceeds 15 percent.

Section four

MOUNTAIN LIVELIHOODS

4.1 How do rural mountain people survive?

Although most rural mountain people engage in some form of agricultural activity, their livelihood systems are actually quite diversified. Out-migration of one or more male family members is common, and remittances are an important source of income, whose magnitude and impact have yet to be accurately assessed.

In mountain areas with access to urban centres, jobseekers and small entrepreneurs have possibilities to increase and diversify their incomes. In more remote areas, mountaineering, tourism and nature conservancy offer alternative employment opportunities. Nevertheless, the agricultural resource base remains important, and a large number of rural mountain people will continue to depend on it as a main source of livelihood for the foreseeable future.

N - For a more detailed explanation of the method used to develop the data presented in this section, see Sources and Notes for Map 4; Graphs 6 and 7; Tables 4.a-4.d (pp. 24-25)

4.2 Use of mountain resource base for agriculture

In general, mountain areas are not well-suited for crop agriculture. FAO has estimated that 78 percent of the world's mountain area is not suitable or is only marginally suitable for growing crops. Grazing and forestry are more adapted to mountain ecologies, and in fact, these are the predominant uses of mountain land in all regions. Nevertheless, preliminary analysis of available GIS data indicates that in some locations, the potential still exists for sustainable production of food and cash crops on mountain land that is currently forested or under pasture. Work in progress is seeking to identify these locations more precisely, and to indicate the conditions that would need to be met in order to extend the agricultural frontier in such areas in a sustainable manner.

In developing and transition countries, only 7 percent of total mountain area is currently classified as cropland. Barren land occupies 33 percent of the total, with closed forest and grazing land each comprising about 25 percent. Protected area makes up the remaining 10 percent (Table 6.a).

In many locations several types of land cover may be found in close proximity. Thus, to create Map 4, high resolution GIS data for the five types of land cover

TABLE 6.a Mountain area in developing and transition countries, by type of land cover and mountain area class

mountain area class	barren land [1]	protected area	grazing land [1]	closed forest	cropland	grand total
	thousand km^2					
class 6	1 182	316	180	50	2	1 730
class 5	853	155	465	77	11	1 561
class 4	658	139	605	178	44	1 624
class 3	965	265	1 440	788	263	3 721
class 2	1 289	300	1 104	1 095	381	4 169
class 1	2 418	700	1 986	3 097	948	9 149
total area	7 365	1 875	5 780	5 285	1 649	21 954
area in each land cover category as share of total	percent					
	33	10	25	25	7	100

TABLE 6.b Mountain area in developing and transition countries, by land use category and mountain area class

mountain area class	mainly barren land [1]	protected area	grazing land with some cropland, closed forest and barren land [1]	mainly grazing land [1]	mainly closed forest	mixed use: closed forest, grazing land and cropland [1]	mainly cropland	grand total
	thousand km^2							
class 6	1 156	316	268	0	0	0	0	1 740
class 5	732	155	679	neg	5	2	1	1 574
class 4	514	139	879	6	50	47	4	1 639
class 3	654	265	2 106	57	333	318	35	3 768
class 2	964	300	1 860	136	429	477	51	4 217
class 1	1 810	700	3 331	338	1 217	1 668	182	9 246
total area	5 830	1 875	9 123	537	2 034	2 512	273	22 184
area by land use catebory as share of total	percent							
	26	9	41	3	9	11	1	100

[1] Barren land: sparsely vegetated land, desert, semi-desert, tundra, snow and ice; grazing land: grassland, open forest and shrubland.

mentioned above have been combined to form seven mixed land use categories for mountain land. Distribution of mountain area and rural mountain population in developing and transition countries, by land use category, is shown for the six mountain area classes in Tables 6.b and 6.c and Graph 6 and 7.

In mountain areas, grazing of livestock is practised in areas classified as (i) sparsely vegetated barren land, (ii) grazing land interspersed with other land cover, and (iii) mainly grazing land. In developing and transition countries, 88 percent of the total mountain area of 4.8 km^2 above 2 500 m is classified as mainly barren land or as grazing land with some cropland, closed forest and barren land, with protected area making up virtually all of the remainder. Livestock herding is thus the main form of livelihood at higher elevations.

Above 4 500 m (class 6), some 3.7 million people live on sparsely vegetated barren land or grazing land interspersed with other land cover, while 0.4 million live in protected areas.

Between 2 500 m and 4 500 m (classes 4 and 5), around 5 million people live on sparsely vegetated barren land, while 29 million live on grazing land interspersed with other land cover, and 4.0 million live in protected areas.

Although the area under closed forest is limited, forests provide a home for another 1.7 million rural mountain people living above 2 500 m, mainly in class 4.

Mixed land use patterns (e.g. crop agriculture combined with exploitation of forest resources and herding of small livestock) are characteristic of some locations between 2 500 m and 3 500 m (class 4), notably in Central and South America, in the Eastern African and Ethiopian highlands, and in the Nepal hills. Although mountain people in these locations are increasingly vulnerable, their numbers are quite small.

Above 2 500 m, only 2.0 million rural people live in areas classified as mainly cropland or mixed use (Table 6.c), and cropland at higher elevations constitutes only 3 percent of the total mountain area dedicated to crops in developing and transition countries (Table 6.a).

These findings confirm the importance of pastoralism for mountain people at higher elevations in developing and transition countries. However, the breakdown of traditional trade routes and patterns of exchange, the degradation of the resource base resulting from population growth and increase in livestock numbers, and the impact of frequent, severe droughts in recent years have rendered this livelihood system vulnerable, with mountaineering, tourism or migration offering the only

TABLE 6.c Rural mountain population in developing and transition countries, by land use category and mountain area class

mountain area class	mainly barren land [1]	protected area	grazing land with some cropland, closed forest and barren land [1]	mainly grazing land [1]	mainly closed forest	mixed use: closed forest, grazing land and cropland [1]	mainly cropland	grand total
	thousand persons							
class 6	2 284	426	1 387	0	0	0	0	4 097
class 5	2 275	1 062	6 683	10	40	40	0	10 110
class 4	2 746	2 955	21 521	695	1 672	1 264	727	31 580
class 3	4 611	3 773	67 491	6 183	8 489	9 013	5 240	104 800
class 2	5 398	4 122	49 563	11 483	10 599	10 894	5 987	98 046
class 1	4 586	8 448	106 691	42 483	29 449	21 001	28 966	241 624
total population	21 900	20 786	253 336	60 854	50 249	42 212	40 920	490 257
population by land use category as share of total	percent							
	5	4	52	12	10	9	8	100

TABLE 6.d Rural population density, by land use category and mountain area class

mountain area class	mainly barren land [1]	protected area	grazing land with some cropland, closed forest and barren land [1]	mainly grazing land [1,2]	mainly closed forest	mixed use: closed forest, grazing land and cropland [1]	mainly cropland [2]	grand total
	persons per km^2							
class 6	2	1	5	0	0	0	0	2
class 5	3	7	10	0	8	20	0	6
class 4	5	21	24	116	33	27	182	19
class 3	7	14	32	108	25	28	150	28
class 2	6	14	27	84	25	23	117	23
class 1	3	12	32	126	24	13	159	26

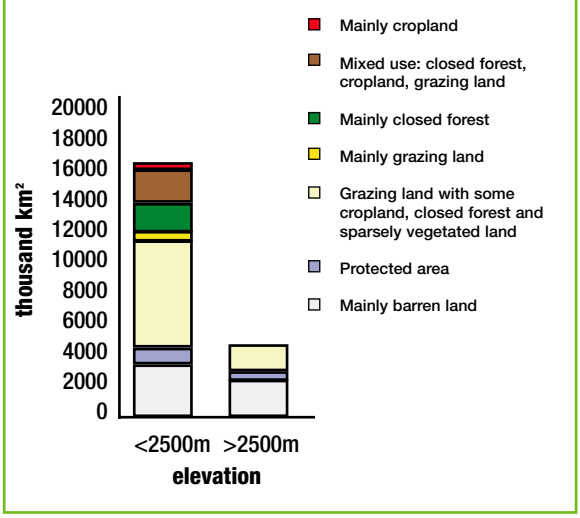
[1] Barren land: sparsely vegetated land, desert, semi-desert, tundra, snow and ice; grazing land: grassland, open forest and shrubland.
[2] High rural population densities in this land use category probably reflect proximity to urban centres, and not population pressure on productive land.

significant alternatives. As men leave, women are forced back into crop agriculture, for which the land is barely suitable.

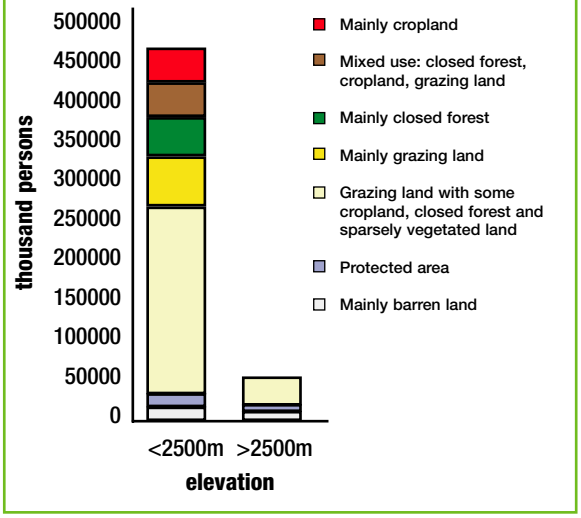
Below 2 500 m, grazing land still predominates, with 20 percent of the mountain area in developing and transition countries classified as mainly barren land, 42 percent as grazing land interspersed with other land cover, and 3 percent as mainly grazing land. Around 299 million people, representing two-thirds of the rural mountain population living below 2 500 m in developing and transition countries, inhabit these areas and rely on livestock as a significant source of income. Along with raising animals, people living on grazing land interspersed with other land cover at elevations below 2 500 m also practice crop agriculture.

In mountain areas, pastoral farming systems generally rely on extensive grazing methods that cannot support more than 25 persons per km^2 and the associated number of animals common to these systems. On average globally, this critical number has been reached or surpassed in all mountain area classes below 3 500 m (Table 6.d). However, the significance of this finding needs to be seen in relation to the specific geographical context of each farming system described in Table 7.

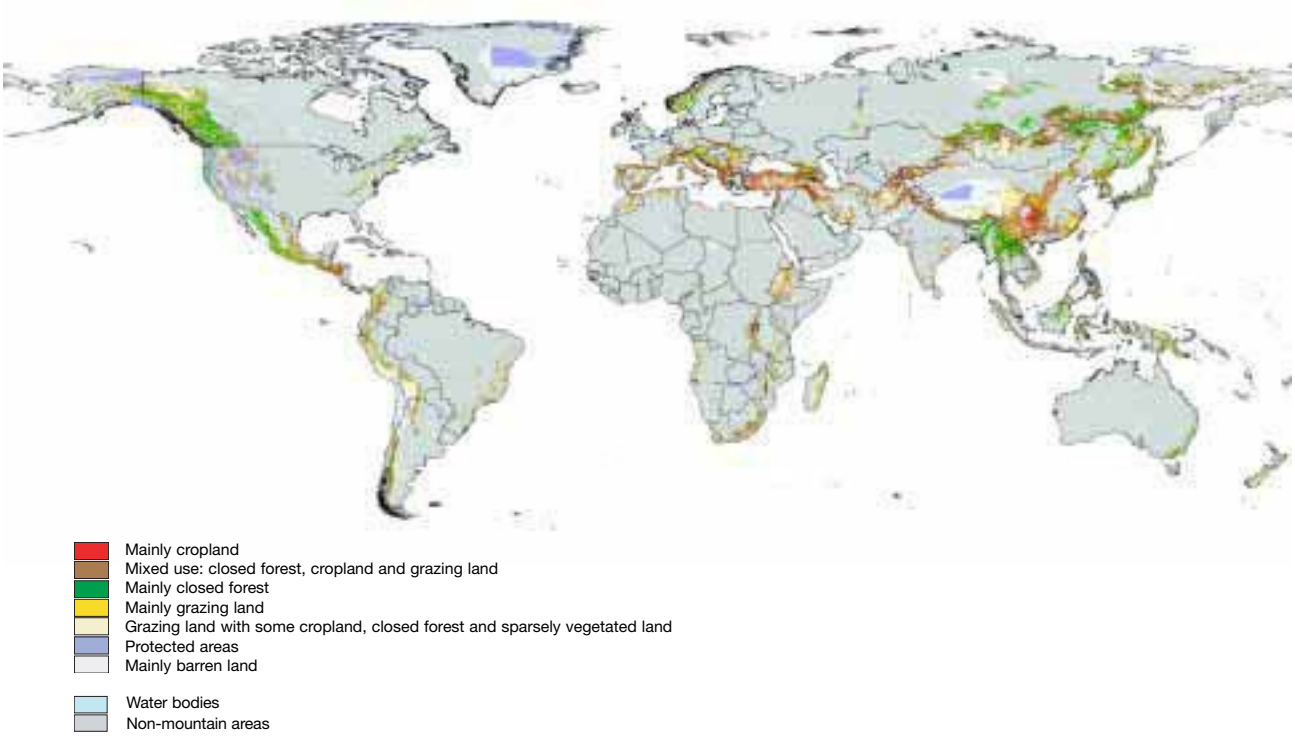
GRAPH 6
Mountain area in developing and transition countries, by elevation and rural land use category



GRAPH 7
Mountain population in developing and transition countries, by elevation and rural land use category



MAP 4 Rural land cover and agricultural land use in mountain areas of the world



4.3 Main farming systems in mountain areas

In a recently published study, Dixon et al. identified 44 farming systems practised to greater or lesser extent in developing and transition countries. Many farming systems, especially those with their largest diffusion in the lowlands, are not unique to mountain environments. The 17 systems described in Table 7 include only those that are significant in mountain areas at elevations above 1 000 metres. Together, these systems account for 67 percent of total mountain area and 82 percent of total rural mountain population in developing and transition countries. Map 5 shows the locations of eight relatively homogeneous groupings for these mountain farming systems; the regional significance of each is described briefly below.

4.3.1 Asia and the Pacific

Himalaya Range (South Asia)

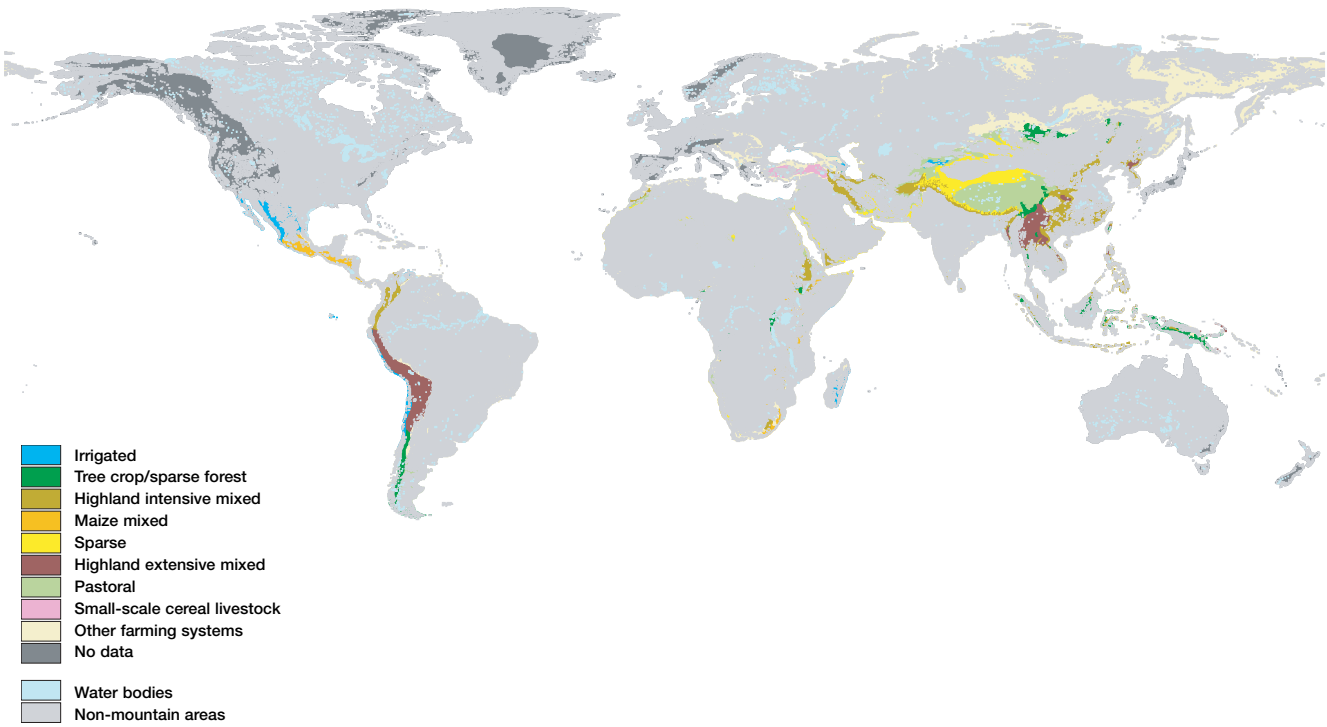
Highland Mixed System. Generally intermediate between the rice-wheat system of the lowlands and the sparse mountain system above, the highland mixed system extends across the entire Himalaya range and into the Near East and North Africa (see below). With 48 million rural mountain people occupying this area, it represents one of the most significant of the mountain farming systems under study. Generally, ruminant livestock are an important part of the system because they provide draught power, milk, manure and cash income. However, the system is vulnerable, due to overgrazing of rangeland, remoteness and lack of social services in many areas. The prevalence of poverty and food insecurity is rated between moderate and severe, depending on the location.

Sparse Mountain System. Lying at elevations above 3 000 m along the middle and upper Himalaya slopes, this system has a rural population of only 4 million. Soil erosion in the highland and upper watersheds is widespread and is being worsened by heavy grazing and the loss of nutrients from cropland, posing grave threats to household survival. Households supplement their income by seasonal migration and in some cases by trade, mountaineering and tourism. In some areas, social cohesion is absent or very poorly developed, making it difficult to resolve land-ownership disputes or to obtain agreement on the use and management of common lands. Poverty is moderate overall, although more severe in some remote areas.

Truong Son, Ningling Shan and Wuhi Shan Ranges (East and Southeast Asia and the Pacific Islands)

Upland Intensive Mixed System. Throughout East and Southeast Asia, upland and hill landscapes of moderate elevation and slope are characterized by similar topography but considerable climatic variation, from the humid/sub-humid tropics and sub-tropics to temperate environments. Major areas where intensive upland agriculture is practised are found in Indonesia, Philippines, northern Thailand, Viet Nam and southern China. Inhabited by 147 million rural people, it is the most populous mountain farming system. Although terracing and use of organic matter to maintain soil quality is common in many parts, high population densities have led to the cultivation of marginal sloping lands without adequate soil and water management. Thus average incomes are low and poverty and food insecurity are moderate to severe.

MAP 5 Main farming systems in mountain areas (developing and transition countries)



Upland Extensive System. Extensive agriculture is practised in the same sub-region in hill and upland landscapes of high elevation and steep slopes where the natural resource base is poor. The rural mountain population of 40 million is comprised of mainly tribal (indigenous) groups, with traditional cultures that depend heavily on mountain forests for their livelihoods. Deforestation resulting from population pressure poses a serious threat to this system, and poverty and food insecurity are widespread and severe.
Sparse Forest System. Small numbers of rural mountain people in East Asia and scattered across the Pacific islands belong to the sparse forest system. This is a livestock-based system that relies on sparsely vegetated grazing land and open forest, with cultivation of food crops appropriate to the local ecology. Poverty and food insecurity are low to moderate.

Kunlun Range and Plateau of Tibet (Central and South Asia)
Pastoral and Sparse Arid Systems. (see discussion under Central Asian CIS, p. 16)

4.3.2 Latin America and the Caribbean

Andean Range (South America)
Intensive Highland Mixed (North Andean) System. This system includes two sub-systems: the higher elevation inter-mountain valleys and the lower slopes. It is still an agriculturally viable farming system. However, due to the attractions of urban life and the crisis in traditional indigenous culture, out-migration to lower mountain regions and to the Amazon and Chaco lowlands is widespread, and the rural mountain population now numbers only 10 million. Poverty is generally moderate in the lower areas but becomes extensive and severe at higher elevations.
High Altitude Mixed (Central Andean) System. High elevation farming is theoretically feasible in a large area in the Central Andes, including the steep valleys of the high Sierra as well as the Altiplano of southern Peru, western Bolivia, northern Chile and northern Argentina. However, the rural mountain population is only 9 million, of which three-quarters is in Peru. The vast treeless Altiplano is composed of an undissected tableland above 3 500 m, with some agricultural land reaching 4 500 m. The small size of most landholdings, the lack of external inputs, the naturally low productivity typical of high elevation arid land, the widespread erosion of topsoil and the loss of soil fertility, have resulted in endemic poverty and growing out-migration. Poverty and food insecurity are extensive and very severe.
Sparse Forest (Southern Andean) System. The high elevations and low temperatures characteristic of the southern Andes render cultivation generally sub-marginal, but the small rural mountain population obtains a good living from livestock, forestry and tourism. Poverty and food insecurity thus remain low to moderate.

Sierra Madre and Cordillera de Salamanca Ranges (Mexico and Central America)
Maize-Bean (Mesoamerican) System. This system stretches from the upland areas of Central Mexico to

TABLE 7
Main mountain farming systems in developing and transition countries

farming system	location
1. Irrigated	Madagascar and some mountain riverbanks in Africa; coastal areas of Chile, Ecuador and Peru and of Caspian and Aral seas; terraced hills of Mexico, and South and Southeast Asia
2. Tree-crop	Hilly areas of West African coastal countries from Côte d'Ivoire to Angola
3. Rice-tree-crop	Upland areas of Madagascar
4. Highland perennial	Highlands of Burundi, Ethiopia, Rwanda and Uganda
5. Highland temperate mixed	Ethiopian Highlands and small pockets in Angola, Cameroon, Eritrea, Lesotho and Nigeria
6. Maize mixed	Uplands of Kenya, Lesotho, Malawi, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe
7. Pastoral	Semi-arid and arid areas in all regions – important in Central Asian CIS countries and also in Hindu-Kush and Himalaya highlands and plateaus
8. Sparse (arid)	Arid areas throughout North Africa and Near East; and in China, Kazakhstan, Mongolia, Pakistan, Turkmenistan, and Uzbekistan
9. Highland mixed	Himalayan, South Asian, Near Eastern and North African hills below 3000 m
10. Small-scale cereallivestock	Turkey
11. Sparse (mountain)	Middle and upper Himalayan slopes over 3 000 m
12. Upland intensive mixed	Indonesia, northern Thailand, Philippines, South China and Viet Nam
13. Upland extensive mixed	Cambodia, Indonesia, Laos, Myanmar, northern Thailand, Philippines, southeastern China, Viet Nam
14. Sparse (forest)	Indonesia, Malaysia, Mongolia, Myanmar, Pacific islands, southern Argentina and southern Chile, western China
15. Maize-bean	Central Mexico, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama
16. Intensive highland mixed	Colombia, Ecuador and Venezuela
17. High altitude mixed	Bolivia, northern Chile, northwestern Argentina and Peru
18. Other mountain farming systems	All regions
Total mountain area	
Total rural population	

– location, characteristics, area and rural population, by mountain area class

characteristics	area and rural population							
		class 1	class 2	class 3	class 4	class 5	class 6	total [1]
Usually dispersed small/micro-scale irrigated areas in otherwise arid or semi-arid environments with interstices of grazing land and scattered rain-fed cropping.	thousand km²	296	205	271	65	12	0	849
	thousand persons	2 445	1 200	1 108	230	32	3	5 019
Mostly industrial tree crops (cocoa, coffee, tea, oil palm, rubber) that are highly vulnerable to price fluctuations. Subsistence food crops often inter-planted.	thousand km²	50	16	7	0	0	0	74
	thousand persons	1 406	1 215	619	5	0	0	3 245
Banana and coffee complemented by rice, maize, cassava and legumes. Farm size is small, but irrigation is important. Poor development of markets and off-farm activities.	thousand km²	72	35	9	0	0	0	115
	thousand persons	1 122	847	379	0	0	0	2 349
Industrial tree crops (banana, plantain, coffee) complemented by enset, cassava, sweet potato, beans, and cereals for subsistence.	thousand km²	12	48	72	8	0	0	140
	thousand persons	1 044	4 750	8 859	842	12	0	15 507
Wheat, barley, peas, lentils, broad beans, rape and potato. Income mostly from small ruminants, wool, local beer, migrant remittances.	thousand km²	20	57	158	70	4	0	309
	thousand persons	640	2 314	9 552	6 548	163	1	19 219
Diverse livestock species, but mainly sheep and goats and less commonly, cattle. Maize for subsistence and cash sale; other field and fodder crops in mountain valleys; cassava and potatoes for subsistence.	thousand km²	172	187	85	10	1	0	455
	thousand persons	3 981	5 403	4 493	624	8	0	14 510
More favourable areas used for extensive cereal production, complemented by raising of sheep. Drier parts used by semi-nomadic pastoralists.	thousand km²	522	456	517	330	557	1 155	3 537
	thousand persons	6 012	9 335	13 885	4 113	2 518	1 403	37 267
Opportunistic grazing where animal watering is feasible, intensive localized irrigation and some run-off crop production where moisture supply is sufficient.	thousand km²	470	384	310	315	211	291	1 982
	thousand persons	2 904	2 000	1 234	619	181	239	7 177
Cereals, legumes, tubers, fodder and fodder trees, ruminant livestock; potatoes and apples grown for market sale.	thousand km²	192	218	473	197	14	0	1 096
	thousand persons	14 705	11 954	16 276	5 117	99	0	48 151
Wheat and barley (partially marketed), small ruminants. Traditional integrated crop-livestock system led to overgrazing of grassland, but this is now decreasing due to reduced population pressure.	thousand km²	38	98	117	17	0	0	270
	thousand persons	1 267	2 691	2 300	192	0	0	6 449
Potatoes and buckwheat together with cattle and yak herds in seasonal transhumance. Household income supplemented by seasonal migration, and in some cases by trade and tourism.	thousand km²	0	0	1	55	128	155	339
	thousand persons	0	0	17	1 199	1 504	1 199	3 919
Rice, paddy, wheat, maize, sugar cane, cotton, legumes, oil-seeds, fruits. Income mainly from vegetables, fruits, pig and poultry	thousand km²	1 315	376	120	7	0	0	1 817
	thousand persons	111 857	28 194	6 599	74	8	0	146 731
Occurs above the upland intensive mixed system, but with less resources and population. Based on perennial crops (mainly fruit trees), livestock and forest products.	thousand km²	241	231	256	63	11	2	806
	thousand persons	7 550	9 571	21 340	2 313	143	9	40 927
Potatoes and buckwheat plus cattle and yaks on the Asian mainland; upland rice, root crops and ruminants in Indonesia, Malaysia and Papua New Guinea; livestock, forestry and sub-marginal agriculture in Argentina and Chile.	thousand km²	469	244	289	102	67	20	1 190
	thousand persons	3 367	1 253	1 595	835	324	57	7 431
Subsistence production of maize and beans, plus cash crops such as coffee, horticulture, vegetables, flowers, beef meat. Family income often complemented with seasonal out-migration.	thousand km²	183	108	148	36	1	0	476
	thousand persons	6 776	4 561	8 514	4 150	53	1	24 055
Coffee and horticulture (in lower valleys and slopes); temperate crops and maize (in highlands and upper valleys).	thousand km²	74	57	102	79	26	1	339
	thousand persons	2 573	1 647	2 950	2 598	410	6	10 184
Vegetables, maize, coffee, indigenous grains, potatoes, sheep and llamas. Over one-third of the cultivated land is irrigated using traditional techniques and systems.	thousand km²	59	80	168	233	534	151	1 225
	thousand persons	563	553	1 096	1 753	4 635	1 175	9 775
About twenty-five other farming systems are present in mountain areas, but with a much lower incidence. Altogether they only cover about 23 percent of the total mountain area and contain 18 percent of the total rural mountain population.	thousand km²	5 041	1 614	695	79	5	0	7 434
	thousand persons	73 201	10 654	3 983	388	19	0	88 245
	thousand km²	9 226	4 414	3 798	1 668	1 572	1 775	22 453
	thousand persons	241 412	98 143	104 800	31 602	10 110	4 093	490 160

In an earlier version of his work, Dixon identified 46 rather than 44 farming systems, leading to a count of 19 rather than 17 present in mountain areas. The poster version of Map 5 refers to that earlier count. In this report, the 17 mountain farming systems described in Table 7 cover all rural mountain area above 1 000 m in developing and transition countries. Their correspondence to the eight homogeneous groupings depicted in Map 5 is shown by the colour codes in column one of the table.

[1] Slight differences in totals from one table to another are due to small differences in the placement of coastal boundaries in the different data sources.

those above the Panama Canal, with a rural population of about 24 million (half of them in Mexico). The area where this system prevails is historically and culturally distinguished by the significant proportion of indigenous population, the central role of maize in the traditional culture, the small size of holdings, the high degree of on-farm consumption of production, and the importance of seasonal migration. Cultivated land extends up to 3 500 m, but the majority is between 400 and 2 000 m. The historical loss of the better inter-mountain valley lands to non-indigenous settlers and commercial operations have led to serious degradation of upland areas, and severe poverty and food insecurity.

4.3.3 Near East and North Africa

Atlas Range (North Africa); Zagros Range (Iraq and Iran); Pontic and Taurus Ranges (Turkey); Hindu Kush (Afghanistan)

Highland Mixed System. This system is a continuation of the highland mixed system found in the middle Himalaya (see above), and is the most important system in the Near East and North Africa region, extending from Morocco to Afghanistan, with several pockets in other countries, such as Iran, Lebanon, Syria and Yemen. It is a traditional integrated crop-livestock system, characterized by quite high population densities. Environmental degradation is a widespread phenomenon, due to inadequate maintenance of terraces and overgrazing. Adult male migration is common, and poverty is extensive.

Small-scale Cereal-Livestock System. This system is unique to Turkey, with many similarities to the highland mixed system. The rural mountain population practising this system numbers over 6 million. In recent years, out-migration has reduced population density, and the trend toward increasing erosion of the topsoil and loss of soil quality has been reversed. Poverty and food insecurity are now low.

Pastoral and Sparse Arid Systems. (see discussion under Central Asian CIS, p. 16)

4.3.4 Sub-Saharan Africa

Ethiopian and Eastern African Highlands; Mitumbar, Mutchinga, Drakensberg and Madagascar Ranges (Eastern and Southern Africa)

Highland Perennial System. Perennial crops grown mostly in the sub-humid and humid highlands of Burundi, Ethiopia, Rwanda and Uganda support high densities of rural mountain population, currently totalling around 16 million. Population pressure has resulted in intense land use on very small landholdings (below 1 ha per family on average, with over half cultivating less than 0.5 ha). Farm size continues to decline, and soil fertility is being lost rapidly. Coping mechanisms that involve intensifying land use also result in low return to labour, leading to further increases in the prevalence and severity of poverty and hunger, which are already high.

Highland Temperate Mixed System. This system supports a rural population of 19 million, mostly located between 1 800 m and 3 000 m in the Ethiopian Highlands, with smaller pockets in Angola, Cameroon, Eritrea, Lesotho and Nigeria. Population density is high and increasing, with the result that landholdings are becoming smaller, and the system less and less sustainable. In addition, variability in the length of the growing period results in serious crop failures in some years. Poverty is moderate to extensive.

Maize Mixed System. This is the most important mountain food production system in eastern and southern Africa, extending across plateaus and highlands between 800 and 1 500 m from Kenya to South Africa, and providing a livelihood for around 15 million rural mountain people. Population density is quite high and average landholding is below 2 ha. Socio-economic diversification is considerable and vulnerability is mainly linked to drought, market volatility and high incidence of HIV-AIDS. Chronic poverty has been moderate, but is increasing.

Rice-Tree Crop System. Over 2 million people living in the Madagascar uplands practise the rice-tree crop system. Farm size is small but largely under irrigation, and surplus is sold, although access to markets can be difficult. Prevalence of poverty and food insecurity is moderate.

Hilly Coastal Areas (West Africa)

Tree-crop System. Industrial tree crops, with subsistence foodcrops interplanted, characterize this system, which is practised by over 3 million people in hilly coastal areas of West Africa. The prevalence of poverty and food insecurity has been moderate, but increasing price volatility - the main source of vulnerability - is having an adverse impact.

4.3.5 Countries in Transition

Pamir and Tien Shan Ranges (Central Asian CIS)

Pastoral System. Pastoralism is practised throughout much of Central Asia, Mongolia, eastern China, and the highland plateaus of South Asia and the Hindu Kush. Altogether, 37 million rural mountain people in these sub-regions follow a pastoral way of life. Most pastures are in high mountainous areas or adjacent dry zones. Cereals, fodder crops and potatoes are cultivated for subsistence in mountain valleys. Due to excessive animal population and poor grazing techniques, rangeland is being rapidly degraded and erosion processes are spreading. Although meat output is increasing, wool production has fallen dramatically and poverty is becoming more widespread.

Sparse Arid System. At higher elevations in the same sub-regions, where cold winters lead to dormancy or very slow growth of crops and fodder species, some crop cultivation is still possible, and animals are grazed wherever the condition of the vegetation permits. Altogether, 7 million rural mountain people use this system. As in the pastoral areas, degradation of the natural resource base is a growing phenomenon, and poverty and food insecurity are moderate to severe.

VULNERABILITY OF MOUNTAIN PEOPLE

5.1 What constraints do rural mountain people face?

5.1.1 Environmental constraints

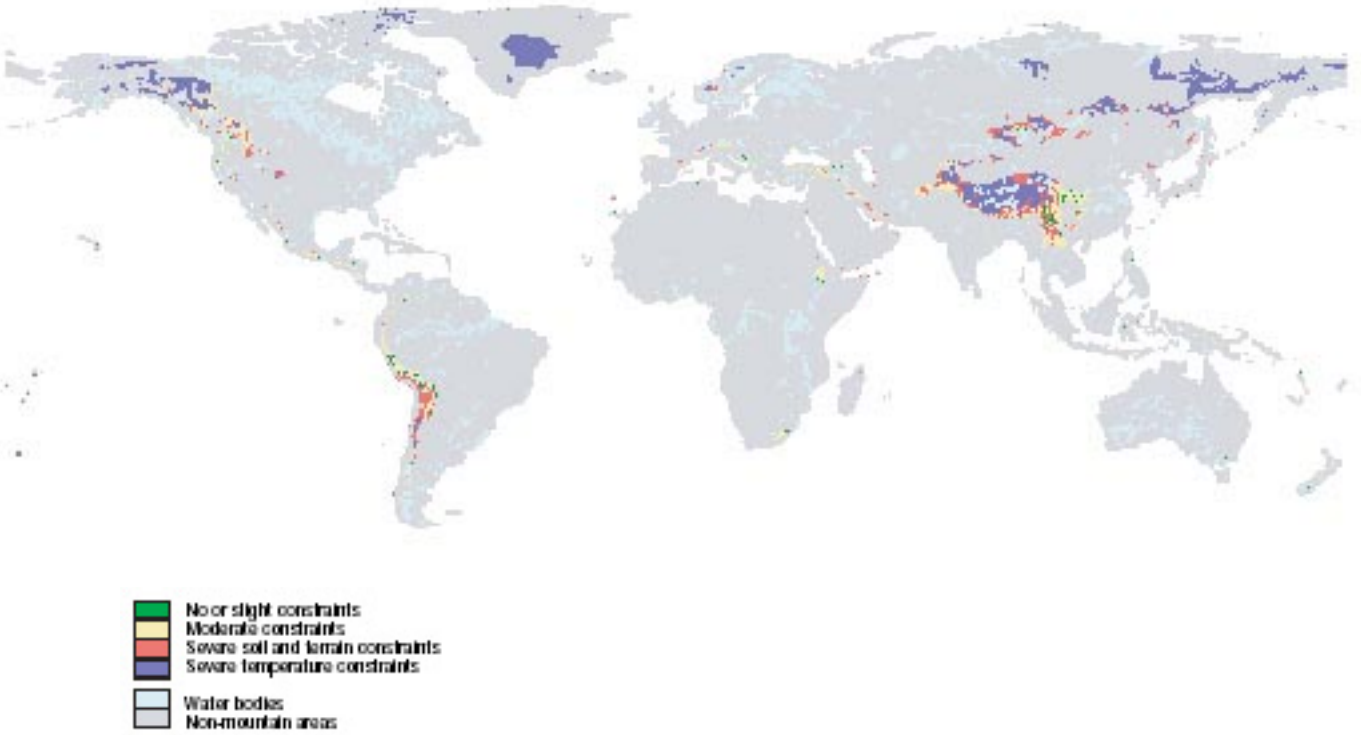
Although mountain areas are generally more adapted for pastoralism and forestry than for crop agriculture, production of staple cereals for home consumption figures in virtually all of the mountain farming systems described in the previous section. However, in mountain areas, most crop agriculture is practised under conditions where at least some environmental constraints are present. In fact, in some locations agricultural activity is practised even in severely constrained areas, such as, for example, where slopes are steep and soils are shallow. While crop production in such areas this may be very important for the livelihoods of local mountain people, it is also an important factor in the on-going environmental degradation processes taking place wherever population pressure is pushing the agricultural frontier into areas that are only marginally suitable. Since crop agriculture becomes truly impossible only in locations above the permafrost line, uncultivated lands in marginal areas below the permafrost line are attracting increasing numbers of vulnerable people.

Maps 6.a, 6.b and 6.c show the prevalence of each of the three main types of environmental constraints in mountain areas, namely, unfavourable climatic conditions, sloping terrain, and poor quality and/or very shallow soil. Map 6 is the result of combining the separate analyses that have been made on climate, terrain and soil constraints that limit rainfed crop production.

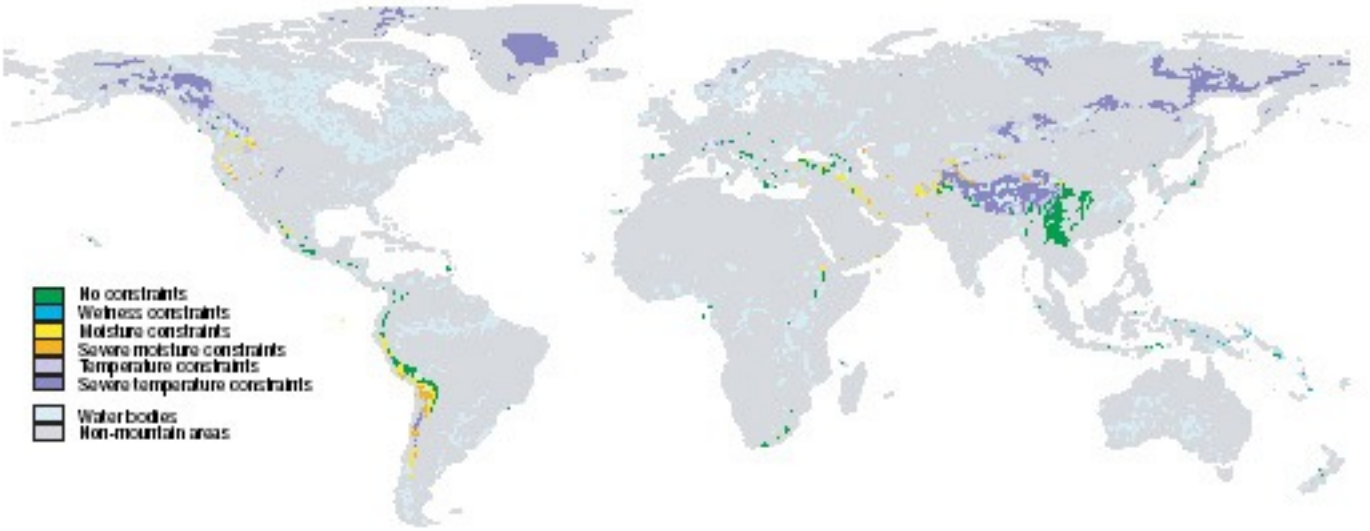
Each type of constraint is composed of several elements, summarized in Box 2. On Map 6, where severe constraints are indicated, both severity and occurrence of constraints are high. Similarly, where moderate constraints are indicated, severity and occurrence of constraints are both moderate. Where both severity and occurrence are low or no constraints are present, this is indicated as no or slight constraints on the map.

The widespread presence of environmental constraints to crop agriculture in most arable mountain areas does mean that crops produced are generally not likely to be competitive in global markets, due to the relatively lower productivity of the land. On the other hand, with the growth of mountain cities and consequent development of transport infrastructure linking urban centres to upland rural areas, there will be opportunities to diversify.

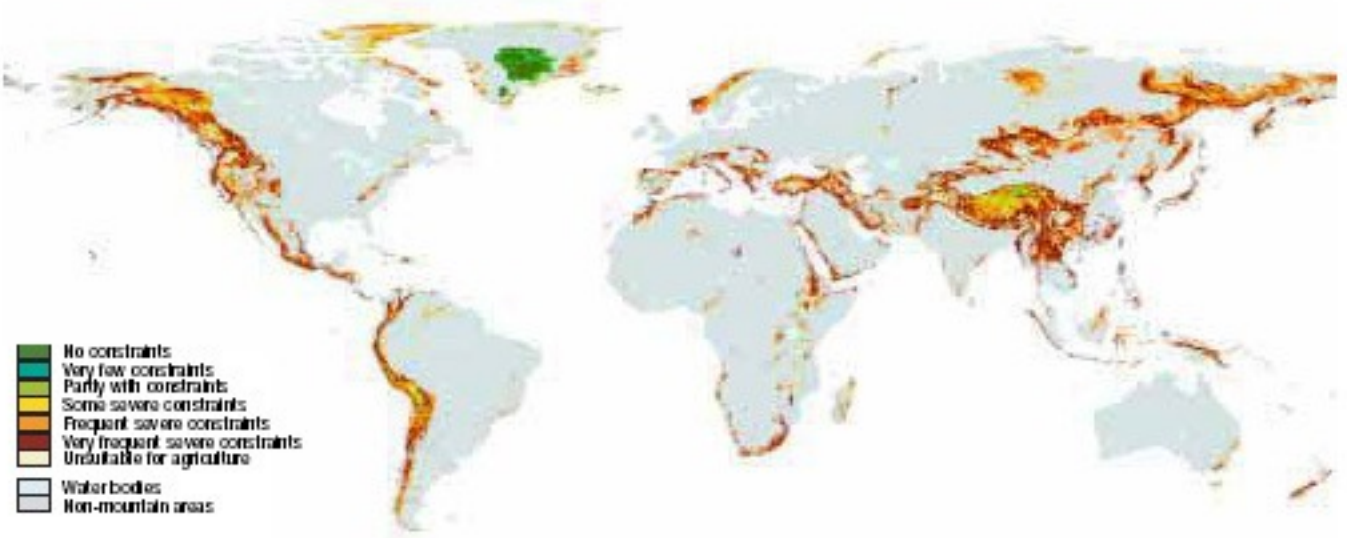
MAP 6 Environmental constraints in mountain areas of the world

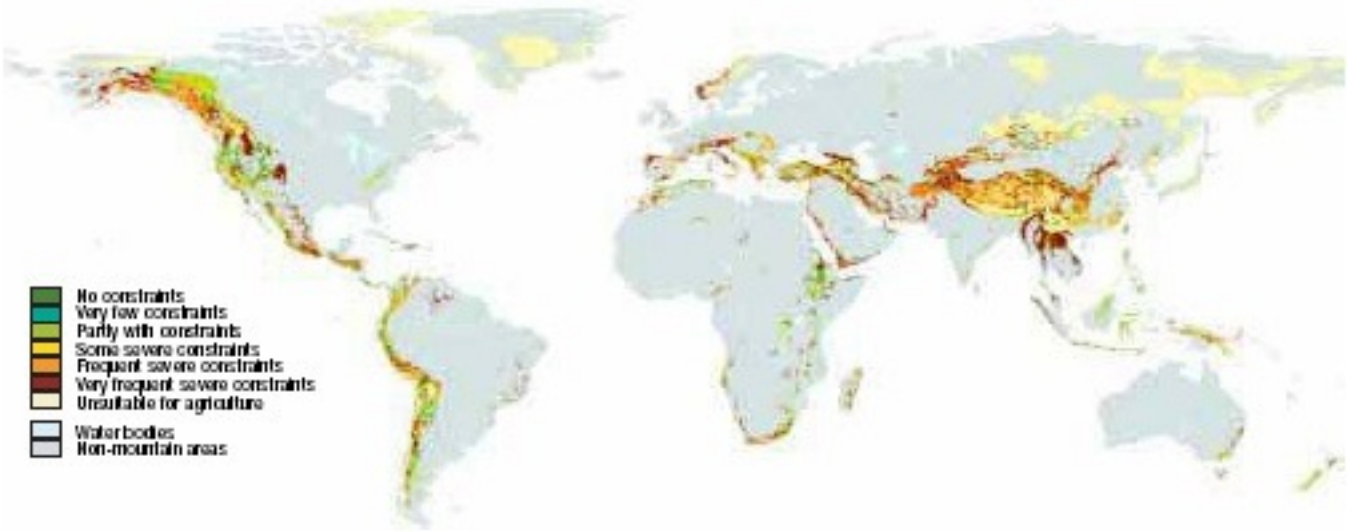


MAP 6.a Climate constraints in mountain areas of the world



MAP 6.b Terrain slope constraints in mountain areas of the world





BOX 2 Nature of environmental constraints for crop production in mountain areas

Constraints to crop production in mountain areas are of three kinds. In order of importance, they are: (i) unfavourable climatic conditions, (ii) sloping terrain, and (iii) poor quality and/or shallow depth of the soil.The following description of the nature of each of these constraints is taken from the recently published *Global agro-ecological assessment for agriculture in the 21st century: methodology and results.* (Fischer, et. al.).

Climatic conditions

Note: Climate constraints are classified according to length of periods with cold temperatures and moisture limitations.

Moisture constraints: These are related to the length of the growing period in which moisture is available. This is expressed as LGP. Hyper-arid and arid moisture regimes (LGP < 60 days) are considered severe constraints, and dry semi-arid moisture regimes (LGP 60-119 days) as moderate constraints.

Temperature constraints: These are related to the length of the temperature growing period. This is expressed as LGPt=5, i.e., number of days with mean daily temperature above 5ºC. An LGPt=5 of less than 120 days is considered a severe constraint, while an LGPt=5 of less than 180 days is considered as posing moderate constraints to crop production.

Slope of the terrain

Note: When referring to slope in the context of suitability of a land area for agriculture, the unit of measurement used is the percent slope, which refers to the rise in elevation in metres over a range of 100 metres. For defining mountain area, however, the unit of measurement used is the angle of slope.

Rain-fed land: Land with slopes greater than 30% are severely constrained; land with slopes from 16-30% is moderately constrained; land with slopes 0-8% is not constrained.

Non-terraced land with gravity irrigation: Land with slopes greater than 8% is severely constrained; land with slopes 5-8% is moderately constrained; land with slopes 0-2% is not constrained.

Land with sprinkler irrigation: Land with slopes greater than 16% is severely constrained; land with slopes 8-15% is moderately constrained; land with slopes 0-5% is not constrained.

Soil depth and quality

Depth: Soils with a depth of less than 50 cm are severely constrained; those with a depth of 50 –100 cm are moderately constrained. Deeper soils are not constrained.

Soil chemicals and natural fertility: Soils with severe salinity, sodicity or gypsum limitations are severely constrained, as are soils with low natural fertility; those with moderate natural fertility are moderately constrained; those with high natural fertility are not constrained.

Drainage: Soils that are poorly or imperfectly drained (gleysols, planosols, soils with antraquic phases) are severely constrained; soils with gleyic and stagnogleyic subgroups are moderately constrained; excessively and well-drained soils are not constrained.

Texture: Coarse textured soils and soils with stones, boulders or rock outcrops in the surface layer or at the surface are severely constrained; soils with heavy cracking clays are moderately constrained; other soils with medium and fine textures are not constrained.

Unusable land: Unusable land such as dunes, shifting sands, salt flats, rock debris, desert detritus, and glaciers and snow caps is classified as severely constrained.

TABLE 8 Distance from roads of mountain and non-mountain areas and populations in four selected mountainous countries

country and accessibility class (distance from roads)	mountain area		non-mountain area		mountain population			non-mountain population		
	thousand km²	% of total	thousand km²	% of total	thousand persons	% of total	persons per Km²	thousand persons	% of total	persons per km²
AFGHANISTAN										
<5km	174	46	133	50	9 562	69	55	9.493	80	71
5-10 km	115	30	68	26	2 655	19	23	1 573	13	23
10-15 km	59	16	31	12	1 178	8	20	462	4	15
>15 km	28	7	33	13	532	4	19	388	3	12
Total	376	100	265	100	13 927	100	37	11 916	100	45
CHINA										
<5km	1 702	35	2 231	50	144 393	65	85	848 913	81	381
5-10 km	1 089	22	949	21	43 902	20	40	150 375	14	159
10-15 km	605	12	372	8	20 837	9	34	34 828	3	94
>15 km	1 520	31	915	20	14 304	6	9	13 826	1	15
Total	4 915	100	4 467	100	223 435	100	45	1 047 942	100	235
ETHIOPIA										
<5km	145	31	239	36	17 372	49	120	17 120	59	72
5-10 km	113	24	155	23	6 681	19	59	4 798	17	31
10-15 km	79	17	99	15	4 372	12	55	2 878	10	29
>15 km	134	28	169	26	6 798	19	51	4 077	14	24
Total	471	100	664	100	35 222	100	75	28 874	100	44
PERU										
<5km	299	49	79	11	9 752	79	33	12 130	87	154
5-10 km	136	22	43	6	1 475	12	11	384	3	9
10-15 km	59	10	33	5	459	4	8	131	1	4
>15 km	116	19	530	77	721	6	6	1 259	9	2
Total	610	100	684	100	12 425	100	20	13 903	100	20

5.1.2 Isolation and lack of access to infrastructure

It is generally accepted that mountain people live in remote, isolated areas that are poorly served by physical infrastructure and social services. However, evidence to support this assertion is scarce. As an initial step towards investigating the phenomenon of isolation, and its impacts on mountain people, an analysis has been made of the distance from roads in mountain and non-mountain areas in selected mountainous countries (Afghanistan, China, Ethiopia and Peru). Summary results are presented in Table 8; the corresponding maps (7.a-7.d) have been published in the map collection associated with this report.

These preliminary results are based on national definitions of what constitutes a road. These definitions are not uniform across countries and may either include or exclude various types of secondary roads and farm-to-market roads. Nevertheless, a comparison of the available data for mountain and non-mountain areas in the four selected countries does appear to confirm the assertion that mountain areas and populations are more isolated than non-mountain areas, although the extent of this isolation may not be as great or as unique as previously thought.

In Ethiopia, about half of the mountain population and 40 percent of the non-mountain population live more than 5 km from roads. In Afghanistan and China, the figure for mountain people is around one-third, and for non-mountain people about 20 percent. In Peru, just 20 percent of mountain people and 13 percent of non-mountain people live more than 5 km from a road.

Although the differences among the countries are significant, within each country the difference in access between mountain and non-mountain people is not as great as expected. One reason for this may be the presence of relatively remote and isolated areas in non-mountain as well as mountain areas. Examples are the non-mountainous arid plateaus of China or the Amazonian rainforests of Peru, where access to roads is certainly limited.

Looking at the population densities in areas where people live more than 5 km from roads, some striking anomalies emerge. Normally, one would expect population density to be lower in more remote, isolated mountain areas with poor access to roads. However, among the four countries examined, only in China does the population density pattern conform to expectations. In Ethiopia, population density is actually significantly higher in mountain than in non-mountain areas, because the traditional culture developed in the highlands, and the lowlands are much less hospitable for agriculture

and human habitation. This also applies to Afghanistan, though to a lesser extent. Yet, in these two instances, even though the lowlands are less densely populated, they have better access to roads than the densely populated highlands, a disparity that confirms the discrimination experienced by mountain people with respect to construction and maintenance of transport infrastructure.

In Peru, population density in mountain areas with poor access to roads (mainly in the Altiplano), is also higher than in non-mountain areas with poor access (mainly in the Amazon Basin), but the actual densities in both cases are very low. As noted above, these preliminary results should be treated with caution. Nevertheless, they suggest issues that warrant further investigation and, in some cases, remedial policies and investments.

5.1.3 Malnutrition and poor health

Malnutrition is a broad term that describes any condition that results when food intake is insufficient, excessive, or unbalanced, or when the body is unable to absorb nutrients from food that is consumed.

Lack of sufficient macronutrients obtained from eating cereals, sugar, fats and oils is the cause of chronic hunger, with its debilitating effects on labour productivity and human well-being. But vitamin and mineral (micronutrient) deficiencies can also impair growth, development and body maintenance.

Globally, the three most significant micronutrient deficiencies are those of vitamin A, iron and iodine. Vitamin A deficiency is most common in young children. Untreated, it can lead to blindness and increase risk of illness and death. Iron deficiency is the most common dietary deficiency globally, affecting mostly children and women of childbearing age. It leads to anemia, a significant contributor to maternal and neonatal deaths. Anemia also lowers the work capacity and productivity of adults.

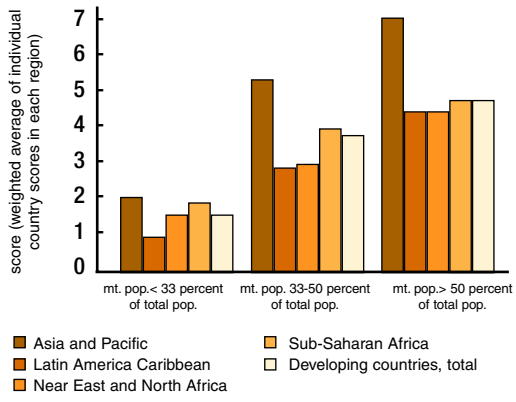
Iodine deficiency disorder occurs in mountain and flood plain areas of the world where iodine has been washed away from soils. It is the most common cause of preventable mental retardation, including low IQ (intelligence quotient). Severe iodine deficiency can lead to cretinism, stillbirth and birth defects.

Data on the prevalence of vitamin A, iron and iodine deficiencies in 33 of the 40 mountainous developing countries covered by this report (see Table 5 for list) show an increase in malnutrition as the proportion of mountain people in total population increases (Graph 8). They also reveal significant differences in the distribution of micronutrient deficiencies across regions (Graph 9). Vitamin A deficiency is particularly common in mountainous countries of eastern and southern Africa, where consumption of fruits and vegetables that are rich in vitamin A is low, while iodine deficiency is particularly prevalent in the Himalaya, where the soils have been leached of their iodine-carrying salts. Iron deficiency is common across all regions, though with somewhat greater incidence in Sub-Saharan Africa.

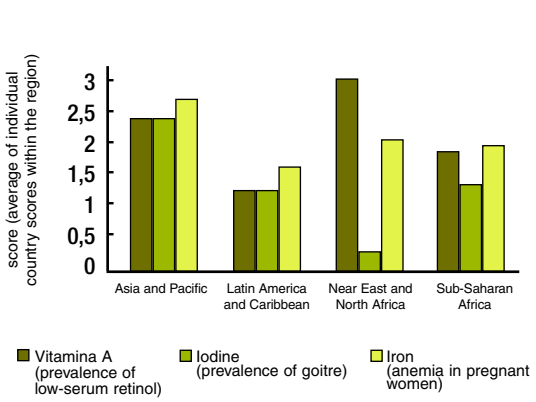
Micronutrient deficiencies can often be reduced with quite small investments: food-based approaches are often recommended in this regard. But for some deficiencies such as iodine, fortification of common salt has been a most successful intervention and may be the only choice.

Mountain people are also particularly afflicted by respiratory infections attributable to harsh climate and exposure to smoke inside their shelters in the winter. Because of their relative isolation, mountain people in many parts of the world have developed traditional medicines that make use of natural substances found in their own environment. Nevertheless, many treatable health problems go unattended, due to the lack of access to primary health-care facilities in more isolated mountain regions.

GRAPH 8
Prevalence of selected micronutrient deficiencies in developing mountainous countries, by mountainous country class and region



GRAPH 9
Prevalence of selected micronutrient deficiencies in developing mountainous countries, by region and type of deficiency



N - In both graphs, a low score indicates low prevalence of selected micronutrient deficiencies, and a high score, high prevalence. Scoring ranges used for prevalence of micro-nutrient deficiencies are as follows:

Vitamin A:	0. Absent;	1. Very Low (prevalence < 10%);	2. Low (prevalence = 10-15%); 3. Medium (prevalence = 15-20%); 4. High (prevalence > 20%)
Iodine:	0. Absent;	1. Very Low (prevalence < 15%);	2. Low (prevalence = 15-25%); 3. Medium (prevalence = 25-35%); 4. High (prevalence > 35%)
Iron:	0. Absent;	1. Very Low (prevalence < 25%);	2.5. Medium (prevalence 25-50%); 4. High (prevalence > 50%)

5.2 Preliminary estimates of the number of vulnerable mountain people

The plight of mountain people living in deteriorating environments at high elevations has attracted considerable public attention. However, the analysis presented in this report shows that the number of vulnerable mountain people is far greater at lower elevations. There population pressure, deforestation and land degradation and, in some instances, drought are undermining farming systems practised by large numbers of people. With more than three-quarters of mountain population in developing and transition countries still classified as rural, the performance of agriculture is likely to be a crucial factor in determining the degree of their vulnerability to food insecurity.

5.2.1 Global estimates

In *The state of food insecurity in the world 2002*, (SOFI), FAO published a first indication of the possible size of the vulnerable mountain population. That estimate used yields of staple cereals as an indicator of the presence or absence of environmental and infrastructural constraints and hence of vulnerability. It considered vulnerable mountain people to be those living in rural areas where rainfed cereal production is less than 100 kg per person per year, together with those living in closed forests and protected areas, and 15 percent of urban mountain population. That approach found more than half of the mountain population in developing and CIS countries (in the range of 250 - 370 million people) to be vulnerable to food insecurity.

For this report a more refined approach that takes into account the important role of livestock in mountain farming systems has been tested. In this approach, data for cereal production less than 200 kg per person and a low to medium bovine density index have been combined to indicate areas where rural mountain people are likely to be vulnerable to food insecurity. Again, people living in closed forests and protected areas are also considered vulnerable, as well as 15 percent of urban mountain people. Inclusion of a livestock indicator reduces the vulnerability estimate to around 40 percent of the mountain population in developing and transition countries, or around 271 out of 662 million people.

5.2.2 Vulnerability of rural mountain people in developing and transition countries

The results for developing and transition countries (Table 9) put the number of rural mountain people who meet the new vulnerability criteria at 245 million. Unless they have access to significant sources of off-farm income or remittances, these people are likely to be vulnerable to food insecurity. Altogether, their number represents about 50 percent of the total rural mountain population in developing and transition countries.

Below 2 500 m, these vulnerable people represent about 48 percent of the total rural mountain population in developing and transition countries, but above 2 500 m the figure soars to almost 70 percent. The higher prevalence of vulnerability at higher elevations helps attract attention to these areas. But the total number of vulnerable people is seven times greater at lower elevations. Considerations of human equity and environmental sustainability both call for greater policy attention to their needs.

N - These estimates of the number of vulnerable mountain people are not to be confused with FAO's estimates of the undernourished, or food insecure, population. Typically about half of those identified as vulnerable are actually undernourished.

TABLE 9 Vulnerable rural mountain people (developing and transition countries) by region and mountain area class

region [1]	vulnerable rural mountain population						
	class 1	class 2	class 3	class 4	class 5	class 6	total
	thousand persons						
ASIA AND THE PACIFIC	77 463	28 820	19 756	6 538	4 299	3 123	139 999
LATIN AMERICA AND CARIBBEAN	9 901	5 037	8 941	4 888	3 956	183	32 906
NEAR EAST AND NORTH AFRICA	10 659	7 120	7 503	4 141	282	33	29 738
SUB-SAHARAN AFRICA	10 629	10 596	7 344	2 215	90	0	30 874
COUNTRIES IN TRANSITION	7 710	1 922	1 016	359	176	17	11 200
TOTAL DEVELOPING AND TRANSITION COUNTRIES	116 362	53 495	44 560	18 141	8 803	3 356	244 717
vulnerable as share of rural mountain population in the class	percent						
	48	55	43	57	87	82	
vulnerable in the class as share of total rural mountain population	percent						
	48	22	18	7	4	1	100

These women farmers in a mountainous part of southern Africa are using hand-carried buckets to irrigate their fields, probably drawing the water from a nearby well. Although in good years, total rainfall may be adequate, managing the amount crops receive through use of simple watering and drainage techniques can reduce erosion and enhance productivity. In drought-prone mountain regions improved water management is particularly important.

Cultivation of maize is characteristic on the steep slopes of the middle Andes. This Peruvian farmer will obtain a good crop, possibly due to the use of appropriate seed varieties, the judicious application of fertilizers and organic matter to enhance soil quality and fertility, and use of integrated pest management techniques. Where good seeds and soil quality enhancements are not used, and pests are not controlled, productivity is likely to be considerably lower. Widespread introduction of appropriate technology packages in arable areas, including reliance on traditional knowledge, could significantly improve the food security situation for many mountain people.

In China, the terracing of sloping mountain landscapes is a highly-developed art. Here the extent of the terraces over a large mountain area is evident. This technique is widely used at lower elevations, permitting mountain farmers with relatively small landholdings to produce enough food for their families, with some surplus for market sale. At higher elevations, where slopes are steeper, terracing is also practised, but preparing and maintaining the terraces is more difficult and lengthy work, while soil and climate constraints reduce productivity. Participatory forestry and rangeland management are usually better suited to higher-elevation mountain areas.

MOUNTAIN PROSPECTS

Despite the constraints to sustainable development of mountain environments, a significant potential remains for diversifying and enhancing mountain production systems and livelihoods. Enhanced dialogue between mountain people and lowlanders around key resource management issues will be crucial for realizing this potential. Possible opportunities include:

Water
Since much of the fresh water in the world originates in mountain areas, capturing the value of this strategic resource could provide important economic benefits for mountain people.

Agriculture
Adoption of a conservation-by-use philosophy and better integration of agriculture, livestock, forestry, aquaculture and local processing could help diversify income sources and strengthen mountain food systems.

Conservation and tourism
Investments in training and infrastructure to support careful development of the tourist industry would allow mountain people to capitalize on the natural beauty and biodiversity of their environments.

Forests and rangelands
Promotion of participatory forestry and rangeland management practices, together with co-management schemes for protected areas, would allow mountain people to manage their forests, herds and parks more sustainably.

Mountain industry and services
Balanced development of mountain cites and semi-urban centres could help maintain the equilibrium between the still growing mountain population and the carrying capacity of the natural resource base, while providing on-site services to rural communities. Cottage and agro-industry would add value to local products and reduce bulk prior to expensive shipment to markets.

MAP 1; GRAPHS 1 AND 2; TABLES 1, 4 AND 5

Source: United Nations Environment Programme-World Conservation Monitoring Centre (UNEP-WCMC), 2000. *Mountains of the world – 2000*. Cambridge, UK.
Web site: http://www.wcmc.org.uk/habitats/mountains

Notes: The UNEP-WCMC map published in *Mountains of the world - 2000* has been used as the reference map for all the analysis contained in this report. To produce this map, UNEP-WCMC used topographical data from the 1996 United States Geological Survey - EROS Data Center (USGS-EDC) global digital elevation model (GTOPO30) to generate slope and local elevation range (LER) on a 30 arc-second grid of the world. These parameters were combined with elevation to define the areas of the world corresponding to the six mountain area classes defined by UNEP-WCMC in 2000. UNEP-WCMC has recently added a seventh mountain area class, used a 7 km instead of 5 km radius for calculating LER, and introduced a numbering system for the mountain area classes, beginning with Class 1 with elevation ≥ 4 500 m. These changes are explained in Groombridge, B., Miles, L., Lysenko, I., Blyth, S. and Newton, A., *Mountain watch: environmental change and sustainable development in mountains*. Cambridge, UK and Geneva: UNEP-WCMC and UNEP Mountain Programme.
Web site: http://www.unep-wcmc.org/mountains/mountain_watch/pdfs/

MAP 2; GRAPHS 3 AND 4; TABLES 2, 3, 4 AND 5

Source: Oak Ridge National Laboratory, 2000. *LandScan 2000 global population database*, Oak Ridge, TN, USA.
Web site: http://www.ornl.gov/gist/

Notes: The LandScan 2000 data set is a worldwide population database compiled on a 30 arc-second grid. Census counts (mainly at sub-national level) were apportioned to each grid cell based on probability coefficients, which are based on proximity to roads, slope, land cover and night time lights.

MAP 3

Sources: 1. United Nations Environment Programme (UNEP)-GRID-Arendal, 1990. *The world cities population database* (*WCPD*).
Web site: http://www.grida.no/db/gis/prod/html/human 2.htm
2. Environmental Systems Research Institute (ESRI), 2002. *World cities, ESRI data and maps 2002*. Redlands, CA, USA.
Web site: http://www.esri.com

Notes: The databases from UNEP-GRID and ESRI provide two GIS sources for major cities. In order to produce this map, these two databases were merged and the cities that fall in mountain areas were selected.

MAP 4; GRAPHS 6 AND 7; TABLES 6.a - 6.d

Sources: 1. Global agricultural extent: Wood, S., Sebastian, K., Scherr, S.J., et al., 2001. *Pilot analysis of global eco-systems (PAGE), agricultural extent*. Washington, D.C.: International Food Policy Research Institute (IFPRI).
IFPRI, 2002. *Reinterpretation of global land cover characteristics database (GLCCD v2.0, EROS Data Center (EDC), 2000)*, *unpublished dataset.* Washington, D.C.
Web site: http://www.ifpri.cgiar.org/
2. Crop and pasture suitability: Fischer, G., van Velthuizen, H., Shah, M. and Nachtergaele, F., 2002. *"Suitability for rainfed crops (maximizing technology mix)"* and *"Suitability index for rain-fed mixed pasture - Low inputs"* in *Global agro-ecological assessment for agriculture in the 21st century: methodology and results.* Rome and Vienna: FAO and International Institute for Applied Systems Analysis (IIASA).
Web site: http://www.iiasa.ac.at/Research/LUC/SAEZ/index.html
FAO, 2003. *Grassland of the world, unpublished map*. Rome: FAO/AGPC.
3. Irrigated areas: Siebert, S., Döll, P. and Hoogeveen, J., 2002. *Global map of irrigated areas version 2.1.* Rome and Kassel, Germany: FAO and Center for Environmental Systems Research, University of Kassel.
Web site: http://www.fao.org/ag/agl/aglw/aquastat/irrigationmap/index10.stm
4. Closed forest: FAO, 2000. *Global forest resources assessment 2000, FRA 2000.* Rome.
Web site: http://www.fao.org/forestry/foris/webview/forestry2/index.jsp?siteId=101&langId=1
5. Protected areas: UNEP-WCMC, 2002. *Protected areas database 2002.* Cambridge, UK.
Web site: http:// www.unep-wcmc.org

Notes: The five GIS databases mentioned above were combined to estimate the part of each pixel falling in the following rural land cover categories: cropland, grazing land, closed forest, protected area, and barren land. In order to generate a map, pixels were grouped according to the land use shares in each pixel. The method used was the following. First, data on extent of cropped area (IFPRI unpublished dataset 2002) and data on irrigated area (Siebert, Döll and Hoogeveen, 2002) have been combined with data on area suitable for rainfed crops (Fischer, van Velthuizen, Shah and Nachtergaele 2002), to produce a global GIS database containing area under crops (cropland), by pixel. Second, data on extent of pastureland (IFPRI unpublished dataset 2002 and FAO unpublished grassland map 2003) have been combined with

data on area suitable for low-input, rainfed mixed pasture (Fischer, van Velthuizen, Shah and Nachtergaele 2002), to produce a global GIS database containing area used for pasture and browse (grazing land), by pixel. Data on area under open forest (FAO FRA 2000) have also been included in the grazing land database. The cropland and grazing land databases have then been combined with data on protected areas (UNEP-WCMC protected areas database 2002), and data on closed forest area not in protected areas (FAO FRA 2000) to produce a global land cover and agricultural land use database containing area data by pixel for the five rural land cover categories mentioned above. The method used attributes all rural land area in the world to one of these five categories. In order to generate a map, data from this very high resolution GIS database had to be combined to create a reasonable number of mixed land use categories covering large enough contiguous areas to be seen visually on the map. After deducting protected area from all pixels where it is found, the categories finally retained and displayed in this map are comprised as shown in the table below.

Distribution of rural land area within pixels (percent)

Agricultural land use categories	Land cover categories			
	Cropland	Grazing land	Closed forest	Barren land
Mainly cropland	75-100	0-10	0-25	0-10
Mixed use: closed forest, grazing land and cropland	0-75	0-85	0-75	0-85
Mainly closed forest	0-10	0-10	75-100	0-10
Mainly grazing land	0-10	85-100	0-15	0-10
Grazing land with some cropland, closed forest and barren land (also includes small number of pixels where cropland is 50-75 percent and grazing land no more than 30 percent)	0-30	30-85	0-30	0-30
Mainly barren land	0-10	0-10	0-15	85-100

MAP 5; TABLE 7

Source: Dixon, J. and Gulliver, A., with Gibbon, D., 2001. *Farming systems and poverty: improving farmers' livelihoods in a changing world*. Rome and Washington, D.C.: FAO and World Bank.
Web site: www.fao.org/FarmingSystems/

Notes: Many farming systems found in mountain areas are much more widespread in non-mountain areas. The farming systems depicted here, and used in the analysis contained in the full report, are limited to those that are significant in mountain areas at altitudes above 1 000 m.

MAP 6

Source: Fischer, G., van Velthuizen, H., Shah, M. and Nachtergaele, F., 2002. *Global agro-ecological assessment for agriculture in the 21st century: methodology and results*. Rome and Vienna: FAO and International Institute for Applied Systems Analysis (IIASA).
Web site: http://www.iiasa.ac.at/Research/LUC/SAEZ/index.html

Notes: The map is the result of combining separate analyses that have been made on (i) climate constraints (Map 6.a), (ii) terrain constraints (Map 6.b) and (iii) soil constraints (Map 6.c) that limit rainfed crop production.

MAPS 7.a - 7.d (POSTER SIZE ONLY); TABLE 8

Source: National Imagery and Mapping Agency (NIMA), 2002. *Vector map (VMap) level 0 (VMAP0), scale: 1:1,000,000*. Bethesda, MD, USA.
Web site: http://www.nima.mil/publications/vmap0.html

Notes: The road network layer of NIMA-VMAP0 vector database was rasterized at 30 x 30 arc-second grid cell size (approximately 1km x 1km), and distance to the nearest road was calculated from each cell centre. Road attribute definitions may not be consistent from one country to another, and may include some secondary roads that are usable for only part of the year, or are not maintained for use by motor vehicles.

GRAPH 8

Source: FAO, 2002. *The micronutrient initiative.* Rome.

TABLE 9

Source: FAO, 2002. *Estimated cereal production per person, unpublished map*. Rome: SDRN.
FAO, 2001. *Livestock geography: new perspectives on global resources*. Rome: CD-ROM prepared with assistance of the Environmental Research Group Oxford (ERGO).

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POVERTY MAPPING

GEOGRAPHY OF POVERTY
GEOGRAFÍA DE LA POBREZA
GÉOGRAPHIE DE LA PAUVRETÉ

Environment and Natural Resources

Working Paper No. 10

Towards a GIS-based analysis of mountain environments and populations

The value of spatial information for understanding development issues and improving decision-making is increasingly being recognized. With this publication, FAO seeks to apply the techniques of GIS-based analysis to deepen understanding of conditions underlying poverty and hunger in the world, with special reference to mountain environments and populations.

This focus is especially appropriate in 2003, as we begin the follow-up activities to the International Year of Mountains, 2002 and consider the ways in which the international community can respond more effectively to the special needs and concerns of mountain people.

This report uses newly available geo-referenced data to explore the distribution and characteristics of mountain populations and their livelihood systems in different mountain environments. The results contained in this report represent a first set of findings from work in progress.

The report notes that mountain water, mountain forests and mountain flora and fauna constitute a rich global resource. Yet, in many locations, the people who inhabit mountain environments are exposed to harsh climatic conditions and soil

and terrain constraints that make the pursuit of agriculture difficult, while their relative isolation limits non-agricultural options.

Grazing predominates on 44 percent of mountain land in developing and transition countries, but 64 percent of rural mountain people occupy this land. On average, population density on grazing land at all elevations up to 3 500 m has reached or surpassed the critical point of 25 persons per km², creating severe environmental problems. Only 17 percent of rural mountain people practise crop agriculture or integrated tree-crop-livestock farming, while 19 percent obtain their subsistence from barren or sparsely vegetated land, protected areas and closed forests. In all, around 245 million rural people in these countries are estimated to be vulnerable to food insecurity, of which 87 percent live below 2 500 m.

Growth of mountain cities, currently home to about 30 percent of the total mountain population, offers prospects for diversification of livelihood opportunities. Expansion of the non-agriculture sector, combined with more widespread use of improved land and water management technologies adapted to their environments, can provide sustainable livelihoods for future generations of mountain people, without degrading the natural resources found in their unique environment.

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