PR189

Atlas of Sorghum

(*Sorghum bicolor* (L.) Moench)

Production in Eastern and Southern Africa

INTSORMIL
Sorghum/Millet International Research

USAID
FROM THE AMERICAN PEOPLE

Authors

Charles S. Wortmann and Martha Mamo, Department of Agronomy and Horticulture, University of Nebraska-Lincoln, Lincoln, NE, USA

Christopher Mburu, Kenya Agricultural Research Institute, Kakamega, Kenya

Elias Letayo, Agricultural Research Institute – Hombolo, Department of Research and Development, Dodoma, Tanzania

Girma Abebe, Melkassa Agricultural Research Center - Ethiopian Institute of Agricultural Research, Nazareth, Ethiopia

Kaizzi C. Kayuki, Kawanda Agricultural Research Institute - National Agricultural Research Organization, Kampala, Uganda

Medson Chisi, Zambia Agricultural Research Institute, Zambia

Munyaradzi Mativavarira, Zimbabwe Agricultural Research and Extension Services, Zimbabwe

Soares Xerinda, Chokwe Agricultural Research Center, Gaza, Mozambique

Theophile Ndacyayisenga, Institut des Sciences Agronomiques du Rwanda, Rwanda

Preface

Grain sorghum (*Sorghum bicolor* (L.) Moench) is a major crop in many parts of Africa and is noted for its versatility and diversity. It is adapted over a wide range of precipitation and temperature levels and is produced at sea level to above 2000 m altitude. In eastern and southern Africa, it is primarily a crop of resource-poor, small-scale farmers and is typically produced under adverse conditions such as low input use and marginal lands. There are numerous biotic and abiotic constraints to production. The grain and stover are used in many different ways with localized preferences. Much information is needed to effectively address the problems and opportunities of this diverse crop.

The *Atlas of Sorghum Production in Eastern and Southern Africa* presents information on sorghum in nine countries to serve information needs of researchers, extension and rural development specialists, policy makers, and emergency relief personnel. It accounts for 85% of the sorghum production on an area basis, or 3,400,000 ha, from Ethiopia south to Mozambique with most of the uncovered production in Somalia (*FAOSTAT*, 2008). Numerous researchers and others knowledgeable of sorghum in their country contributed information and expert opinions for the *Atlas*. The *Atlas* presents information in maps and tables for 39 sorghum production areas in nine countries addressing production constraints, cropping systems, management, uses, preferences, gender roles, and marketing.

Acknowledgements

This publication was made possible through support provided to INTSORMIL by the U.S. Agency for International Development, under the terms of Grant No. LAG-G-00-96-900009-00. We thank the numerous researchers and other sorghum specialists who contributed information on sorghum production in their countries. We also thank Mark Strnad for his assistance in creating the map graphics for this publication.

Table of Contents

Abbreviations:

- SPA, Sorghum Production Area;
- ILRI, International Livestock Research Institute.

Grain Sorghum Production in Nine Countries Of Eastern And Southern Africa

The domestication of grain sorghum of the durra race may have occurred before 2000 BC in Ethiopia (Doggett, 1998), but an estimate of 1000 BC is now more widely accepted (Balole and Legwaila, 2006). However, early archaeological evidence for the crop is lacking in Africa while such evidence is much stronger in Arabia and India (Rowley-Conway et al., 1999; Young and Thompson, 1999). Remains of grain of wild sorghum, presumably collected from natural stands for food or irregularly cultivated, have been found in an early Neolithic site in southern Egypt that has been dated as 8,000 years old (Wasylikowa and Dahlberg, 1999). Archaeobotanical work at Aksum in northern Ethiopia found sorghum grain in deposits of 6th to 7th centuries AD, but not in pre-Aksumite deposits that dated to the 5th century BC, while kernels of teff, oat, barley and other crops were found in the early deposits (Boardman, 1999).

Sorghum is the fifth most important cereal globally and the dietary staple of around 500 million people. It is an important food crop in many parts of eastern and southern Africa. Sorghum is tolerant, relative to other major cereal crops, to adverse growing conditions. It is efficient in photosynthesis and in water and nutrient use. Some early-maturing sorghum cultivars require less than two months of rainfall to produce grain, and the species is genetically very diverse with preferred cultivars for different uses.

A constraint to greater demand for grain sorghum as a human food is its nutritional quality. The grain of some cultivars is high in tannin, which blocks the body's ability to absorb and use protein and other nutritional ingredients. Another nutritional concern is that a large proportion of protein in sorghum grain is prolamine which has low digestibility in humans (Balole and Legwaila, 2006).

The *Atlas* presents information on sorghum production in eastern and southern Africa to serve the needs of researchers, extension and rural development specialists, policy makers, and emergency relief personnel. It is intended as an aid in prioritization of research and development activities, such as identification of the primary production constraints or most important traits considered by farmers in cultivar selection. The information is useful to regional collaboration between researchers facing similar problems in similar situations. The information is potentially useful in targeting the exchange of sorghum germplasm by matching genotypes to the needs of sorghum production areas (SPAs).

Sources of sorghum production data

Collection, compilation and analysis of sorghum production data were conducted for nine countries of eastern and southern Africa: Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Tanzania, Uganda, Zambia, and Zimbabwe. The process involved a series of stages: 1) obtaining and processing sorghum production data; 2) delineating SPAs; 3) collecting attribute data for each SPA; 4) analysis of the data; and 5) presentation of results in map and tabular forms. The availability and quality of data varied by country and all estimates reported have some margin of error.

Sorghum production data for Ethiopia were government statistics obtained through ILRI (2002). The data set contained estimates of area, yield and quantity of production at the wereda, a sub-district administrative unit level, for up to five years. Median values of hectares of annual sorghum production for the available years were estimated for each wereda while excluding extreme outliers. When data were unavailable or very inconsistent for a wereda, estimates were made in consideration of information from surrounding weredas and agro-climatic conditions.

Production data for Kenya at the province level was obtained through ILRI (2002) and the area of production was assigned to districts based on the authors' knowledge of sorghum production in the country. Production estimates by agro-ecological zones and by province were used for Rwanda and Zambia, respectively. A county-level set of data developed by Wortmann and Eledu (1999) was used for Uganda. Estimates of production area by region for Tanzania (Ministry of Agriculture, unpublished) were allocated to districts based on the authors' knowledge of sorghum production in the country. Estimates of production area by province for Mozambique (Ministry of Agriculture, unpublished) were assigned to districts based on an incomplete set of district data obtained through ILRI (2002), province level estimates, and the authors' knowledge of sorghum production in the country. For Zimbabwe and Malawi, national production estimates (FAOSTAT, 2008) were used and assigned to production areas based on the authors' knowledge of sorghum production in the country. National estimates at the regional level were used for Zambia. Detailed data was not obtained for Burundi but Burundi is included in the sorghum distribution map with random distribution of 50,000 ha as estimated by FAO.

Delineation and characterization of sorghum production areas

The authors' knowledge of sorghum production in the country was applied for a rough determination of the boundaries of SPAs. The delineation of the SPAs was refined using information on the agroecology, the presence of park and forested areas, the presence of water bodies and wetlands, and the sorghum production data. The SPAs were characterized for latitude, longitude, altitude, and mean temperature and precipitation during the sorghum-growing periods as determined using LocClim 1.0, a local climate estimator (Grieser, 2002).

Co-authors assumed responsibility for collection of data on production constraints, cropping systems, management, uses, preferences, gender roles, and marketing for the SPAs in their countries. Data collection was done through interviews of people recognized as knowledgeable about sorghum production in the country. These resource people included primarily sorghum researchers, but also government staff with extension and/or administrative responsibilities. Interviews were conducted for Ethiopia (6), Kenya (3), Mozambique (7), Rwanda (3), Uganda (12), Tanzania (7), Zambia (3), and Zimbabwe (2), respectively. The responsible co-author reconciled differences in the responses to establish a value for each variable in each SPA.

Distribution of sorghum production in eastern and southern Africa

Some areas have particularly high concentrations of sorghum production *(Map 1.1)*. Areas of greater concentration of sorghum production include much of north central, northwestern and western Ethiopia; the eastern mid-altitude area of Ethiopia; the area to the east of Lake Victoria in Kenya and Tanzania; Rwanda; central Tanzania; and northern and eastern Uganda. The distribution of sorghum production within SPAs is undoubtedly less uniform than indicated by the production points. The map, however, adequately represents the distribution of sorghum production for national and regional planning and policy formulation needs.

Thirty-nine SPAs were delineated for Ethiopia (10), Kenya (5), Malawi (1), Mozambique (3), Rwanda (3), Uganda (5), Tanzania (7), Zambia (2), and Zimbabwe (3), respectively *(Map 1.2)*. Sorghum production area for the 39 SPAs ranged from 5,000 ha for the Coast Province of Kenya to 515,000 ha for the North Central Highlands of Ethiopia *(Table 1)*.

The results indicate that more than 70% of the sorghum production area is at latitudes greater than six degrees from the equator *(Table 1)* with implications for photoperiod effects. Approximately 24, 30 and 45% of the sorghum is produced with mean temperatures during the growing season of ≤20˚C, 21-23˚C, and ≥24˚C, respectively. Mean temperature is negatively associated with altitude. Within altitude ranges, temperature is associated with latitude as crop production at the higher latitudes occurs during the warmer, longer day-length months of the year. Approximately 19%, 34% and 47% of the sorghum is produced with mean monthly precipitation during the growing season of <100 mm, 101-130 mm, and >130 mm, respectively. About 35% of the sorghum production area is in especially drought-prone areas where a combination of warm mean temperature (>20˚C) and low mean monthly rainfall (< 120 mm) during the growing season combine to create water-scarce conditions.

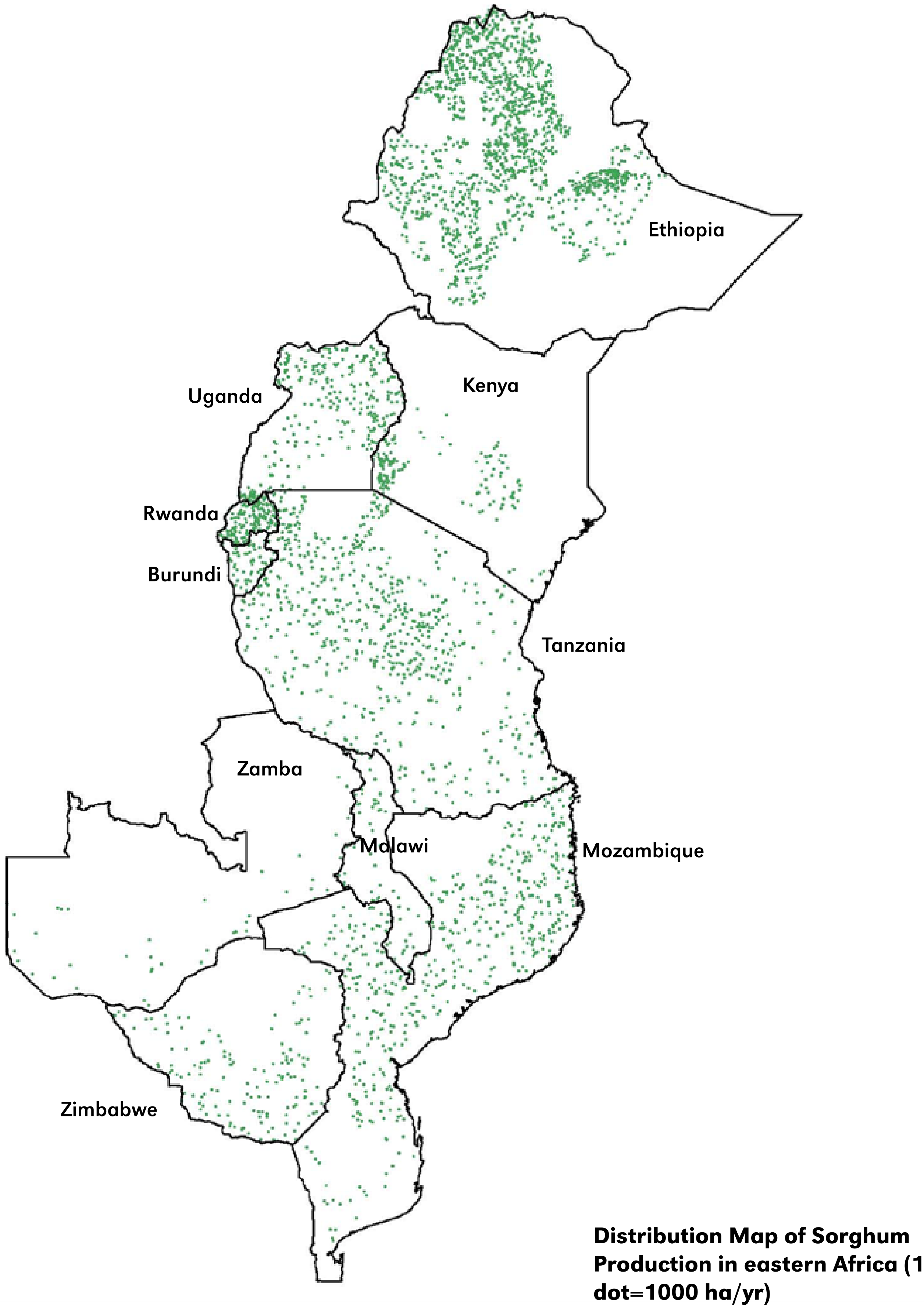
Table 1.1. Sorghum production area and median elevation, latitude, and growing season temperature and rainfall for nine countries of eastern and southern Africa.

Country and SPA	Production area, '000 ha yr^{-1}	Median elevation, m asl	Median latitude	Temperature, °C†	Rainfall, mm month^{-1}
Ethiopia					
Central Rift Valley	42	1630	8	22	100
Eastern, >1500 m altitude	125	2100	9	18	121
Eastern, <1500 m altitude	97	1390	8	26	43
North Central Highlands	515	1900	12	19	212
Northeast Mid-altitude	40	1580	12	20	99
Southern	94	1440	7	21	170
Southwest Lowlands	164	1120	8	26	76
Tigrain Highlands	36	1950	14	20	169
Tigrain Lowlands	219	680	13	27	150
Western	142	1580	8	24	228
Kenya					
Coast	3	185	-3.8	24	87
Rift Valley	14	1915	-0.1	16	75
Western	9	1370	0.4	21	174
Eastern-Central	46	1385	-1.1	21	76
Nyanza	51	1190	-0.2	22	130
Malawi					
Malawi	63	490	-15	25	140
Mozambique					
Northern	230	490	-14	25	153
Central	235	520	-18	25	128
Southern	42	25	-24	26	99
Rwanda					
>1800 m	50	1900	-2	17	120
1500 – 1800 m	71	1700	-2	21	120
<1500 m	32	1300	-2	22	90
Tanzania					
Lake Zone	122	1250	-2	22	118
Western	172	1140	-4	23	120
Central	164	1080	-6	24	131
Eastern	37	230	-7	25	101
Southern	61	290	-10	26	100
North	30	990	-4	22	64
Southern Highlands	87	1600	-8	22	126
Uganda					
Central and West	51	1160	0	22	98
Karamoja	37	1250	3	26	82
Northern	112	1100	2	23	130

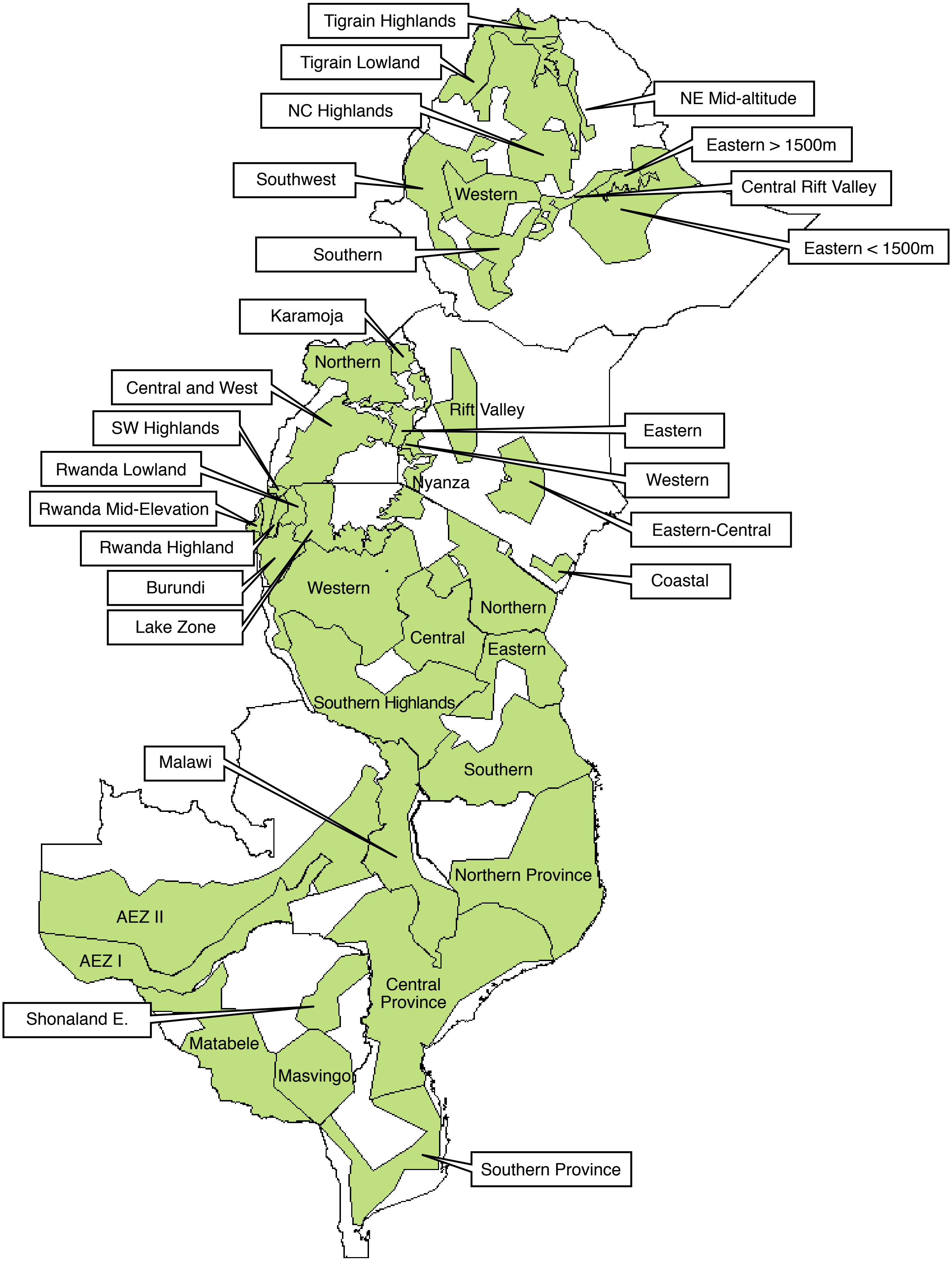
Country and SPA	Production area, '000 ha yr^{-1}	Median elevation, m asl	Median latitude	Temperature, °C†	Rainfall, mm $month^{-1}$
South West Highlands	32	1900	-1	18	110
Eastern	31	1170	1	22	98
Zambia					
AEZ I	24	1000	-15	25	120
AEZ II	19	1200	-13	22	180
Zimbabwe					
Matabeleland	70	1100	-20	23	80
Masvingo	32	400	-21	25	100
Mashona East	17	1200	-18	22	110

† Climate data source: Grieser, 2002.

Map 1.1. Distribution of grain sorghum production in five countries of eastern Africa.



Map 1.2. Thirty-nine sorghum production areas of eastern and southern Africa.



CHAPTER 2.

Grain Sorghum Production Systems

Grain sorghum production in northern Ethiopia to southern Mozambique spans 38 degrees of latitude. Production occurs from near sea level to above 2000 m in altitude, and in semi-arid to humid conditions. Small-scale, resource-poor farmers, who use it primarily as a staple food for home consumption, produce most grain sorghum. The result is a wide range of cropping systems.

Data collection

Information about grain sorghum production systems was obtained by interviewing sorghum specialists in each country as described in Chapter 1. Interviewees assigned a total of 20 points to a list of nine cropping system options. These included sole crop production of sorghum and intercropping with maize, finger millet, pearl millet, common bean, cowpea, pigeon pea, groundnut, or cassava. Allocation of more points indicated more importance for that attribute. No points were allocated if the attribute was considered to be of little or negligible importance in an SPA. In the analysis of the data, each point was considered to be the equivalent of 5% of the annual sorghum area for the SPA.

Interviewees assigned a total of six points for both sowing time and harvest time to the 12 months to indicate the relative importance of the months for sowing and harvest of sorghum. Each point was considered to be the equivalent of 16.7% of the total area sown or harvested annually for the SPA.

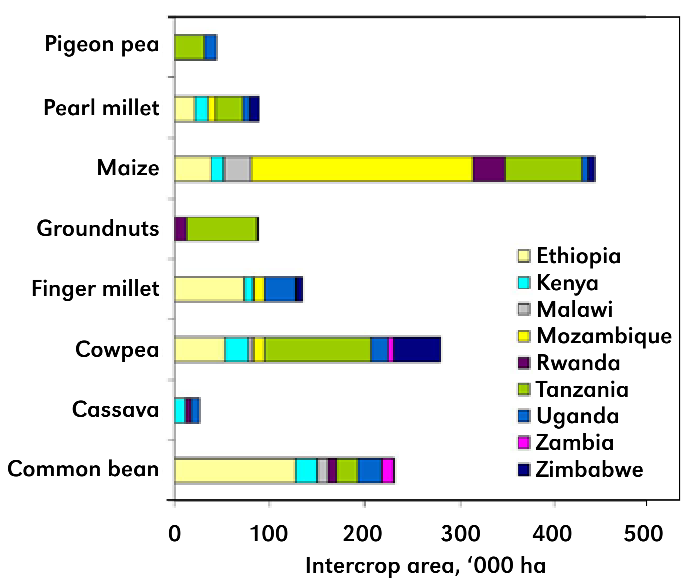
Interviewees qualified the level of mechanization of production by allocating six points to indicate the relative importance of manual, draft animal, and tractor power to sorghum production in each SPA. In the analysis of the data, each point was considered to be the equivalent of 16.7% of the energy used annually for sorghum production.

Information by SPA is presented in maps using pie charts for each SPA and in Appendix A. The diameters of the pie charts vary according to the hectares of production in the SPA. The maps were created using ArcGIS 9.0 (ESRI, Redlands, CA).

Cropping systems

Most sorghum (61%) in eastern and southern Africa is produced in sole crop, which contrasts with western Africa where intercrop production of sorghum is more prevalent. The most important intercrop companion crops of sorghum are maize, cowpea and common bean (Fig. 2.1). Intercropping sorghum with maize is especially common in central Mozambique, and to a lesser extent in western Kenya, eastern Tanzania, and the southern highlands of Tanzania (Map 2.1). Intercropping with cowpea is most important to the Coast and Eastern Provinces of Kenya, southern Mozambique, and in much of Tanzania, Zambia and Zimbabwe. Intercrop production of sorghum and common bean is common in: southwestern, central and western Uganda; the Eastern and Rift Valley Provinces of Kenya; Rwanda; Malawi; and in the southern highlands of Tanzania. The sorghum and groundnut intercrop association is common in several SPAs of Tanzania and Rwanda. Intercropping with pigeon pea is important in eastern Tanzania. Significant intercrop production with cassava and pearl millet occurred in the Coast and Eastern Provinces of Kenya, respectively.

Figure 2.1. Area ('000 ha) of sorghum intercrop production with different crops in nine countries of eastern and southern Africa. Approximately 60% of the sorghum is produced in sole crop.



Sowing times

Sowing of sorghum is determined by the onset of the rain periods in most SPAs. The rainfall pattern and timing are largely determined by the Intercontinental Convergence Zone which moves north to south and returns each year. It thereby crosses the equator twice each year resulting in a bimodal rainfall pattern. As latitude increases, the rainfall pattern becomes increasingly unimodal.

Most sorghum is sown from April to July in Ethiopia *(Fig. 2.2)*. April is the most common sowing time for the Eastern Mid-altitude, North Central, and Tigrain Highlands SPAs *(Map 2.2)*. Sorghum is sown mainly in January and February in the Southern SPA of Ethiopia.

In the Coast and Eastern Provinces of Kenya, sorghum is sown for both rain seasons, in March and April and again in September *(Fig. 2.2, Map 2.2)*. Sowing is primarily in February and March for Nyanza and Western Provinces, and in April for the Rift Valley Province.

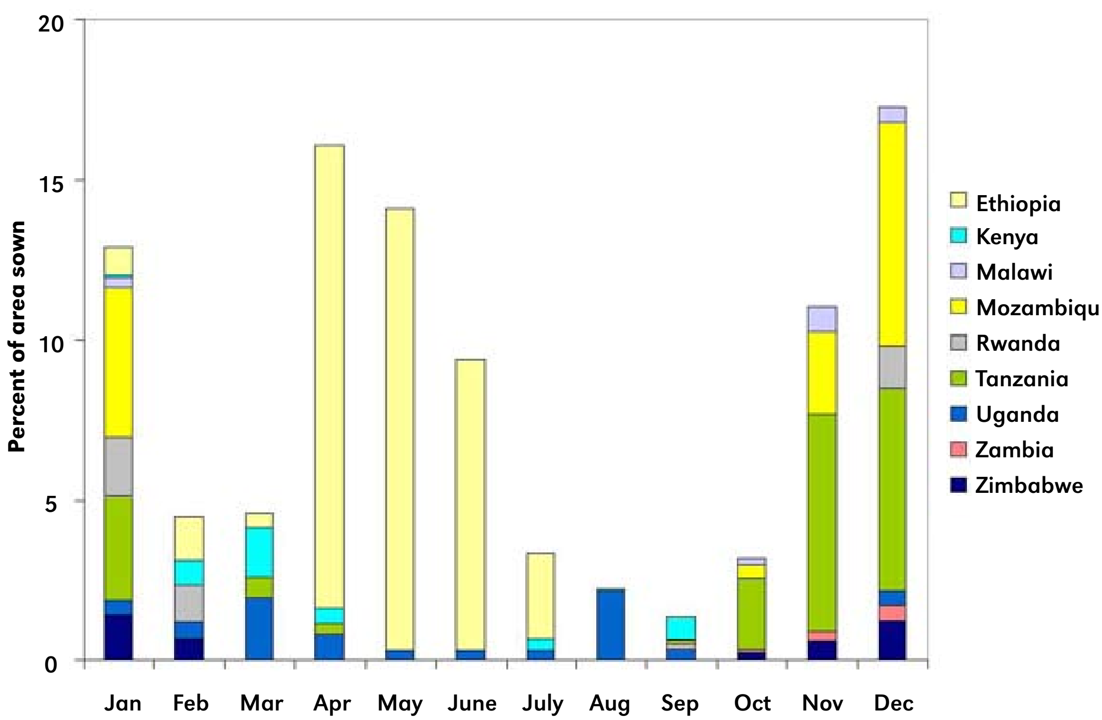
In Uganda, the main sowing times are in March and August. The Southwestern Highlands SPA is an exception for Uganda where sowing is primarily in December and January.

There are two sorghum production seasons in northern and eastern Tanzania with major sowing times in March and October. Most sorghum is sown in November through January elsewhere with relatively more sown in November in the southern parts. Sowing is primarily in November and December in Zambia and Mozambique with later sowing in the south and from November to February in Malawi and Zimbabwe.

Harvesting times

Most sorghum in Ethiopia is harvested from October through December *(Fig. 2.3)*, but harvest in the Southern SPA is in May through July *(Map 2.3)*. The major sorghum harvest period in Kenya and Uganda is July to August, but with some harvest throughout the year, depending on the SPA. Sorghum harvests are primarily from April through July in Tanzania, Malawi and Zambia, and from March through May in Mozambique and Zimbabwe.

Figure 2.2. Percent of sorghum sown by month in nine countries of eastern and southern Africa.



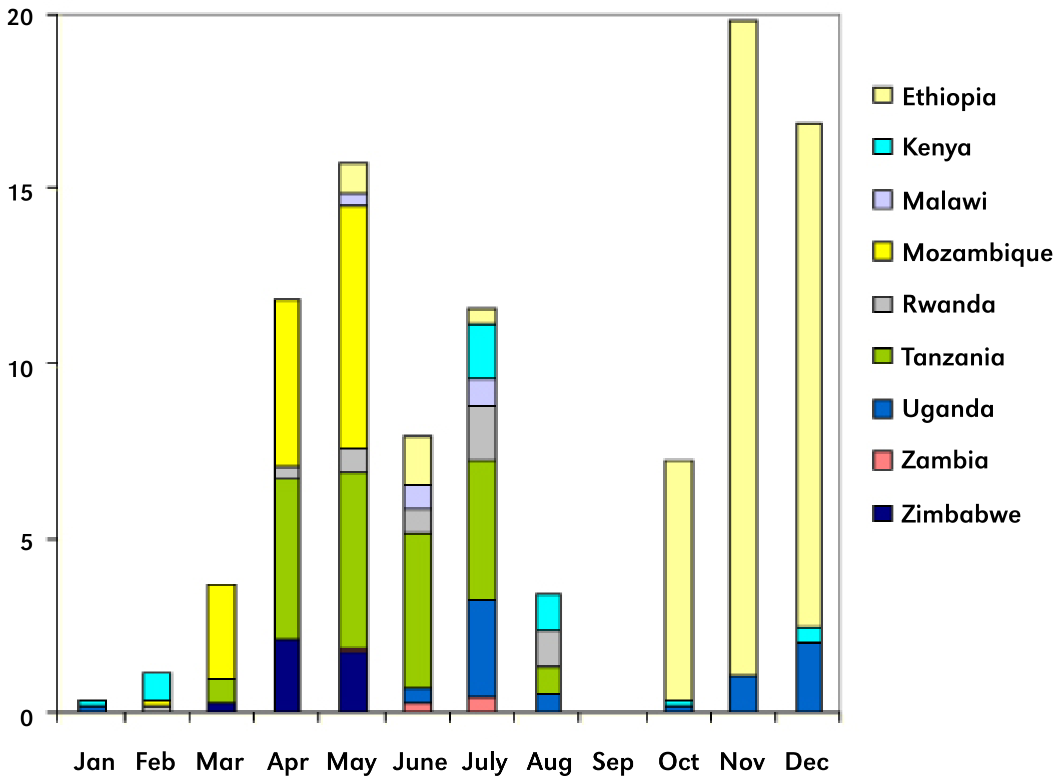


Figure 2.3. Percent of sorghum harvested by month in nine countries of eastern and southern Africa.

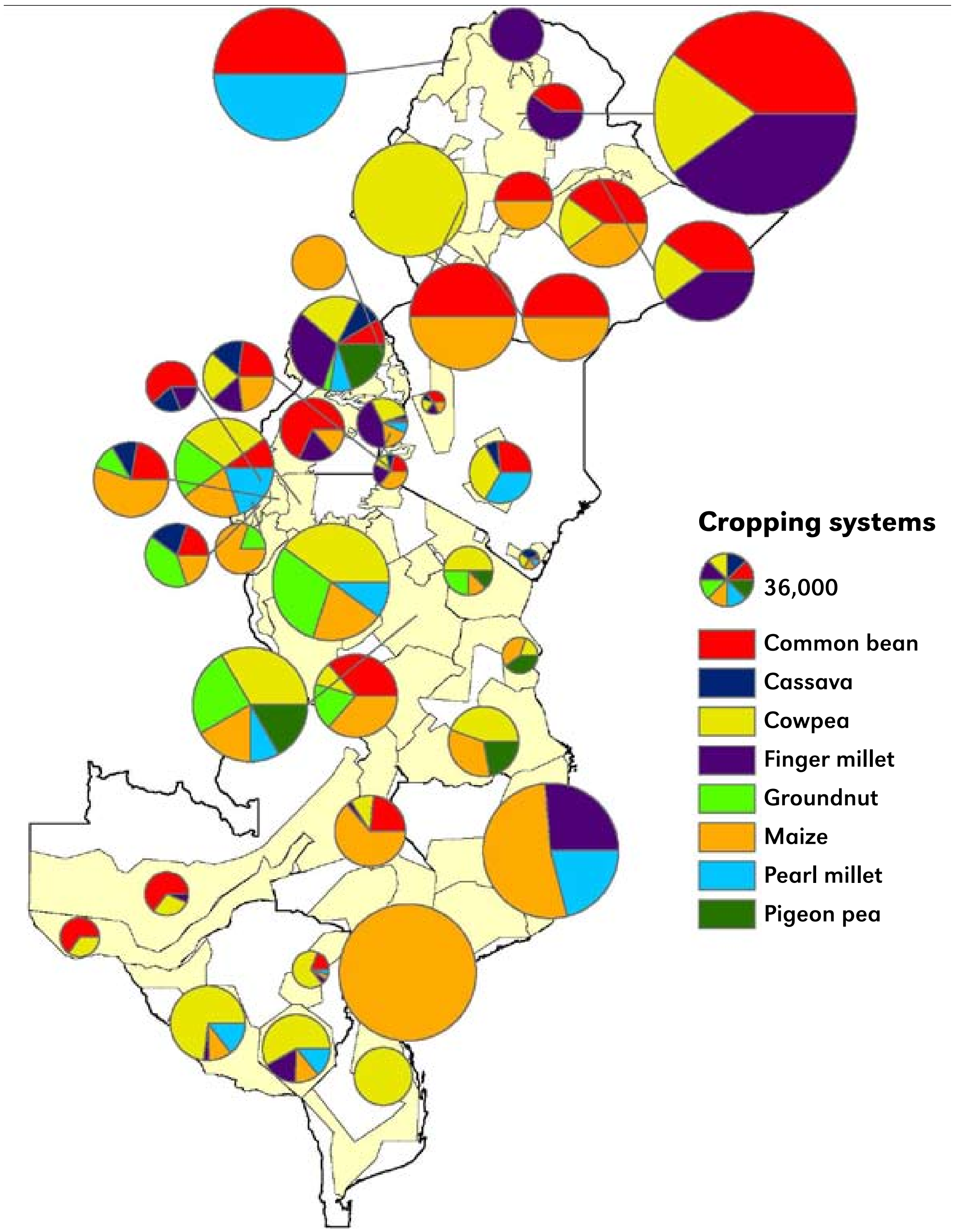
Level of mechanization

Most field operations for sorghum production are done manually in all nine countries and there is generally little use of tractors *(Table 2.1)*. There is relatively more use of tractors for sorghum production in the Tigrain Lowlands of Ethiopia and in Eastern Tanzania than elsewhere, accounting for about one third of the power invested in these SPAs *(Map 2.4)*. Draft animal use for land preparation is important throughout Ethiopia, in Eastern and Nyanza Provinces of Kenya, in northern and eastern Uganda, and in most parts of Tanzania with relatively less use in eastern and southern Tanzania. Draft animal power is also important in Malawi, Zambia, and Zimbabwe.

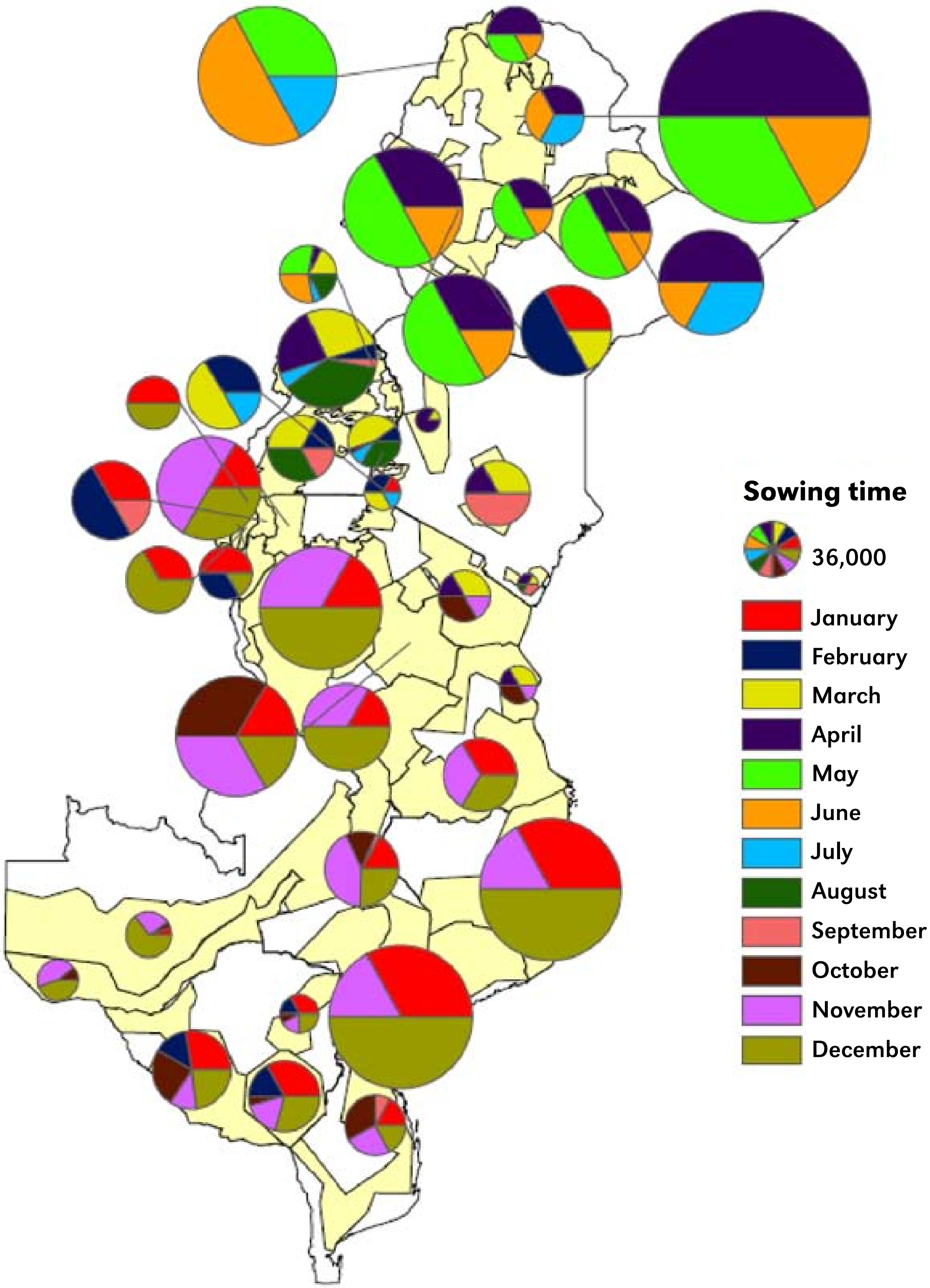
Table 2.1.Level of mechanization as indicated by percent of power for sorghum production from human, animal and tractor sources.

Country	Human labor	Draft animals	Tractor
Ethiopia	57	31	11
Kenya	77	18	5
Malawi	31	69	0
Mozambique	90	10	0
Rwanda	100	0	0
Tanzania	42	52	6
Uganda	61	32	7
Zambia	65	35	0
Zimbabwe	56	42	2

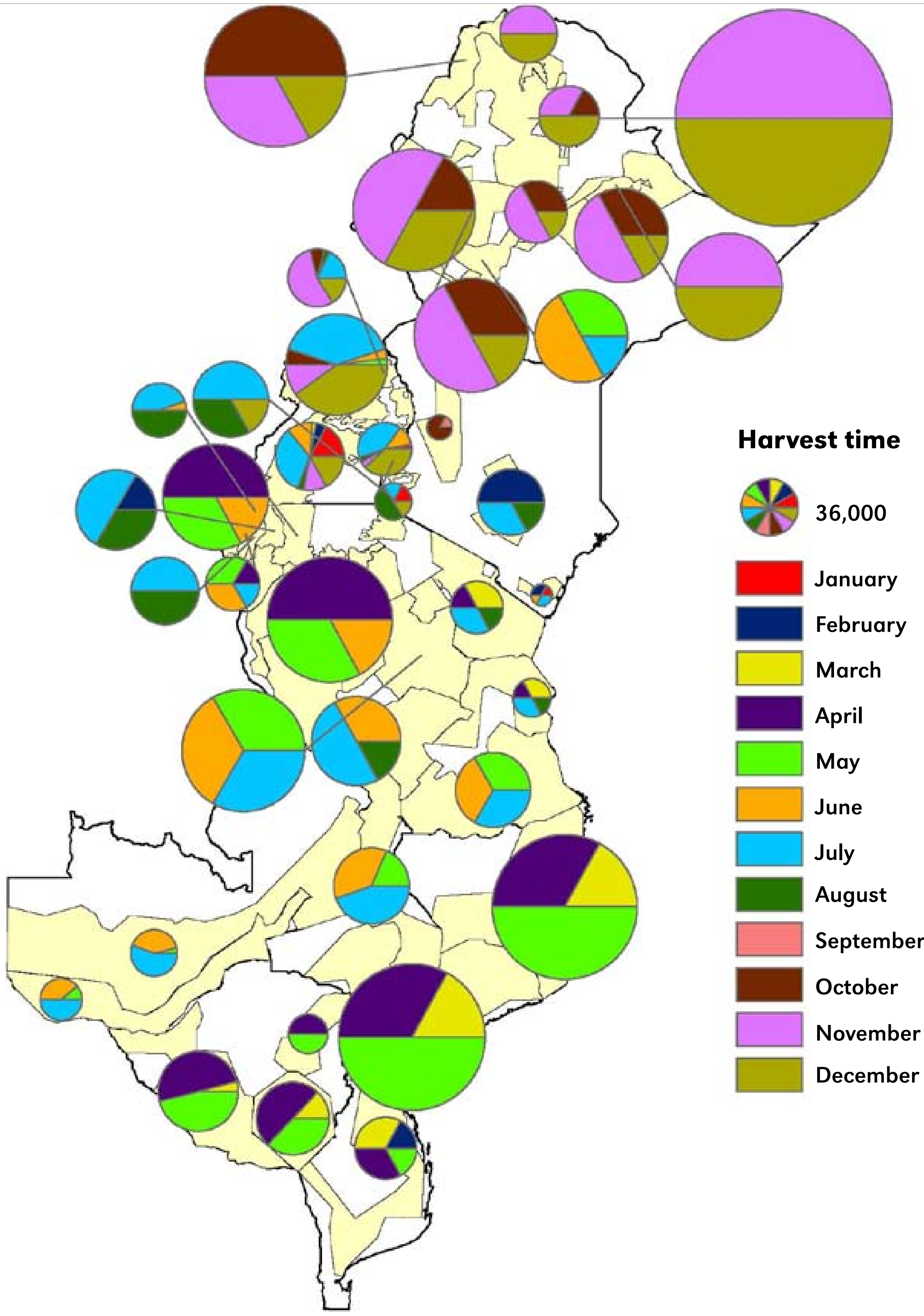
Map 2.1. The relative importance of associated crops in intercrop production of grain sorghum by SPA in eastern and southern Africa. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



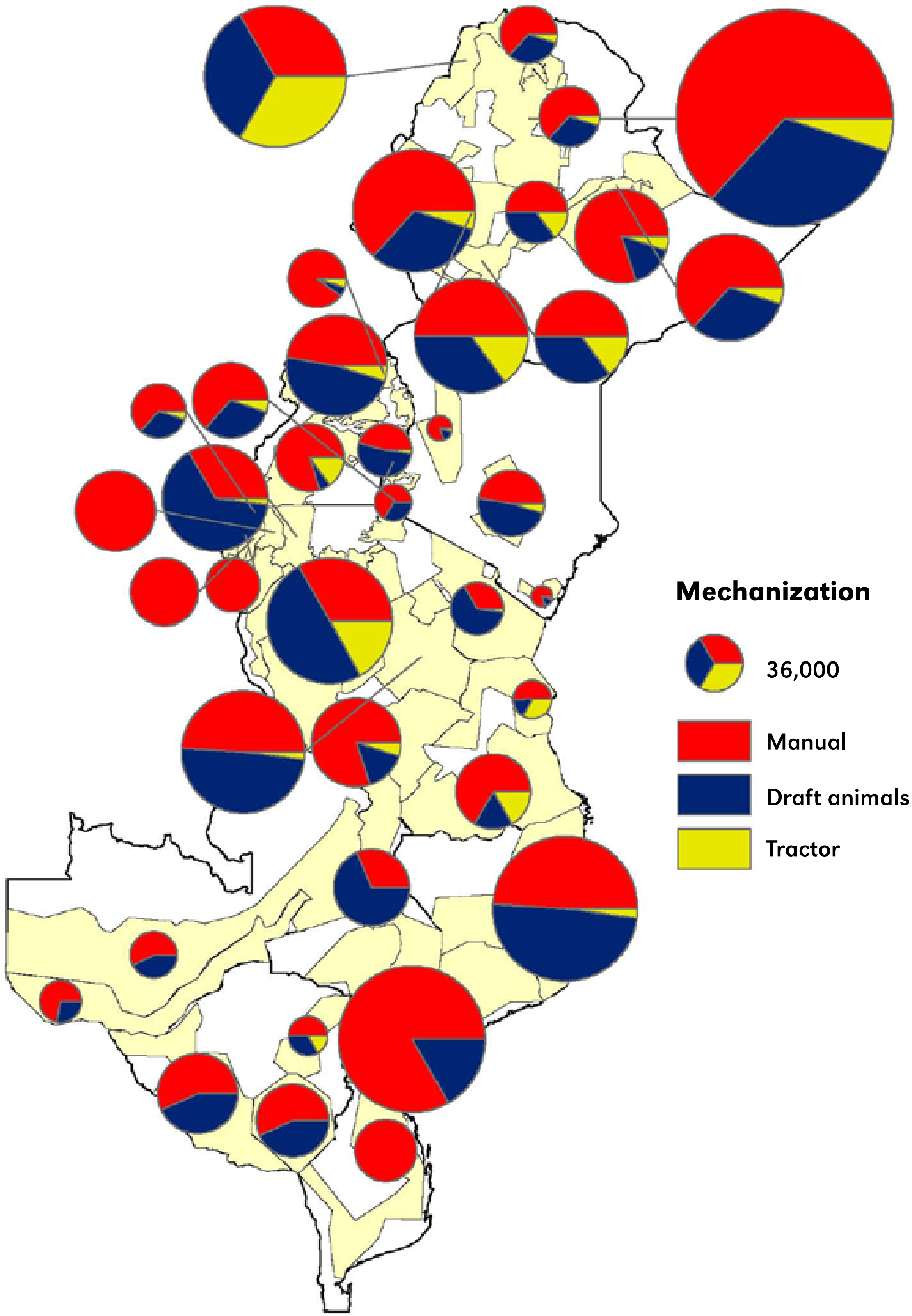
Map 2.2. The relative importance of sowing times by SPA for grain sorghum in eastern and southern Africa. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



Map 2.3. The relative importance of harvesting times by SPA for grain sorghum in eastern and southern Africa. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



Map 2.4. The relative importance of power sources for sorghum production by SPA in eastern and southern Africa. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



CHAPTER 3.

Sorghum Production Constraints

Grain sorghum yields are very low in eastern and southern Africa as compared to yields in the US and well below the genetic potential. The national average yields range from 0.6 to 1.5 Mg ha^{-1} for these nine countries as compared to a mean yield of 4.3 Mg ha^{-1} in the USA (FAOSTAT, 2008). The biotic and abiotic constraints to yield are numerous with a combined effect of much yield loss. In this chapter, these constraints are evaluated for their importance at SPA, national and regional levels.

Data collection and analysis

Information about grain sorghum production systems was obtained by interviewing sorghum specialists in each country as described in Chapter 1. The interviews were conducted by presenting a list of 43 potential constraints to higher sorghum grain yields. Interviewees were encouraged to add constraints to the list that they considered to be important in one or more SPA. The interviewee was asked to allocate exactly 120 points to these 43 constraints for each SPA. Allocation of more points indicated greater yield loss associated with the constraint. No points were allocated to constraints considered to be of negligible or very minor importance in an SPA.

Yield losses due to constraints were estimated assuming: mean sorghum grain yield was 1.5 Mg ha^{-1} for all SPAs; potential yield with existing cultivars and with each of these 43 constraints removed was 6.3 Mg ha^{-1}; and that each of the 120 assigned points represented 40 kg ha^{-1} yield loss. The number of assigned points was therefore multiplied by 40 to estimate yield loss per hectare due to each constraint in each SPA. Estimated yield loss due to each constraint in each SPA was calculated by multiplying estimated loss per hectare by the number of hectares of grain sorghum produced annually.

The 43 constraints were assigned to nine sets of constraints. These were comprised of eight diseases, nine insect pests, nine soil fertility- and soil water-related constraints, seven other biotic constraints, and seven other abiotic constraints.

The importance of the four or five constraints for each of the five sets determined to be responsible for the greatest yield losses is presented in maps using pie charts for each SPA. The diameter of the pie charts varies according to the total yield loss due to that set of constraints. Estimated yield losses caused by the various biotic and abiotic constraints are reported for each SPA in Appendix B.

Overview of sorghum production constraints

The combination of soil water deficits is the most important constraint to production, accounting for over 2 million Mg yr^{-1} of yield loss for these nine countries *(Table 3.1; Fig. 3.1)*. Soil water deficits during grain fill are most important for Ethiopia and Mozambique. Mid-season deficits are relatively less important than for other growth stages in Ethiopia but very important in the other countries.

The stalk borer complex, (including *Chilo partellus* (Swinh.), *Busseola fusca* (Fuller), and *Sesamia calamistis*) is found to be a very important constraint to yield regionally. Total loss of production potential to stalk borer is estimated to be more than 1.3 million Mg yr^{-1}. The stalk borer complex is recognized as the most important constraint in Ethiopia and Uganda, but of relatively less importance in Mozambique. *Chilo partellus* (Swinh.) is identified as the most important stem borer species.

Nitrogen deficiency is recognized as a major constraint accounting for about 1.2 million Mg yr^{-1} loss. Nitrogen deficiency is the most important constraint in Mozambique, Tanzania, and Zambia, and is in the top six constraints in the other countries.

Striga *(Striga hermontheca* and *Striga asiatica)* is the next most important constraint overall, causing more than 1 million Mg yr^{-1} loss in production. Striga is the most important constraint in Kenya and Rwanda, and the second most important in Ethiopia, Uganda, and Zimbabwe.

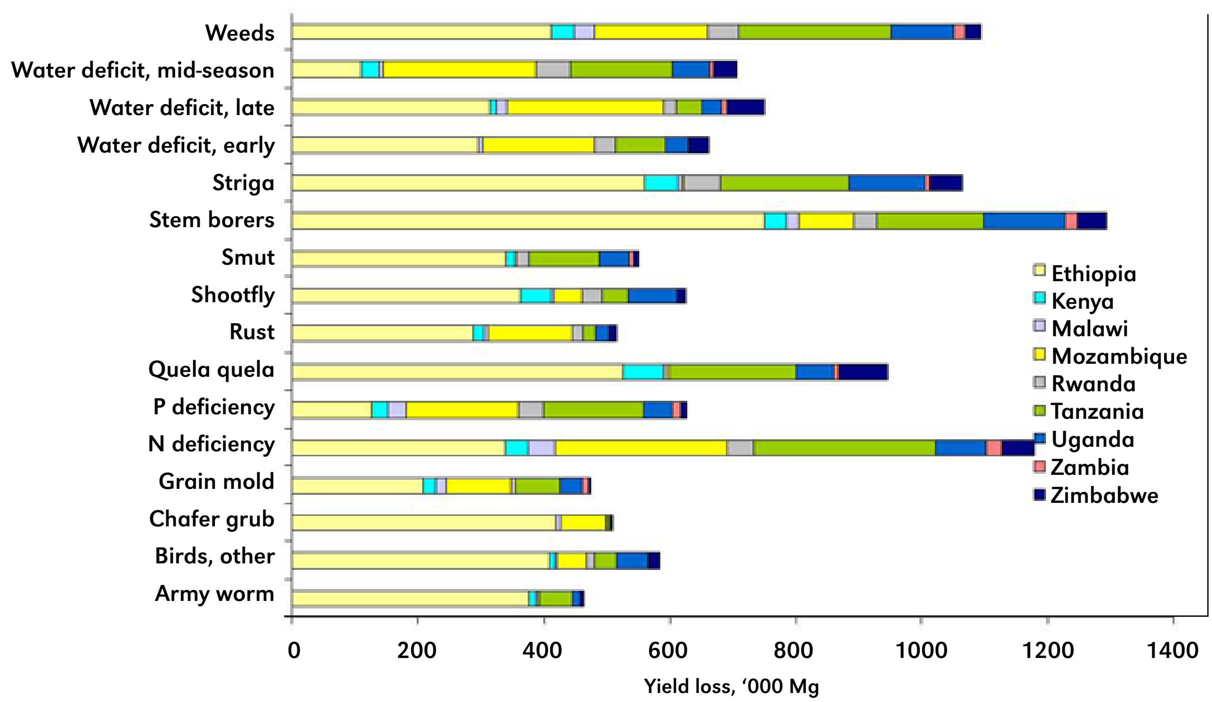
Weeds, quelea (primarily *Quelea quelea*), other birds, shootfly (*Atherigona soccata.*), phosphorus deficiency and smut each cause more than 0.5 million Mg yr^{-1} loss in production. Bird damage is an especially important yield constraint in Ethiopia, Kenya, Malawi, and Rwanda, and has probably accounted for a significant decline in sorghum production area in Kenya.

Table 3.1. Estimated losses of grain sorghum production due to the 12 most important constraints in nine countries of eastern and southern Africa ('000 Mg yr^{-1}).

Constraint	All	ET	KE	MA	MZ	RW	TZ	UG	ZA	ZM
Stem borers	1273	749	36	20	86	22	170	131	13	46
Nitrogen deficiency	1173	339	37	41	273	43	288	81	17	54
Striga	973	412	37	1	178	1	243	100	0	1
Weeds, other	882	515	40	118	205	4				
Quelea	946	526	63	5	4	0	202	61	5	80
Late water deficit	746	314	11	17	247	21	41	30	6	59
Mid-season water deficit	707	109	28	7	243	53	163	59	4	41
Early water deficit	661	295	1	7	176	34	79	37	2	30
Birds, other	639	409	8	32	45	42	36	48	2	17
Shootfly	623	361	51	3	44	34	41	76	0	13
Phosphorus deficiency	623	126	25	45	180	10	39	29	16	9
Smut	546	339	13	1	4	20	111	47	5	6

All, overall; ET, Ethiopia; KE, Kenya; UG, Uganda; TZ, Tanzania; MZ, Mozambique; ZA, Zambia; MA, Malawi; ZM, Zimbabwe; RW, Rwanda

Figure 3.1. Estimated yield loss due to major constraints to sorghum production in nine countries of eastern and southern Africa.



Plant diseases

The major sorghum diseases in eastern and southern Africa are primarily fungal diseases. Smut, caused by *Sphacelotheca* spp., is determined to cause more yield loss than other diseases and is widely important (*Table 3.2; Map 3.1*). Rust, caused by *Puccunia purpurea*, is the next most important and widely distributed. Grain mold, caused by several fungi, and anthracnose (*Colletotrichum graminicola*) are the most important diseases in Uganda.

Grain mold is also considered to be important in the mid-altitude SPAs of Ethiopia, Kenya, and Zambia. Anthracnose and rust are considered to be of high importance in the Eastern Lowlands and the Tigrain Lowlands areas of Ethiopia. Smut is important in the low and mid-altitude SPAs of Ethiopia, Eastern Province of Kenya, and for much of Uganda. Downy mildew (*Peronosclerospora sorghi*) is seen to be of moderate importance in all SPAs. Ergot (*Claviceps africana*) and bacterial streak (*Pseudomonas andropogoni*) are occasionally important in some wetter SPAs, but are rated relatively low compared to other constraints.

Insect pests

The yield losses caused by the stem borer complex are determined to exceed losses due to any other insect pests (*Table 3.3; Map 3.2*). Shootfly is the next important insect pest and is widespread, but especially in the Coast and Western Provinces of Kenya and throughout Uganda. The chafer grub complex is important in Ethiopia and Mozambique, but less important elsewhere. Armyworm (*Spodoptera* and *Mythimna* spp.) is rated of high importance for most SPAs of Ethiopia but of moderate or minor importance in other countries; severe armyworm attack occurs infrequently but can result in complete crop loss. The grasshopper/locust complex is important in parts of Ethiopia, especially in the Tigrain Lowlands of northwest Ethiopia. Sorghum midge (*Stenodiplosis sorghicola*) is of importance in the SPAs of eastern Africa but of less importance in southern Africa.

Soil fertility constraints and soil water deficits

Soil water deficits are the most important constraint to

Table 3.2. Estimated losses of grain sorghum production due to major plant diseases (‘000 Mg yr^{-1}).

Country	Anthracnose	Charcoal rot	Grain mold	Late blight	Mildew	Nematodes	Rust	Smut
Ethiopia	232	191	209	143	191	143	289	339
Kenya	15	8	20	20	6	1	15	13
Malawi	14	1	17	1	3	2	6	1
Mozambique	4	4	100	4	42	4	135	4
Rwanda	16	1	7	18	8	6	18	20
Tanzania	11	13	71	61	23	4	20	111
Uganda	33	9	36	13	10	5	21	47
Zambia	8	1	11	0	1	3	2	9
Zimbabwe	3	6	3	7	4	7	11	6
Total	333	233	471	266	288	173	515	546

Table 3.3. Estimated losses of grain sorghum production due to major insect pests (‘000 Mg yr^{-1}).

Country	Aphids	Armyworm	Cutworm	Grasshoppers/ locusts	Grubs	Midge	Shootfly	Stem borers	Termites
Ethiopia	213	378	233	274	419	295	361	749	14
Kenya	8	11	13	1	1	17	51	36	1
Malawi	2	1	1	6	6	0	3	20	1
Mozambique	4	4	4	4	73	4	44	86	4
Rwanda	5	2	2	12	2	2	34	36	2
Tanzania	53	50	13	10	4	54	41	170	4
Uganda	11	14	19	12	2	42	76	131	3
Zambia	2	0	2	5	0	1	0	19	0
Zimbabwe	11	6	9	3	3	6	13	45	1
Total	308	464	296	325	510	421	624	1286	30

Table 3.4. Estimated losses of grain sorghum production due to soil fertility and soil water-related constraints ('000 Mg yr^{-1}).

Country	Acid soil complex	Nutrient deficiencies				Salinity	Soil water deficits		
		N	P	K	Other		Early	Mid-season	Late
Ethiopia	26	339	126	14	94	19	295	109	314
Kenya	1	37	25	1	2	11	1	28	11
Malawi	6	41	29	14	1	0	7	7	17
Mozambique	4	273	180	67	4	4	176	243	247
Rwanda	42	43	39	29	2	0	34	53	21
Tanzania	7	288	159	21	4	26	79	163	41
Uganda	3	81	45	23	17	3	37	59	30
Zambia	9	24	13	10	0	0	2	5	10
Zimbabwe	2	52	10	8	9	3	29	38	59
Total	97	1171	623	182	133	67	660	705	746

[1] N = nitrogen, P = phosphorus and K = potassium

yield (*Table 3.1; Fig 3.1*). Soil water deficits during crop establishment and early growth and during grain fill are seen as most important in Ethiopia while mid-season deficits are generally seen as most important in Uganda and Kenya.

Nitrogen deficiency is recognized as a major yield constraint in all SPAs (*Table 3.4; Map 3.3*). Phosphorus deficiency is of moderate to high importance in all SPAs, and especially in Nyanza Province of Kenya. Potassium deficiency is generally of low importance for most sorghum production, but of moderate importance in Malawi, Mozambique, Rwanda, Zambia, and parts of Uganda. Deficiency of other nutrients is not indicated except for Southwest Uganda. Soil acidity is a problem in Rwanda and in AEZ II in Zambia. Salinity is seen to be of relatively low importance.

Other biotic constraints

Striga, weeds, and quelea are recognized as major constraints (*Table 3.5*). Quelea is seen as an especially important constraint in the Rift Valley areas of Ethiopia and Kenya, as well as the Southwest Lowlands of Ethiopia, the other SPAs of Kenya, and in Tanzania (*Map 3.4*).

Striga is rated especially high for Eastern and Northern Uganda, Zimbabwe, the production areas of < 1800 m in Rwanda, and for the Western, Nyanza and Coast Provinces of Kenya. Striga is determined to be of minor importance for the Central Rift Valley and Western SPAs of Ethiopia, but of high to very high importance for all other SPAs in Ethiopia.

Weeds, other than striga, are widely recognized as a major constraint to sorghum production. Uncontrolled

Table 3.5. Estimated losses of grain sorghum production due to other biotic constraints ('000 Mg yr^{-1}).

Country	Domestic animals	Wildlife	Birds, other	Quelea	Striga	Theft	Weeds
Ethiopia	31	79	125	526	560	17	544
Kenya	12	14	47	63	52	3	39
Malawi	5	3	32	5	6	1	185
Mozambique	4	4	474	4	4	4	185
Rwanda	21	31	42	0	58	6	50
Tanzania	13	47	184	202	205	4	251
Uganda	36	13	55	61	118	16	116
Zambia	4	5	12	7	9	1	13
Zimbabwe	20	40	35	77	50	13	24
Total	145	234	1003	943	1060	64	1254

Table 3.6. Estimated losses of grain sorghum production due to other abiotic constraints ('000 Mg yr^{-1}).

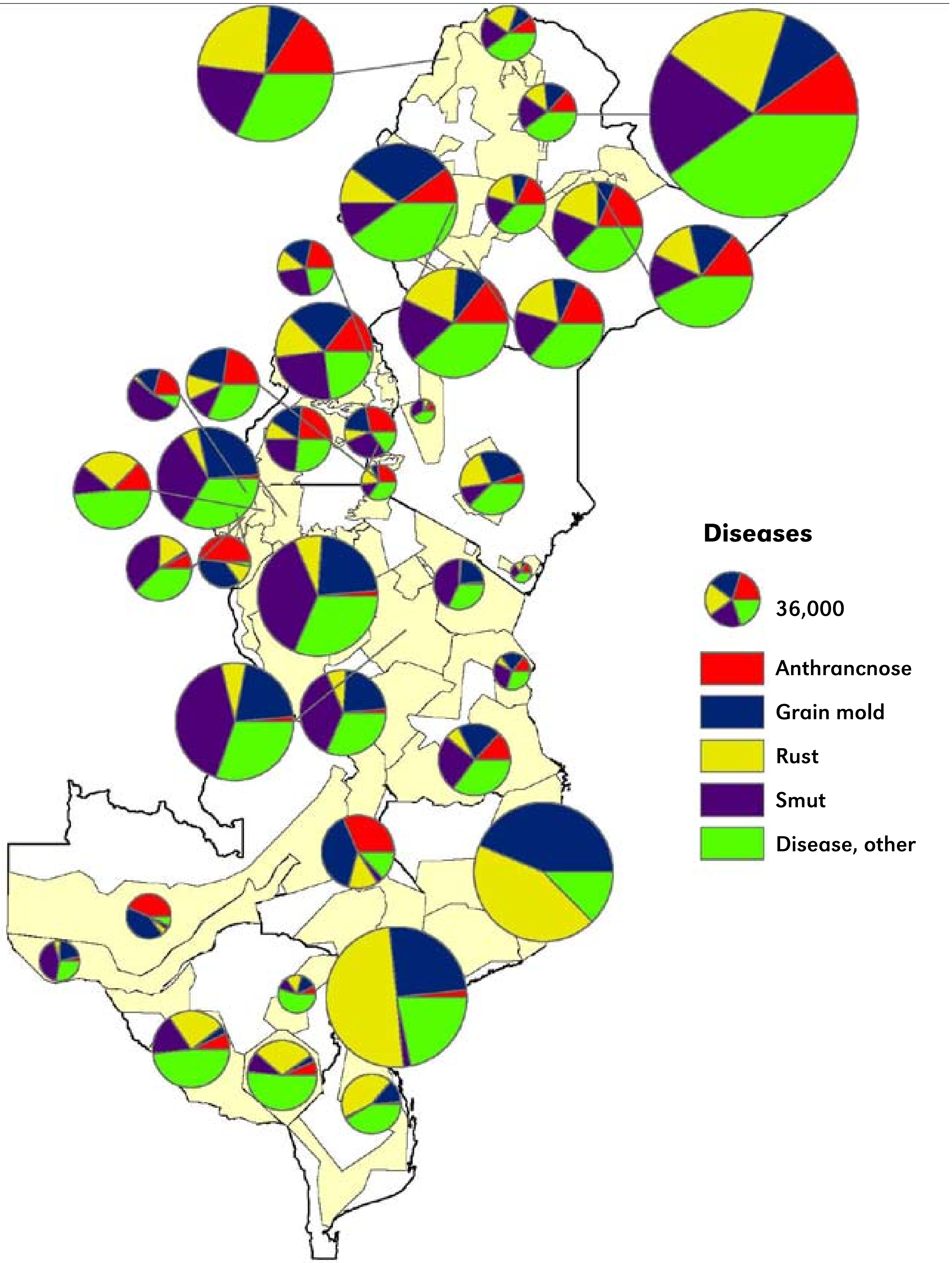
Country	Cold	Flooding	Heat	Low radiation	Root barriers	Soil crusting	Wind
Ethiopia	20	239	39	235	61	17	258
Kenya	26	9	7	17	1	4	7
Malawi	1	1	8	1	1	0	1
Mozambique	4	4	4	4	4	4	4
Rwanda	2	17	6	1	0	5	46
Tanzania	4	33	4	4	4	18	4
Uganda	7	6	6	14	2	16	13
Zambia	0	0	5	2	0	0	0
Zimbabwe	17	3	6	23	0	4	7
Total	80	312	83	300	74	67	340

grazing of fields by domestic animals is of moderate concern in the Northern and Karamoja SPAs of Uganda. Crop damage due to wildlife is of greatest concern in the Southwest Lowlands of Ethiopia, the Rift Valley Highlands of Kenya, the highlands of Rwanda, and in Zimbabwe. Birds of species other than Quelea are seen as a problem generally, but especially for the SPAs of Kenya, Malawi, Mozambique, the Rwanda Highlands, Tanzania, Zambia, and in Central and Western Uganda.

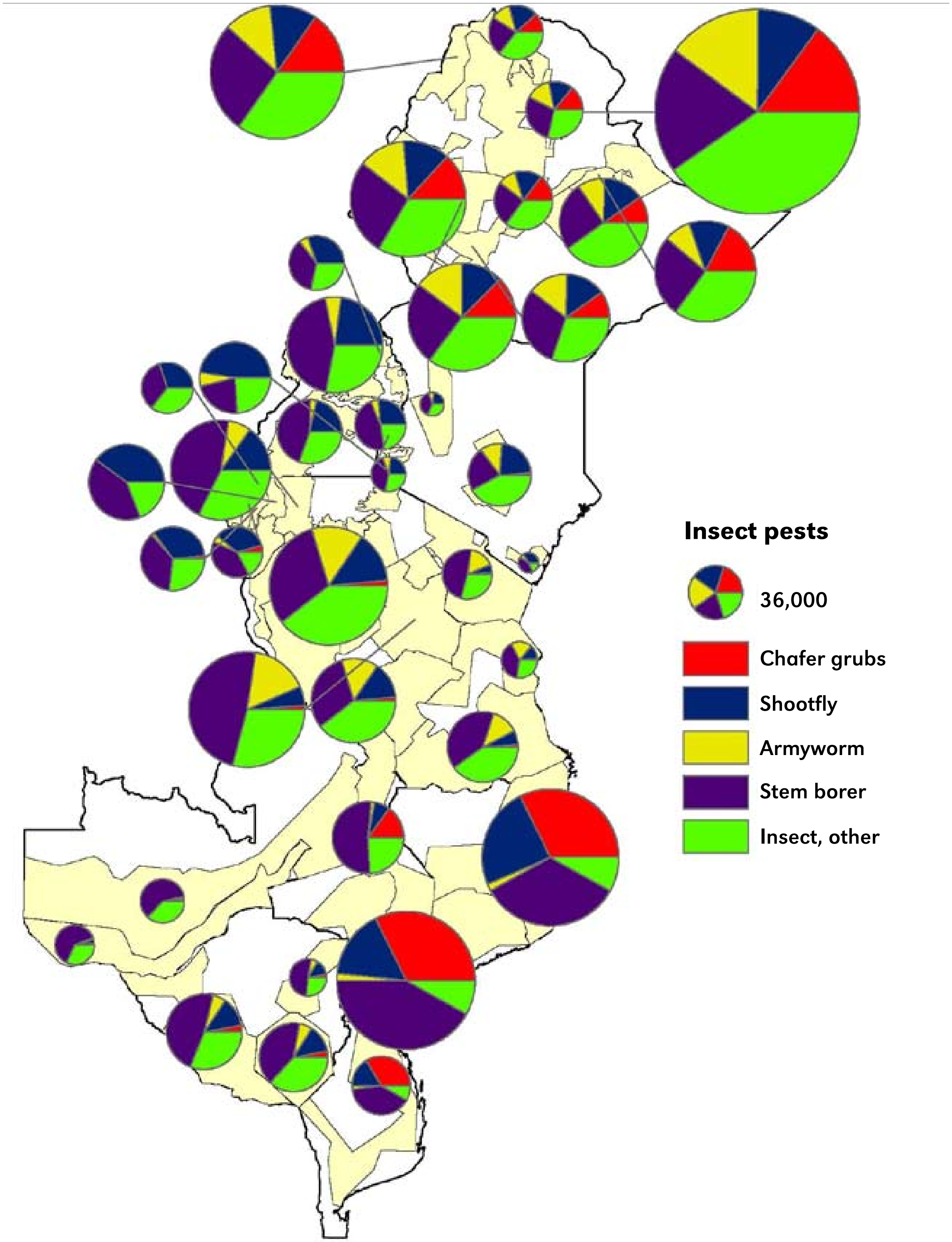
Other abiotic constraints

Wind is rated as a significant constraint for several SPAs of Ethiopia, especially for the Eastern Mid-altitude SPA, and in parts of Rwanda (*Table 3.6*). High temperature is judged to be a significant constraint in the Eastern Province of Kenya, and in several SPAs of Ethiopia, including the Tigrain Lowlands, the Southwest Lowlands, and the Central Rift Valley. Soil crusting is rated of moderate importance in all production areas of Ethiopia except for the Tigrain Lowlands and the Eastern Lowlands SPAs. Barriers to root growth are generally not important but of moderate importance in the Nyanza Province of Kenya and the Southwest Highlands of Uganda, probably due to the presence of laterite layers in these intensively farmed areas.

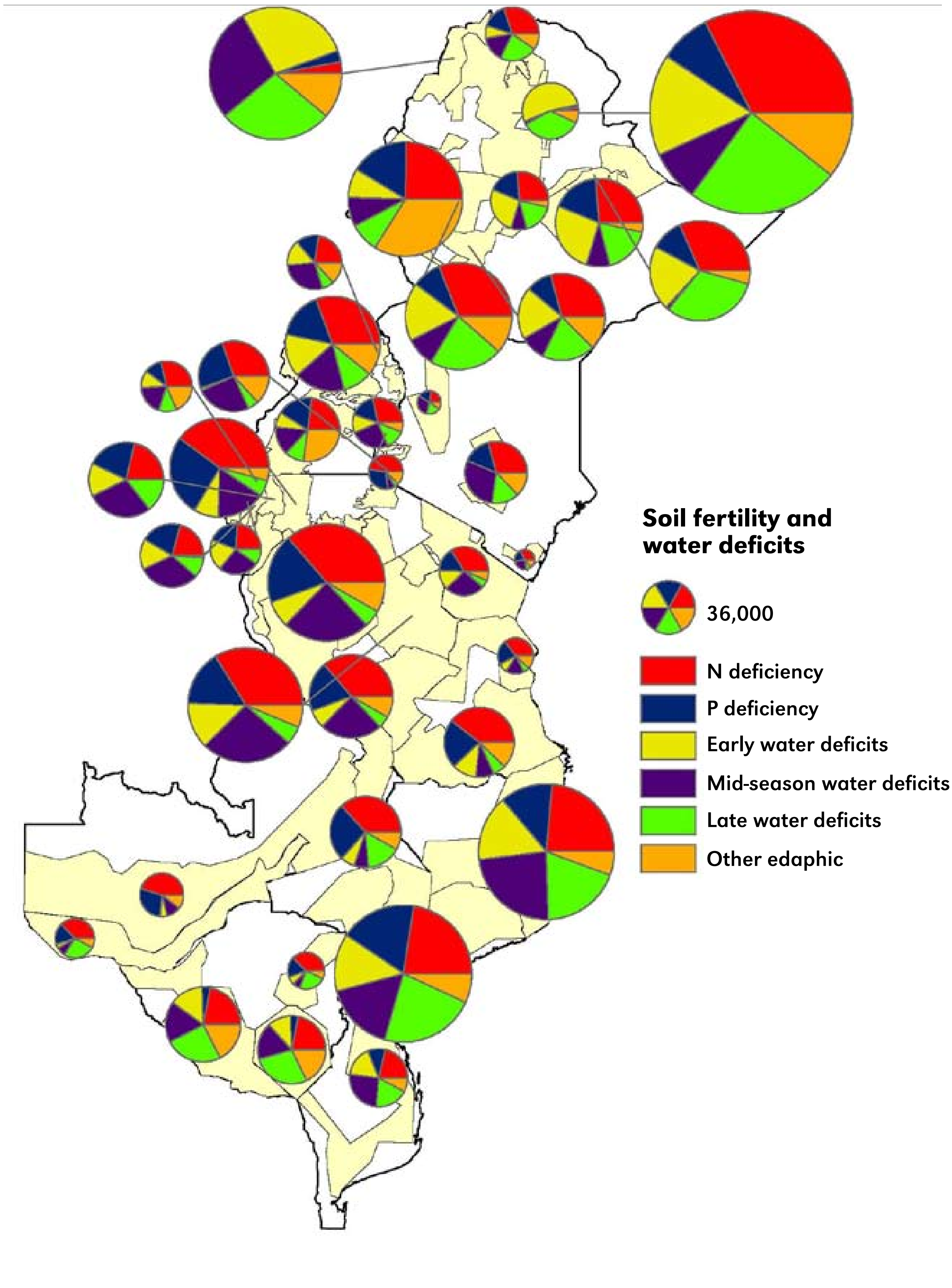
Map 3.1. Relative importance of plant diseases to sorghum production in nine countries of eastern and southern Africa. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



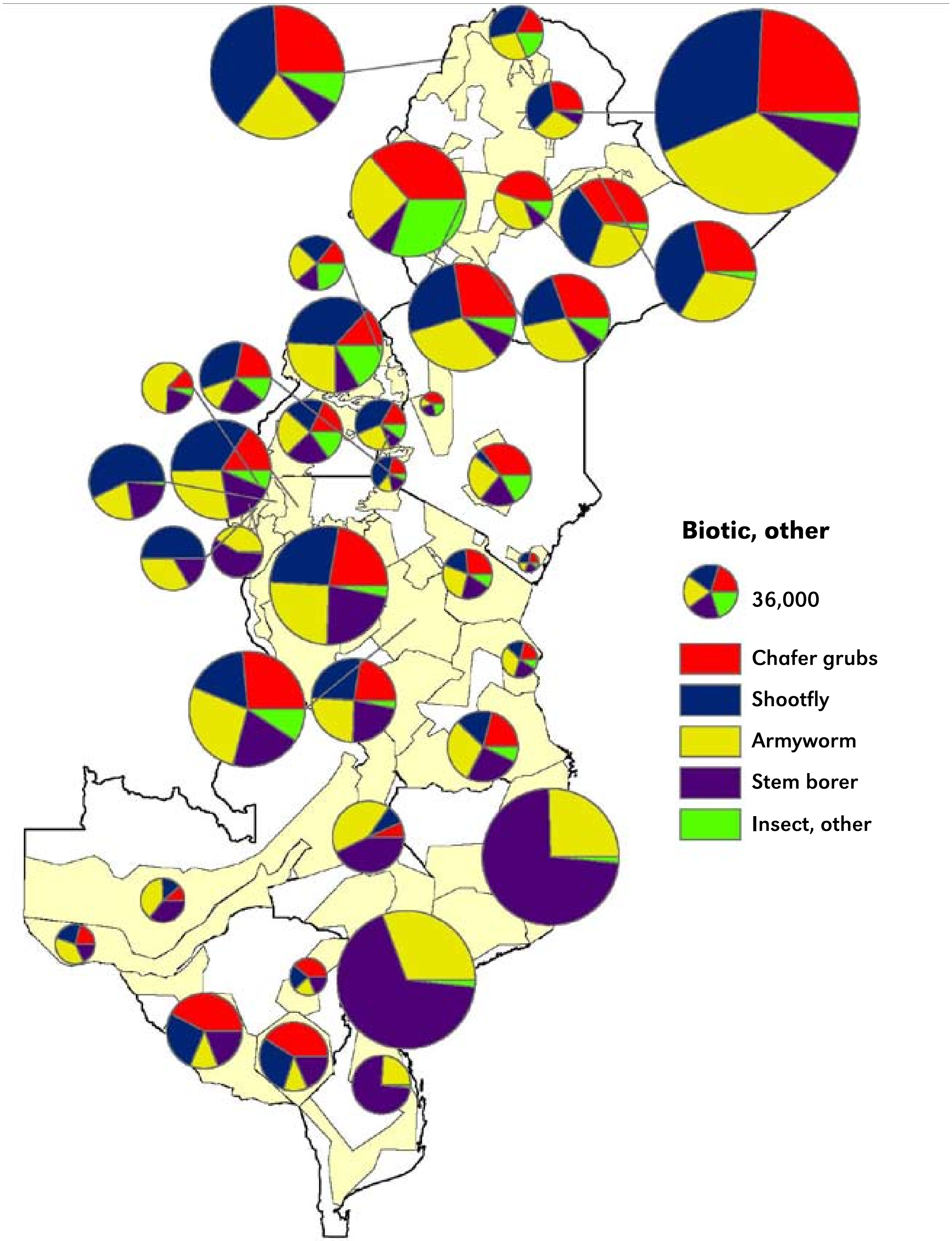
Map 3.2. Relative importance of insect pests to sorghum production in nine countries of eastern and southern Africa. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



Map 3.3. Relative importance of soil fertility and water deficits to sorghum production in nine countries of eastern and southern Africa. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



Map 3.4. Relative importance of other biotic constraints to sorghum production in nine countries of eastern and southern Africa. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



Preferred Phenotypic Characteristics of Sorghum Cultivars

A range of grain characteristics, plant heights, panicle types, and other phenotypic characteristics are considered by farmers in the choice of sorghum cultivars.

Information about grain sorghum production systems was obtained by interviewing sorghum specialists in each country as described in Chapter 1. The assessment of the importance of 28 sorghum phenotypic preferences was done by allocating a total of 30 points among these preferences for each SPA. In the analysis of the data, each point was considered to be the equivalent of 3.3% of the total consideration given to phenotypic preferences for the SPA. Several characteristics were found to be of minor or negligible significance and the results are presented for 17 more commonly expressed preferences. Detailed SPA level information is presented in Appendix C.

Perceived preferences of farmers

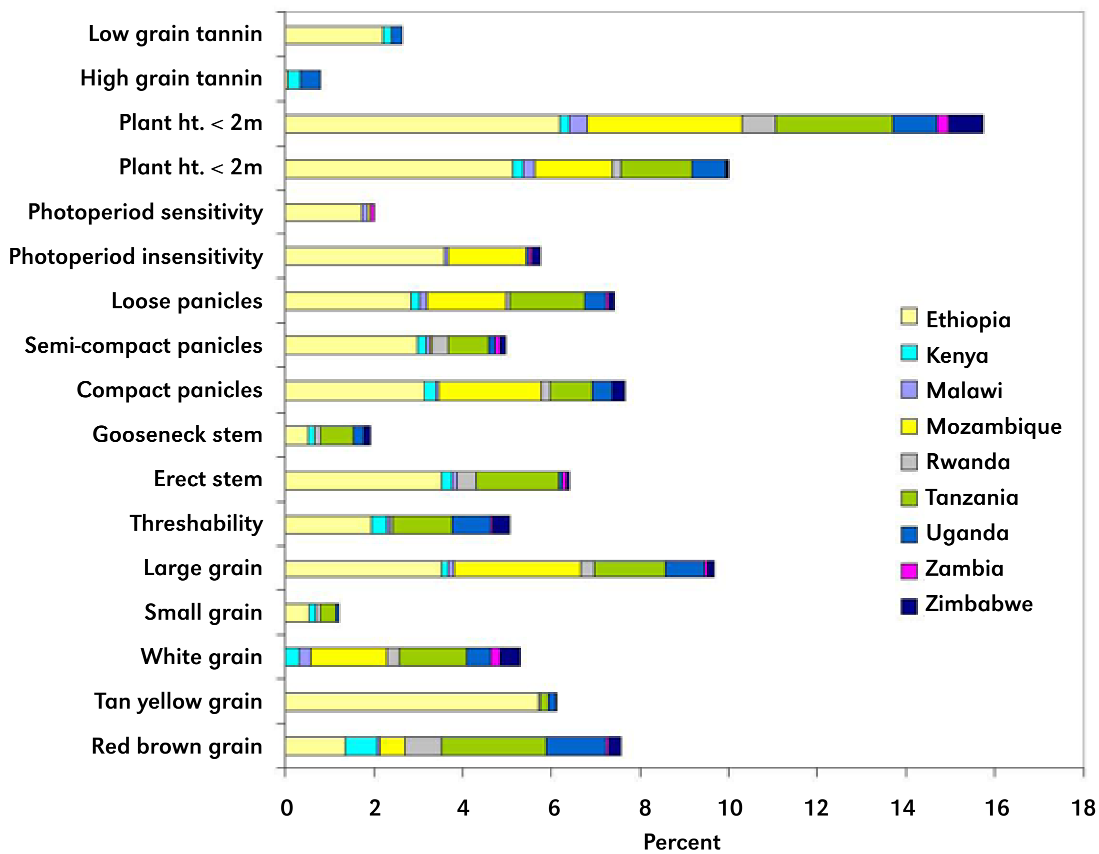
Plant height is a major phenotypic characteristic with more producers favoring plant height of less than 2 m as compared to those favoring taller phenotypes in selection of cultivars (*Fig. 4.1; Map 4.1*). However, tall sorghums as well as shorter sorghums have important places in the sorghum-producing farming systems throughout eastern and southern Africa.

Grain color is recognized as an important consideration in cultivar selection with a greater preference for tan in Ethiopia and white in Mozambique, Zambia, and Zimbabwe as well as parts of Tanzania (*Map. 4.2*). Red and brown grain types are often preferred in Kenya, Rwanda, Uganda, and the Lake and Western SPAs of Tanzania. Red and brown grain types are often associated with higher tannin content, are preferred less by birds, and are less affected by mold. Preferences for brown and red types with high tannin content may also be associated with their localized preference for brewing.

Grain size is less important than grain color with an overall preference for grain of >3g per 100 kernels than for smaller grain. The preference for larger grain size is strongly expressed for Mozambique and some SPAs in Ethiopia (*Map 4.3*).

Preference for panicle positioning varied with SPAs with preferences more strongly indicated in Ethiopia and Tanzania than in the other countries. Crooked, or goose-neck, is less often preferred than erect positioning of the panicle, but the crooked positioning is more preferred in the Eastern Mid-altitude and Northeastern SPAs of Ethiopia, in Nyanza Province of Kenya, and in the Karamoja and Eastern SPAs of Uganda.

Figure 4.1. The importance of sorghum plant phenotypic characteristics in cultivar selection by farmers in nine countries of eastern and southern Africa.

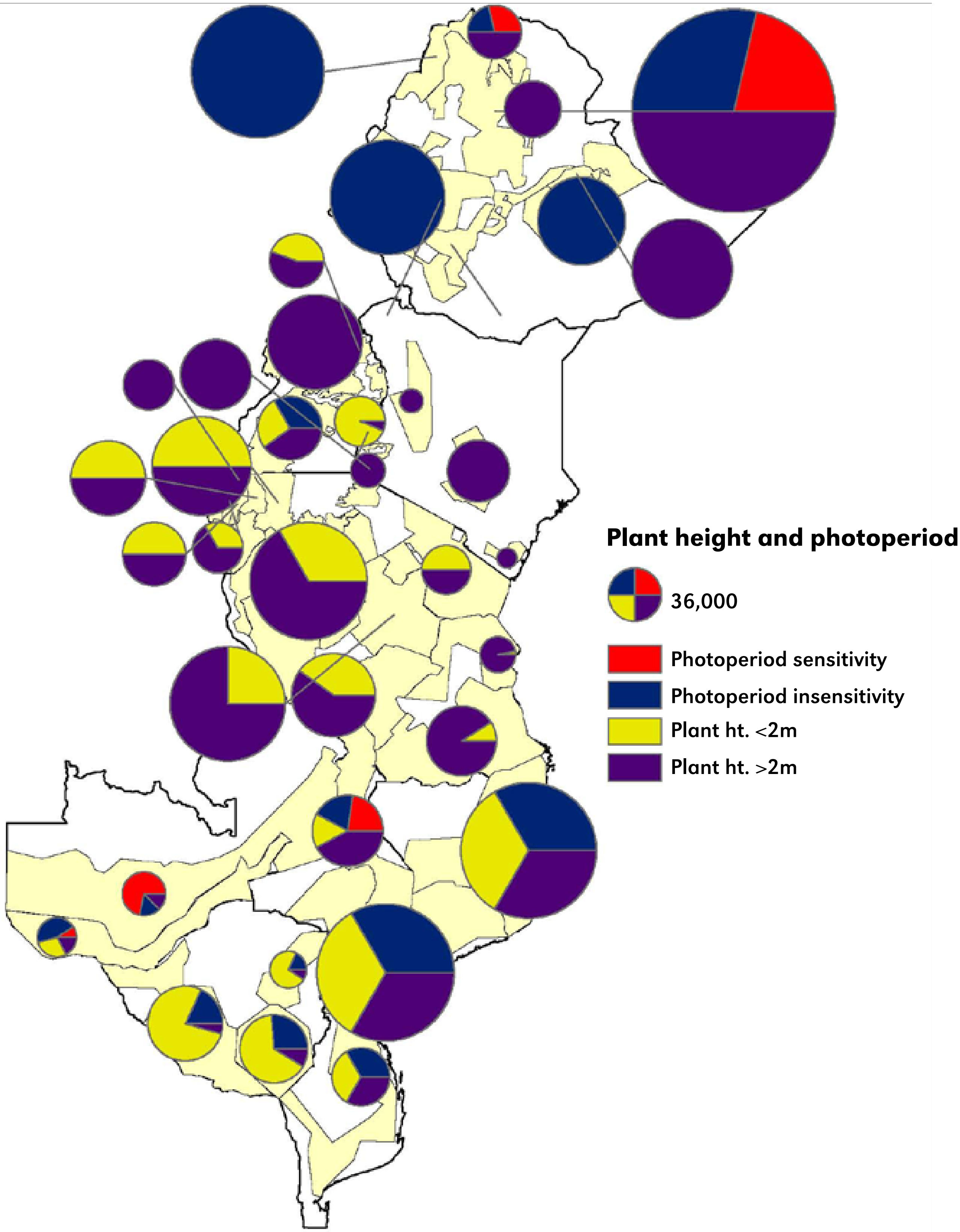


Preference for compact, semi-compact and loose panicles is similar overall, but preferences differed by, and within, SPAs (*Map 4.4*). Compact panicles are most preferred in northwest Ethiopia and in Mozambique. The greatest preferences for semi-compact panicles were expressed for the Central Rift Valley, Southern, Eastern Lowlands, and Western SPAs of Ethiopia. Loose panicles are most preferred in the North Central and Tigrain Highlands SPAs of Ethiopia, in western Kenya, in northern Uganda, and generally throughout Tanzania.

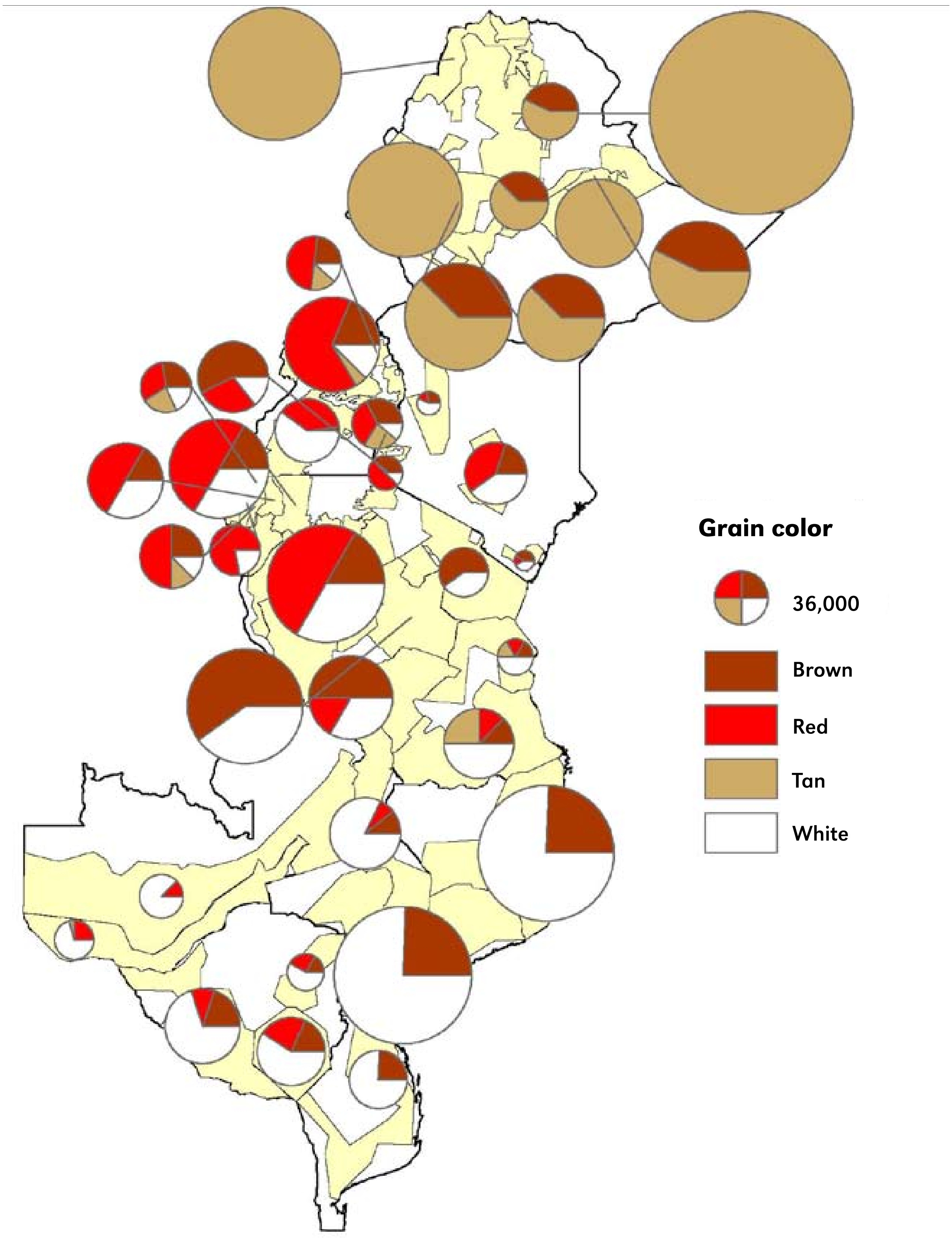
Photoperiod sensitivity is not an important consideration in Kenya, Tanzania and Uganda, as might be expected, as there is little variation in day length. In Ethiopia, as well, the results show little concern about photoperiod sensitivity in most SPAs, but the results indicate some preference for each type in the North Central and Tigrain Highlands SPAs. Preference for photoperiod insensitivity is expressed for the Mozambique SPAs.

Threshability is not expressed as a major consideration of farmers in Mozambique but it is considered to be of some importance elsewhere.

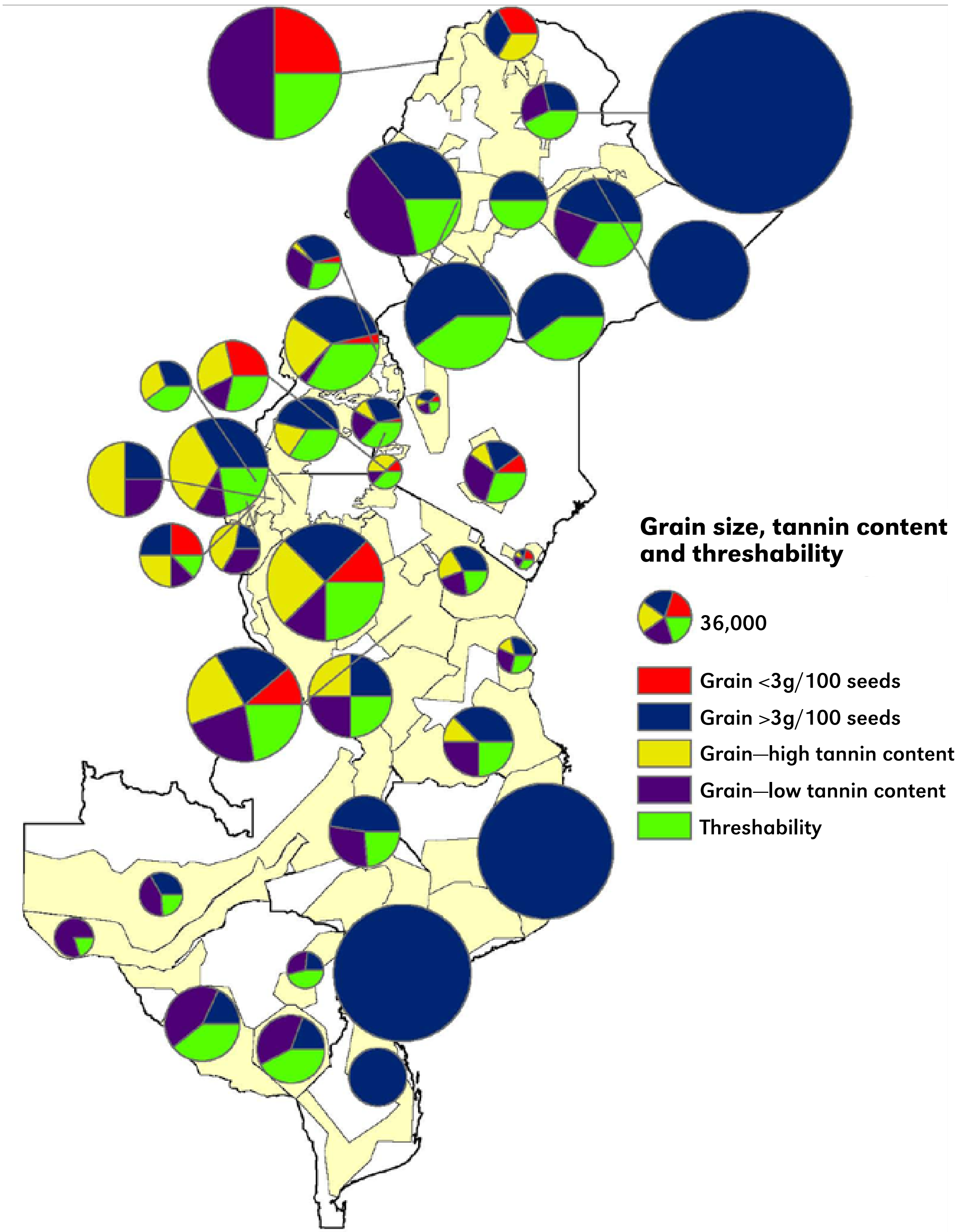
Map 4.1. The relative importance by SPA of plant height and the level of photoperiod sensitivity in farmer preference for cultivars. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



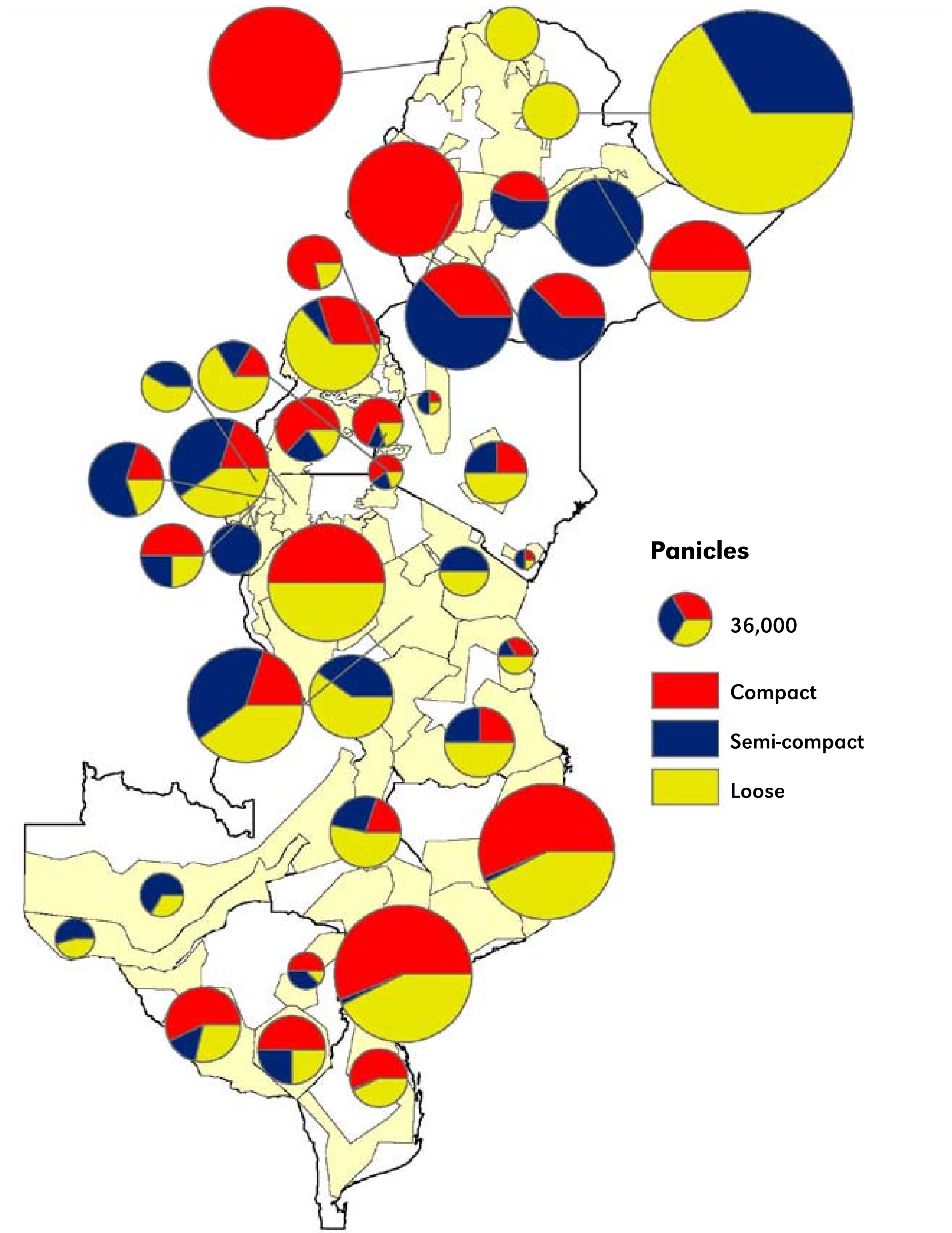
Map 4.2. The relative importance by SPA of grain color in farmer preference for cultivars. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



Map 4.3. The relative importance by SPA of grain characteristics in farmer preference for cultivars. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



Map 4.4. The relative importance by SPA of panicle type and stem type in farmer preference for cultivars. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



Gender and Family Roles in Sorghum Production, Post-Harvest Handling, and Marketing

Women are primarily responsible for sorghum production, post-harvest handling, and marketing in most SPAs. Men and children do assist, but the significance of their roles varies greatly across SPAs.

Information about grain sorghum production systems was obtained by interviewing sorghum specialists in each country as described in Chapter 1. The interviewees were each asked to allocate exactly six points to family members (men, women, and children) to indicate their level of responsibility in sorghum production, post-harvest handling, and marketing for a typical household in each SPA. Allocation of more points indicated more importance for that family member. No points were allocated if the role of the family member was considered to be of little or negligible importance in an SPA. In the analysis of the data, each point was considered to be the equivalent of 16.7% of the total labor and time required to produce the crop, process the harvest, and market the grain.

Men do most of the work for sorghum production in Ethiopia (*Table 5.1*), especially in the Eastern Lowlands and the Tigrain Lowlands SPAs (*Map 5.1*). Women are primarily responsible for the field operations in all of the other countries. Children account for about 16% of the labor invested in production.

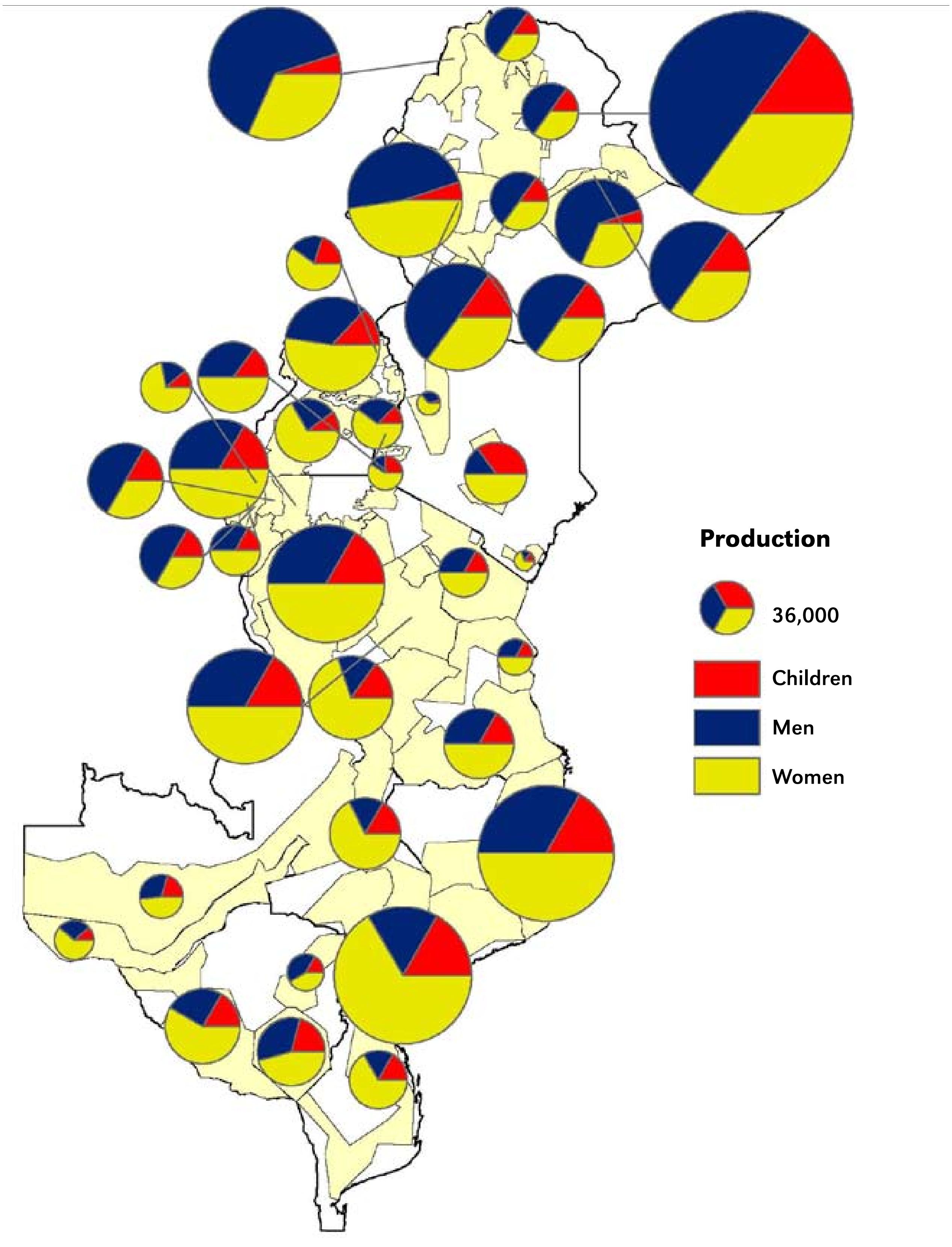
Women are primarily responsible for post-harvest handling which generally is understood to include threshing, winnowing, and storage (*Map 5.2*). The role of women is greatest in Kenya and Uganda.

Marketing of sorghum grain is done by men and women with differences by country. There is not much variation among SPAs within countries (*Map 5.3*). Information was not collected to determine who managed the use of the income resulting from sale of sorghum.

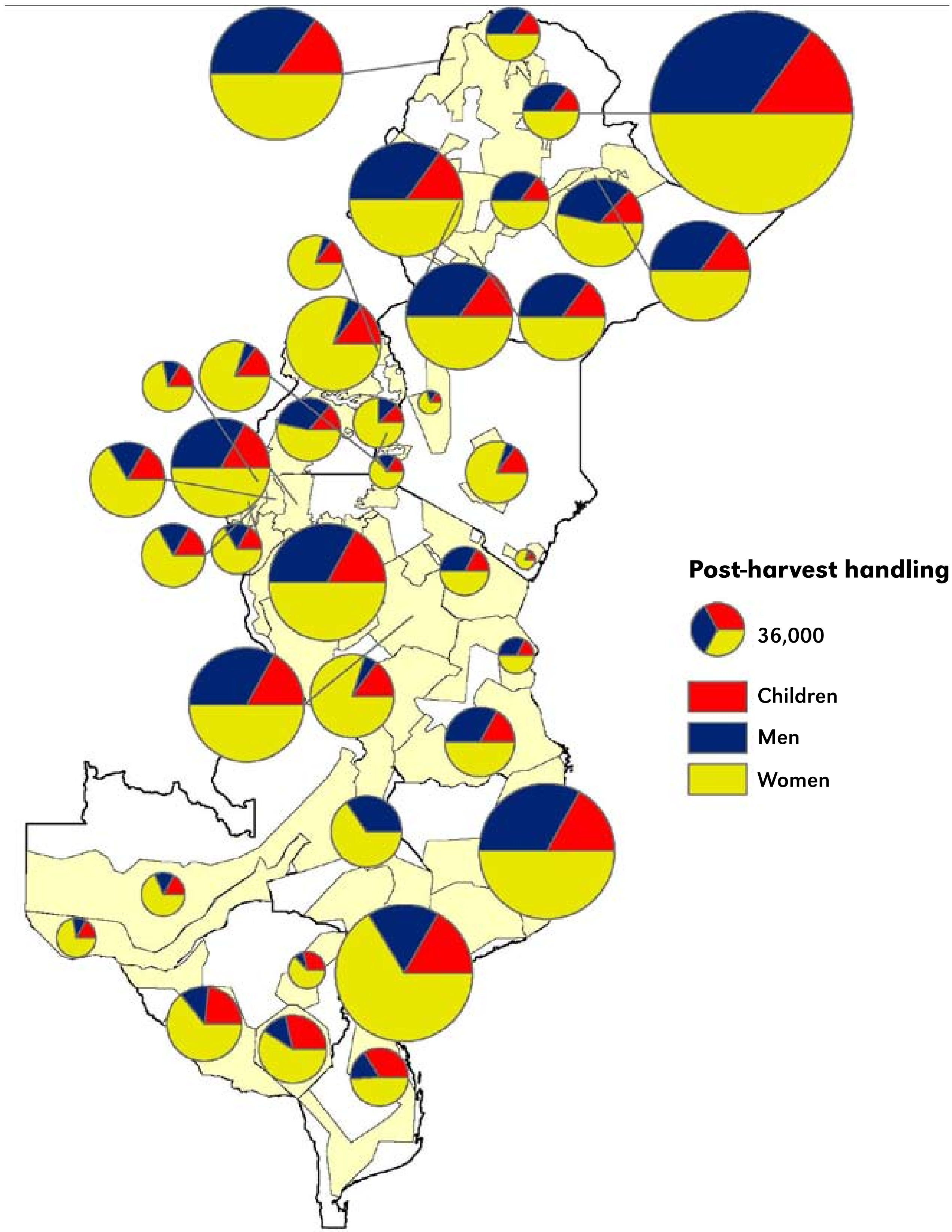
Table 5.1. Family member labor contribution (%) to production, post-harvest handling, and marketing.

Country	Production			Post-harvest			Marketing		
	Men	Women	Child	Men	Women	Child	Men	Women	Child
Ethiopia	53	36	12	35	50	15	48	37	15
Kenya	25	54	21	6	79	15	22	73	5
Malawi	15	68	17	34	65	1	24	50	26
Mozambique	17	64	17	17	58	25	17	74	9
Rwanda	44	39	17	17	66	17	64	36	0
Tanzania	33	50	17	33	50	17	63	37	0
Uganda	28	59	13	12	73	15	33	50	16
Zambia	30	55	15	13	70	17	53	43	4
Zimbabwe	30	52	18	12	62	26	37	56	7

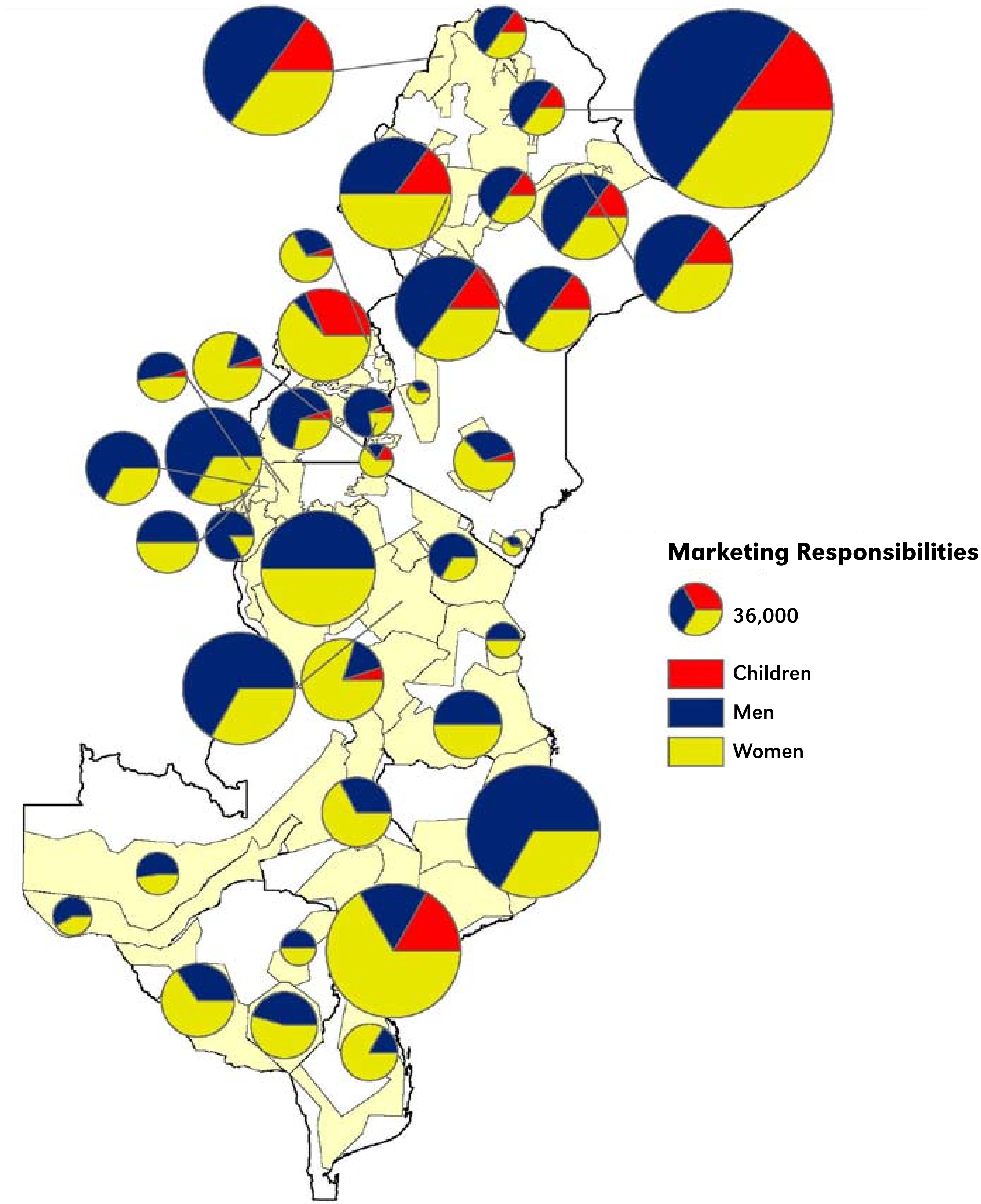
Map 5. 1. The relative importance of the roles of men, women and children in the production of grain sorghum in each SPA. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



Map 5.2. The relative importance of the roles of men, women and children in the post-harvest handling of grain sorghum in each SPA. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



Map 5.3. The relative importance of the roles of men, women and children in the marketing of grain sorghum in each SPA. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



Sorghum Utilization

Sorghum grain and stover have diverse uses with the stover often considered to be as valuable as the grain. The importance of the different uses varies by SPA.

Information about grain sorghum production systems was obtained by interviewing sorghum specialists in each country as described in Chapter 1. Fifteen sorghum grain and stover uses were assessed for importance by allocating a total of 30 points among these uses for each SPA. In the analysis of the data, each point was considered to be the equivalent of 3.3% of the total importance given to uses of sorghum products for the SPA. Several uses were combined and the results are presented for 11 uses in *Fig. 6.1*. Information for each SPA is presented in Appendix D.

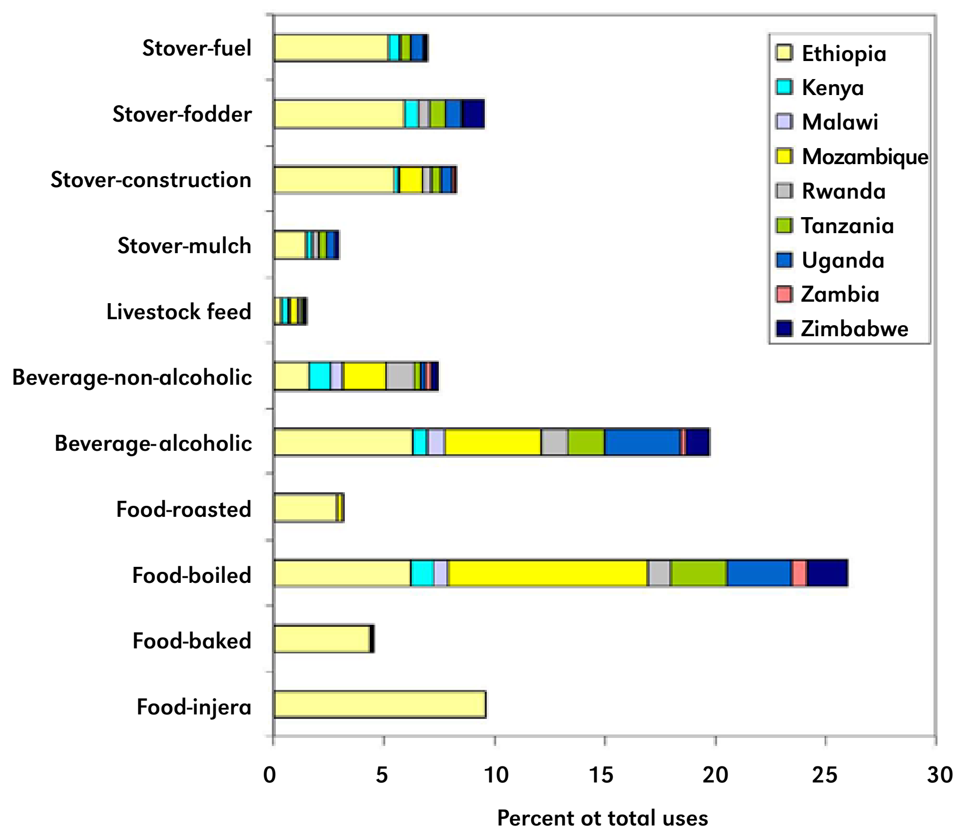
The major use of sorghum grain is for human consumption by boiling, typically of flour to produce foods such as for ugali, sadza, and uji (*Fig. 6.1*). The major use of sorghum in Ethiopia is for making the traditional bread, injera, from fermented dough, for human consumption.

Much grain is produced for brewing such as in the Rwanda highlands, the Southwest Highlands and the Central and Western SPAs of Uganda (*Map 6.1*). Sorghum grain of high tannin content is often produced because of non-preference by birds, less quality loss during storage, as well as preferred taste of the beer. Tannin is degraded during fermentation and during brewing with wood ash. Brewing raises the nutritional value of sorghum as it adds vitamins, neutralizes most of the tannins, hydrolyzes the starch to more digestible forms, and increases the availability of vitamins and nutrients.

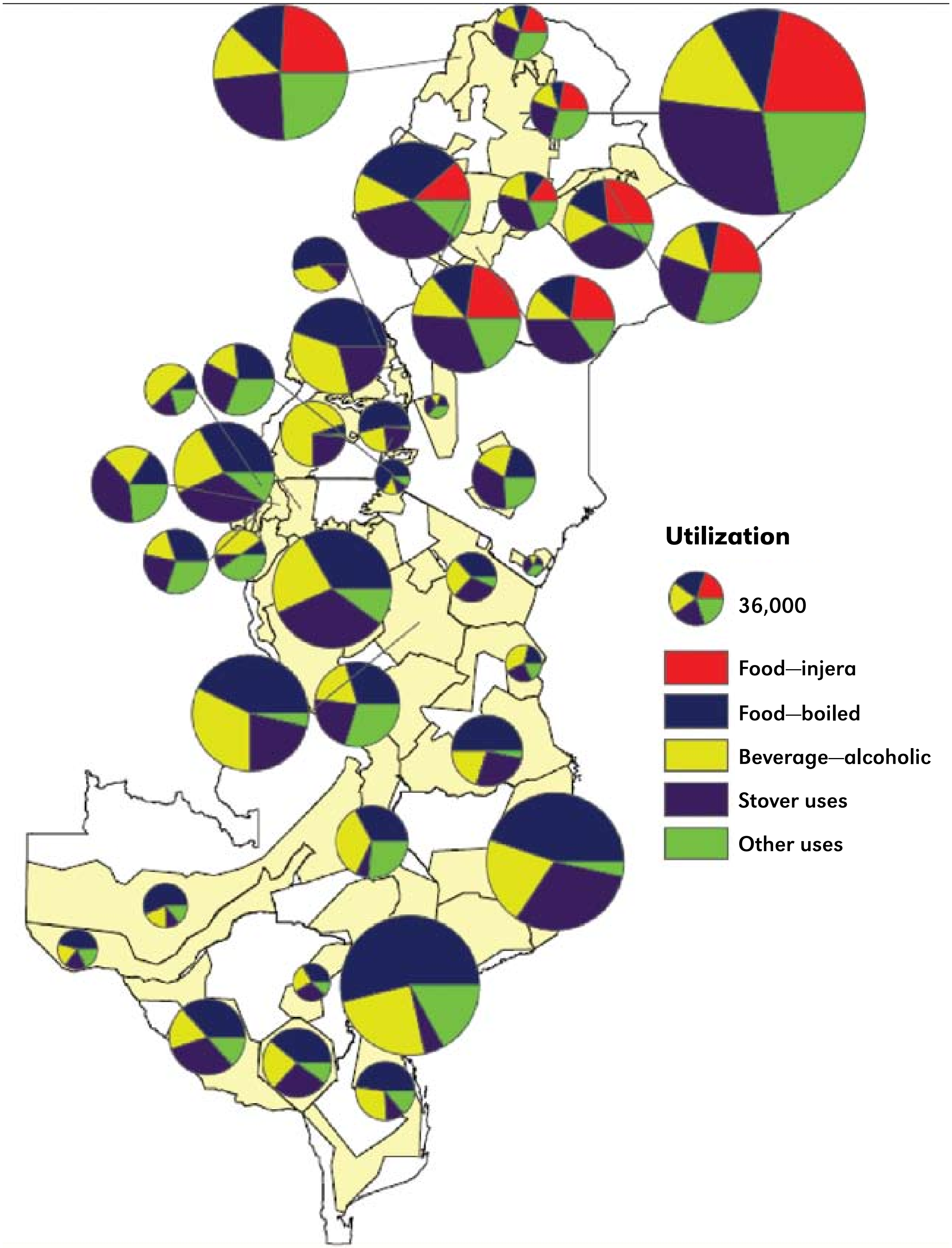
Very little grain is fed to livestock with a greater proportion of the country's production fed to livestock in Kenya, Uganda, and eastern Shonaland of Zimbabwe than elsewhere.

Stover of sorghum is an important product and is used as cooking fuel, fodder and construction material, and to a lesser extent as mulch. No information is gathered on cultivar preferences for stover or fuel. Overall, stover use accounts for 26% of the value of the sorghum crop and for 37% of the crop value in Ethiopia. Overall, the value of stover relative to grain is not related to the percent of grain marketed.

Figure 6.1. The importance of alternative uses of sorghum in nine countries of eastern and southern Africa expressed as percent of the total usage.



Map 6.1. The relative importance of four uses of sorghum in each SPA. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



CHAPTER 7.

Marketing of Sorghum Grain

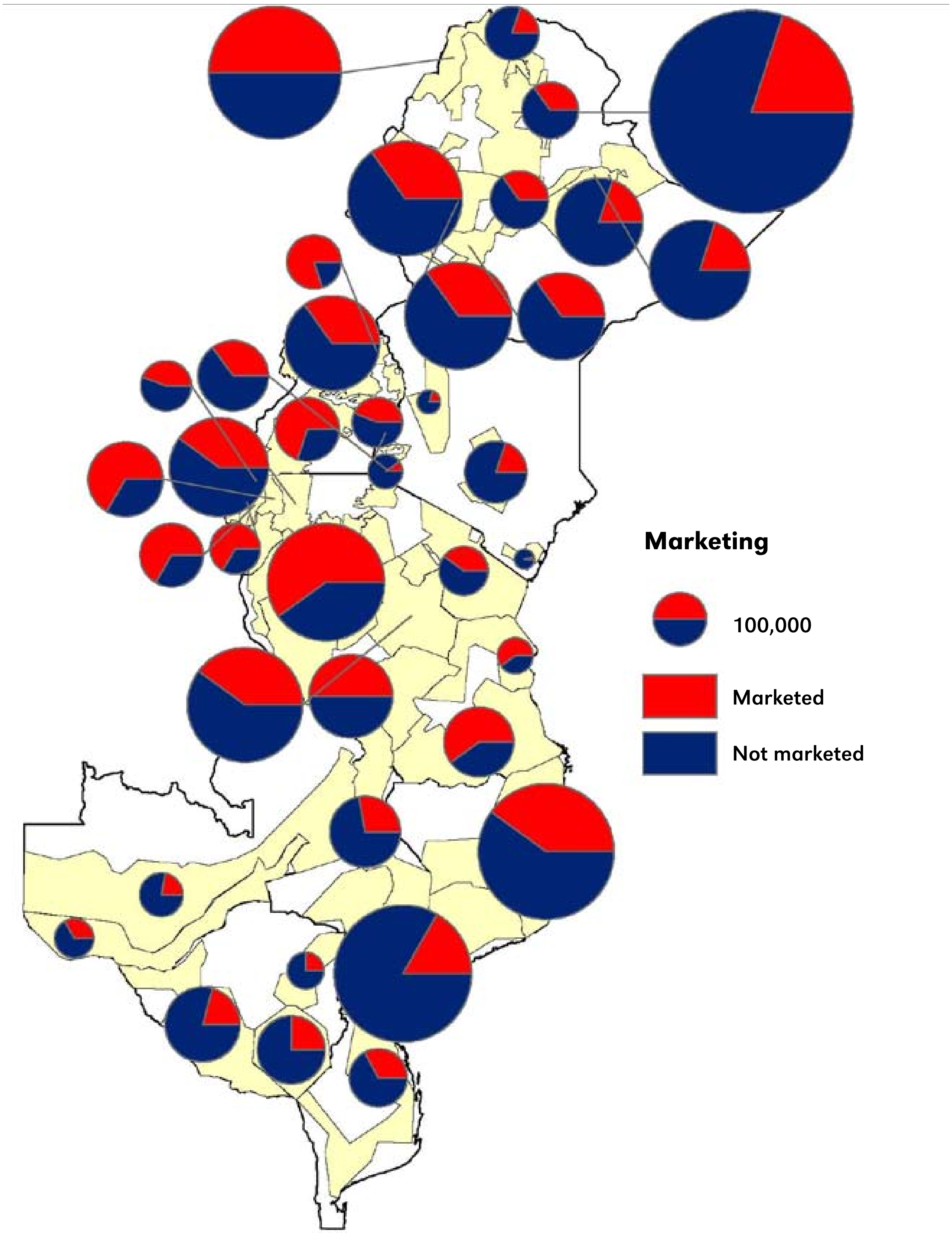
Production of cereals and grain legumes by small-scale, resource-poor farmers typically is at least partly for home consumption. Interviewees assigned a total of six points to indicate the proportion of harvested sorghum grain that is marketed or not marketed. In the analysis of the data, each point was considered to be the equivalent of 16.7% of the annual sorghum produced for the SPA.

Most of the sorghum grain is not marketed but consumed on the farm, especially in Ethiopia (*Table 7.1*). Overall, 34% is marketed. A greater proportion is marketed in Rwanda and Uganda than in other countries. Relatively more of the sorghum produced in the Tigrain Lowlands, where production is relatively large-scale and mechanized, is marketed than elsewhere in Ethiopia (*Map 7.1*). Seventy percent or more of the grain produced in the Karamoja and the Central and Western SPAs in Uganda is marketed, presumably to be used for brewing in urban areas.

Table 7.1. Percent of sorghum grain produced that is marketed in nine countries of eastern and southern Africa.

Country	%
Ethiopia	29
Kenya	30
Malawi	28
Mozambique	24
Rwanda	67
Tanzania	44
Uganda	50
Zambia	28
Zimbabwe	23

Map 7.1. The importance of marketing sorghum in each SPA. Pie chart diameter varies according to the number of sorghum hectares cultivated annually in each sorghum production area.



References

Balole, T.V. and G.M. Legwaila. 2006. Sorghum bicolor (L.) Moench. In: Brink, M. & Belay, G. (Eds.). *Plant Resources of Tropical Africa 1. Cereals and Pulses.* PROTA Foundation, Wageningen, Netherlands / Blackhuys Publishers, Leiden, Netherlands / CTA, Wageningen, Netherlands. Pp 165–175.

Boardman, S. 1999. *The agricultural foundation of the Aksumite Empire, Ethiopia: an interim report.* Pp 137–147. IN *The exploitation of plant resources in ancient Africa.* M. van der Veen (Ed.). Kluwe Academic/Plenum Publishers, New York NY.

Doggett, H. 1988. *Sorghum* (2nd edition). London: Longman. (Tropical Agriculture Series).

FAOSTAT. 2006. (Available at http://faostat.fao.org/ Accessed September 20, 2006.)

Grieser, J. 2002. LocClim 1.0, the FAO local climate estimator. *Environment and Natural Resources Service Working Paper No. 9.* Food and Agriculture Organization. (Available at: www.fao.org/sd/2002/en1203a_en.htm; verified March 27, 2006.

ILRI, 2002. *Agview 2002.* International Livestock Research Institute, Nairobi, Kenya.

Rowley-Conway, P., W. Deakin, and C.H. Shaw. 1999. *Ancient DNA from sorghum: the evidence from Qasr Ibrim, Egyptian Nubia. Pp 55–61. IN The exploitation of plant resources in ancient Africa.* M. van der Veen (Ed.). Kluwe Academic/Plenum Publishers, New York NY.

Young, R. and G. Thompson, 1999. *Missing plant foods? Where is the archaeobotanical evidence for sorghum and finger millet in East Africa? Pp 63–72. IN The exploitation of plant resources in ancient Africa.* M. van der Veen (Ed.). Kluwe Academic/Plenum Publishers, New York NY.

Wasylikowa, K. and J. Dahlberg. 1999. *Sorghum in the economy of the early Neolithic nomadic tribes at Nabta Playa, Southern Egypt. Pp 11–31. IN The exploitation of plant resources in ancient Africa.* M. van der Veen (Ed.). Kluwe Academic/Plenum Publishers, New York NY.

Wortmann, C.S. and C.A. Eledu, 1999. *Uganda's Agroecological Zones: a guide for planners and policy makers.* Centro Internacional de Agricultura Tropical. Kampala, Uganda.

Appendix A. Grain Sorghum Management.

Table A1. Main sowing times expressed as percent of total.

Sorghum production area	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Ethiopia												
Central Rift Valley				33	50	17						
Eastern, >1500 m altitude				50		17	33					
Eastern, <1500 m altitude				33	50	17						
North Central Highlands				50	33	17						
Northeast Mid-altitude				33		34	33					
Tigrain Lowlands					33	50	17					
Southern	33	50	17									
Southwest Lowlands				33	50	17						
Tigrain Highlands				50	33	17						
Western				33	50	17						
Kenya												
Coast			17	33				17	33			
Rift Valley			33	17					50			
West		34	49				17					
East-Central			17	83								
Nyanza	17	33	33				17					
Malawi												
Malawi	17									15	42	25
Mozambique												
Southern	17								8	33	25	17
Northern	33										17	50
Central	33										17	50
Rwanda												
>1800 m	33											67
1500-1800 m	50	33										17
<1500 m	33	50							17			
Tanzania												
Lake Zone	17										50	33
Western	17										33	50
Central	17									33	33	17
Eastern			33	17						33	17	
Southern	33										33	33
North			33	17						33	17	
Southern High	17										33	50

Sorghum production area	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Uganda												
Central and West		17	33					33	17			
Karamoja			17	5	28	28	5	17				
Northern		5	27	23			5	37	3			
Southwest Highlands	50											50
East		10	45	3			9	33				
Zambia												
AEZ I										11	44	45
AEZ II	6									4	26	65
Zimbabwe												
Matabeleland	33	17								8	13	29
Masvingo	33	17								4	17	29
Shonaland, E.	33	17								8	17	25

Table A2. Main harvest times, expressed as percent of total.

Sorghum production area	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Ethiopia												
Central Rift Valley										33	50	17
Eastern, >1500 m altitude											50	50
Eastern, <1500 m altitude										33	50	17
North Central Highlands											50	50
Northeast Mid-altitude										17	33	50
Tigrain Lowlands										50	33	17
Southern					33	50	17					
Southwest Lowlands										17	50	33
Tigrain Highlands											50	50
Western										33	50	17
Kenya												
Coast	17	33				17	33					
Rift Valley		50					33	17				
West							50	33				17
East-Central									17	83		
Nyanza	17						17	50				16
Malawi												
Malawi					19	37	44					
Mozambique												
Southern		17	33	33	17							
Northern			17	33	50							
Central			17	33	50							
Rwanda												
>1800 m							50	50				
1500-1800 m				17	33	33	17					
<1500 m		17					50	33				
Tanzania												
Lake Zone				50	33	17						
Western				50	33	17						
Central					33	33	33					
Eastern			33	17			33	17				
Southern					33	33	33					
North			33	17			33	17				
Southern High						33	50	17				
Uganda												

Sorghum production area	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Central and West	17	5	2			12	33	3			11	17
Karamoja							18	3		8	55	16
Northern					2	3	40			5	10	40
Southwest Highlands						5	45	50				
East	3					12	40	3			4	38
Zambia												
AEZ I					11	39	50					
AEZ II					4	41	56					
Zimbabwe					19	37	44					
Matabeleland			8	50	42							
Masvingo				50	50							
Shonaland, E.			17	50	33							

Table A3. Major crops in intercrop association with grain sorghum and area in sorghum sole crop, expressed as percent of total production hectares in the sorghum production area.

Sorghum production area	Bean	Cassava	Cowpea	Finger millet	Ground-nut	Maize	Pearl millet	Pigeonpea	Sorghum sole crop
Ethiopia									
Central Rift Valley	10					10			80
Eastern, >1500 m altitude	10		5	10					75
Eastern, <1500 m altitude	10		5			10			75
North Central Highlands	10		5	10					75
Northeast Mid-altitude	10			15					75
Tigrain Lowlands	10						10		80
Southern	10					10			80
Southwest Lowlands			10						90
Tigrain Highlands				10					90
Western	10					10			80
Kenya									
Coast	5	25	20			15	10		25
Rift Valley	20	5	25				25		25
West	15	10	15	10		15			35
East-Central	20	5	10	10		10			45
Nyanza	15	5	10	15		25			30
Malawi									
Malawi	17		8	2		45			29
Mozambique									
Southern			30						70
Northern				5		10	4		60
Central						90			10
Rwanda									
>1800 m	0	0	0	0	0	40	0	0	5
1500-1800 m	5	5	0	0	0	5	0	0	50
<1500 m	10	5	0	0	0	25	0	0	40
Tanzania									
Central			20		15	10	5	10	40
Eastern			10			20		20	50
Southern			20			15		10	55
Northern			20		10	5		5	60
Southern Highlands	20		5		10	20			45
Uganda									
Central and West	19			5		4			73

Sorghum production area	Bean	Cassava	Cowpea	Finger millet	Ground-nut	Maize	Pearl millet	Pigeonpea	Sorghum sole crop
Karamoja						6			94
Northern	5	5	12	18	1		4	11	43
Southwest Highlands	27	8		8					57
Eastern	1	1	13	21		8	3		54
Zambia									
AEZ I	25		13						62
AEZ II	33		15	3					48
Zimbabwe	17		8	2		45			29
Matabeleland			38	1		5	8		49
Masvingo			31	9		6	8		46
Shonaland, E.	10		35	3		3	3		48

Appendix B. Constraints to sorghum production expressed as millions of Mg yr annual yield loss.

Table B1. Yield loss to plant diseases.

Sorghum production area	Anthracnose	Charcoal rot	Grain mold	Late blight	Mildew	Nematodes	Rust	Smut
Ethiopia								
Central Rift Valley	6.6	3.3	3.3	3.3	3.3	3.3	6.6	6.6
Eastern, >1500 m altitude	19.1	19.1	19.1	9.5	19.1	9.5	19.1	19.1
Eastern, <1500 m altitude	22.5	15.0	7.5	7.5	15.0	7.5	22.5	22.5
North Central Highlands	40.4	40.4	40.4	40.4	40.4	40.4	80.9	80.9
Northeast Mid-altitude	61.8	61.8	61.8	30.9	61.8	30.9	61.8	92.6
Tigrain Lowlands	34.0	17.0	17.0	17.0	17.0	17.0	42.5	42.5
Southern	14.8	7.4	7.4	7.4	7.4	7.4	14.8	14.8
Southwest Lowlands	12.9	12.9	38.6	12.9	12.9	12.9	12.9	32.2
Tigrain Highlands	2.8	2.8	2.8	2.8	2.8	2.8	5.6	5.6
Western	16.7	11.2	11.2	11.2	11.2	11.2	22.3	22.3
Kenya								
Coast	0.6	0.0	0.2	1.2	0.0	0.0	0.4	0.8
Rift Valley	0.8	0.8	0.3	0.8	1.1	0.1	0.6	2.2
West	2.4	1.2	0.6	1.8	0.1	0.1	1.8	1.2
East-Central	1.9	5.8	9.7	3.9	3.9	0.4	7.8	3.9
Nyanza	9.7	0.5	9.7	12.1	0.5	0.5	4.8	4.8
Malawi								
Malawi	13.7	0.6	17.0	0.6	2.7	1.7	5.7	1.2
Mozambique								
Southern	0.3	0.3	3.0	0.3	9.0	0.3	10.6	0.3
Northern	1.6	1.6	70.8	1.6	15.7	1.6	70.8	1.6
Central	1.8	1.8	26.6	1.8	17.7	1.8	53.1	1.8
Rwanda								
>1800 m	8.0	0.0	6.0	0.0	0.0	0.5	2.0	0.0
1500-1800 m	2.9	0.0	0.7	5.9	5.9	2.9	5.9	14.7
<1500 m	5.0	1.2	0.3	12.5	2.5	2.5	10.0	5.0
Tanzania								
Lake Zone	1.0	4.8	23.8	19.0	4.8	1.0	4.8	28.5
Western	0.1	0.7	2.1	1.4	0.7	0.1	0.7	3.5
Central	1.3	1.3	19.1	19.1	6.4	1.3	6.4	38.3
Eastern	3.1	1.5	4.6	3.1	1.5	0.3	1.5	6.1
Southern	5.0	0.5	7.5	7.5	5.0	0.5	2.5	10.1
Northern	0.2	0.2	3.5	3.5	1.2	0.2	0.2	7.0
Southern Highlands	0.7	3.5	10.6	7.1	3.5	0.7	3.5	17.6

Sorghum production area	Anthracnose	Charcoal rot	Grain mold	Late blight	Mildew	Nematodes	Rust	Smut
Uganda								
Central and West	6.1	3.6	4.4	1.6	0.8	0.8	2.4	6.1
Karamoja	4.7	1.5	4.0	1.5	1.1	0.7	2.9	5.8
Northern	13.4	3.2	21.0	8.9	6.4	2.5	13.4	22.9
Southwest Highlands	2.5	0.3	1.9	0.3	0.3	0.3	0.3	6.3
Eastern	6.0	0.3	4.3	0.9	1.7	0.3	1.7	6.2
Zambia								
AEZ I	0.6	1.3	4.1	0.2	1.3	2.5	0.9	8.2
AEZ II	6.9	0.2	6.6	0.2	0.0	0.7	0.7	0.5
Zimbabwe								
Matabeleland	1.4	2.8	0.7	2.8	1.4	2.8	4.9	3.5
Masvingo	1.1	2.1	0.5	2.1	1.1	3.2	4.7	1.6
Shonaland, E.	0.7	1.4	1.4	2.0	1.4	0.7	1.4	1.0

Table B2. Yield loss to insect pests.

Sorghum production area	Army worm	Aphid	Cut worm	Stem borer				Chafer grub	Grasshopper/ locust	Midge	Shootfly
				B. fusca	C. partellus	Other	Total				
Ethiopia											
Central Rift Valley	6.6	3.3	6.6	6.6	9.9	0.3	16.8	9.9	6.6	6.6	9.9
Eastern, >1500 m altitude	19.1	9.5	19.1	28.6	28.6	1.0	58.2	38.2	19.1	28.6	28.6
Eastern, <1500 m altitude	15.0	15.0	15.0	15.0	22.5	0.7	38.2	15.0	15.0	15.0	22.5
North Central Highlands	121.3	80.9	80.9	80.9	40.4	40.4	161.7	121.3	80.9	80.9	80.9
Northeast Mid-altitude	92.6	30.9	30.9	61.8	123.5	3.1	188.4	92.6	61.8	61.8	92.6
Tigrain Lowlands	42.5	34.0	25.5	34.0	84.9	1.7	120.6	67.9	51.0	34.0	42.5
Southern	22.2	7.4	14.8	14.8	29.6	0.7	45.1	14.8	7.4	14.8	22.2
Southwest Lowlands	19.3	12.9	12.9	12.9	38.6	1.3	52.8	25.7	12.9	25.7	25.7
Tigrain Highlands	5.6	2.8	5.6	5.6	2.8	2.8	11.2	5.6	2.8	5.6	8.4
Western	33.5	16.7	22.3	22.3	27.9	6.1	56.3	27.9	16.7	22.3	27.9
Kenya											
Coast	0.4	0.2	0.4	0.6	0.6	1.2	2.3	0.0	0.0	0.4	2.0
Rift Valley	0.6	0.3	0.8	0.6	0.8	1.4	2.8	0.1	0.1	1.1	1.7
West	1.2	1.2	0.6	1.2	2.4	3.0	6.5	0.1	0.1	2.4	3.6
East-Central	3.9	5.8	1.9	1.9	1.9	3.9	7.8	0.4	0.4	5.8	7.8
Nyanza	4.8	0.5	9.7	2.4	2.4	12.1	16.9	0.5	0.5	7.3	36.3
Malawi											
Malawi	0.6	1.7	1.2	0.6	4.4	15.2	20.2	5.8	5.5	0.3	2.7
Mozambique											
Southern	0.3	0.3	0.3	0.3	3.0	3.8	7.1	6.0	0.3	0.3	3.0
Northern	1.6	1.6	1.6	1.6	15.7	15.7	33.0	31.5	1.6	1.6	23.6
Central	1.8	1.8	1.8	1.8	26.6	17.7	46.1	35.4	1.8	1.8	17.7
Rwanda											
>1800 m	0.5	0.0	0.5	2.0	0.5	2.0	4.5	0.5	0.5	0.5	4.0
1500-1800 m	0.7	2.9	0.7	0.7	0.7	17.6	19.1	0.7	8.8	0.7	17.6
<1500 m	0.3	2.5	0.3	0.3	12.5	0.0	12.8	0.3	2.5	0.3	12.5
Tanzania											
Lake Zone	9.5	14.3	1.0	19.0	19.0	19.0	57.0	1.0	1.0	23.8	19.0
Western	1.4	2.1	0.1	0.1	0.1	2.8	3.1	0.1	0.1	1.4	1.4
Central	19.1	12.8	6.4	12.8	12.8	31.9	57.4	1.3	6.4	12.8	6.4
Eastern	4.6	3.1	1.5	0.3	0.3	9.2	9.8	0.3	0.3	1.5	3.1
Southern	5.0	7.5	2.5	0.5	0.5	15.1	16.1	0.5	0.5	5.0	2.5
Northern	3.5	2.3	1.2	2.3	2.3	5.9	10.6	0.2	1.2	2.3	1.2
Southern Highlands	7.1	10.6	0.7	0.7	0.7	14.1	15.5	0.7	0.7	7.1	7.1

Sorghum production area	Army worm	Aphid	Cut worm	Stem borer				Chafer grub	Grasshopper/ locust	Midge	Shootfly
				B. fusca	C. partellus	Other	Total				
Uganda											
Central and West	1.6	1.2	4.4	5.3	10.1	10.1	25.5	0.4	0.4	9.3	12.1
Karamoja	2.2	1.5	2.9	2.6	7.3	5.1	14.9	0.4	1.5	5.5	12.4
Northern	7.6	5.1	9.5	8.3	20.3	33.1	61.7	1.3	8.9	15.3	32.4
Southwest Highlands	0.3	3.1	1.3	1.6	5.3	4.4	11.3	0.3	0.3	6.6	9.7
Eastern	1.9	0.5	1.1	3.6	5.3	8.4	17.2	0.2	0.6	5.9	9.8
Zambia							0.0				
AEZ I	0.2	0.9	1.3	0.2	2.5	9.4	12.1	0.2	2.5	1.3	0.6
AEZ II	0.2	0.7	0.5	0.2	0.2	6.4	6.8	0.2	2.7	0.0	0.0
Zimbabwe											
Matabeleland	2.8	4.9	3.5	8.3	7.6	7.6	23.6	1.4	2.1	4.2	6.2
Masvingo	2.1	5.3	4.7	3.7	6.3	4.7	14.7	1.1	1.1	1.6	4.7
Shonaland, E.	0.7	1.0	1.0	1.7	2.0	2.6	6.3	0.3	0.3	0.7	1.7

Table B3. Yield loss to other biotic constraints.

Sorghum production area	Domestic animals	Wildlife	Birds, other	Quela	Striga	Theft	Weeds
Ethiopia							
Central Rift Valley	3.3	0.3	3.3	16.5	0.3	0.3	6.6
Eastern, >1500 m altitude	1.0	1.0	1.0	28.6	38.2	1.0	28.6
Eastern, <1500 m altitude	0.7	0.7	0.7	30.0	30.0	0.7	22.5
North Central Highlands	4.0	4.0	40.4	121.3	161.7	4.0	121.3
Northeast Mid-altitude	3.1	3.1	30.9	123.5	154.4	3.1	92.6
Tigrain Lowlands	1.7	17.0	17.0	67.9	101.9	1.7	51.0
Southern	0.7	7.4	7.4	29.6	22.2	0.7	14.8
Southwest Lowlands	12.9	38.6	12.9	64.3	1.3	1.3	38.6
Tigrain Highlands	2.8	0.3	0.3	5.6	11.2	2.8	8.4
Western	1.1	6.1	11.2	39.0	39.0	1.1	27.9
Kenya							
Coast	0.2	0.4	2.0	2.0	2.3	0.2	1.6
Rift Valley	0.3	1.1	1.7	2.8	0.1	0.1	0.8
West	0.6	0.6	3.6	4.7	9.5	0.1	3.0
East-Central	3.9	9.7	15.5	29.1	3.9	0.4	19.4
Nyanza	7.3	2.4	24.2	24.2	36.3	2.4	12.1
Malawi							
Malawi	5.1	3.1	32.3	5.1	6.5	1.2	31.6
Mozambique							
Southern	0.3	0.3	34.7	0.3	0.3	0.3	10.6
Northern	1.6	1.6	236.0	1.6	1.6	1.6	78.7
Central	1.8	1.8	203.7	1.8	1.8	1.8	88.6
Rwanda							
>1800 m	4.0	22.4	21.9	0.0	0.0	0.0	15.9
1500-1800 m	14.7	5.9	14.7	0.0	44.0	5.9	29.3
<1500 m	2.5	2.5	5.0	0.0	13.7	0.0	5.0
Tanzania							
Lake Zone	1.0	9.5	28.5	28.5	61.8	1.0	47.5
Western	0.1	0.7	7.0	7.0	8.4	0.1	7.7
Central	6.4	19.1	57.4	76.6	51.0	1.3	76.6
Eastern	3.1	3.1	15.3	15.3	12.2	0.3	23.0
Southern	0.5	7.5	30.2	25.2	20.1	0.5	35.2
Northern	1.2	3.5	10.6	14.1	9.4	0.2	14.1
Southern Highlands	0.7	3.5	35.3	35.3	42.3	0.7	38.8

Sorghum production area	Domestic animals	Wildlife	Birds, other	Quela	Striga	Theft	Weeds
Uganda							
Central and West	4.0	6.1	19.4	15.8	17.8	3.2	20.2
Karamoja	7.7	1.8	8.4	8.4	13.9	4.7	10.6
Northern	19.7	3.8	15.3	23.5	65.5	6.4	40.7
Southwest Highlands	1.3	0.3	6.9	4.4	0.3	0.3	16.6
Eastern	3.3	0.9	4.8	9.0	21.1	1.1	11.8
Zambia							
AEZ I	1.3	3.8	4.4	5.0	6.0	0.6	9.1
AEZ II	2.5	1.5	7.9	2.5	3.2	0.5	8.6
Zimbabwe							
Matabeleland	9.7	20.8	16.6	36.8	22.9	6.2	10.4
Masvingo	7.9	14.7	13.7	30.5	21.6	5.3	8.4
Shonaland, E.	2.4	4.7	4.7	9.8	5.8	1.0	4.7

Table B4. Yield loss to soil fertility and soil water constraints.

Sorghum production area	Acid soil	Nutrient deficiencies				Salinity	Water deficits		
		N	P	K	Other		Early	Mid-season	Late
Ethiopia									
Central Rift Valley	0.3	9.9	6.6	0.3	0.3	0.3	9.9	3.3	6.6
Eastern, >1500 m altitude	1.0	28.6	9.5	1.0	1.0	1.0	19.1	1.0	28.6
Eastern, <1500 m altitude	0.7	22.5	15.0	0.7	0.7	0.7	22.5	7.5	15.0
North Central Highlands	4.0	161.7	40.4	4.0	40.4	4.0	80.9	40.4	121.3
Northeast Mid-altitude	3.1	3.1	3.1	3.1	3.1	3.1	92.6	3.1	61.8
Tigrain Lowlands	1.7	1.7	1.7	1.7	1.7	1.7	17.0	17.0	17.0
Southern	0.7	22.2	7.4	0.7	7.4	0.7	14.8	7.4	14.8
Southwest Lowlands	12.9	38.6	25.7	1.3	25.7	6.4	12.9	12.9	12.9
Tigrain Highlands	0.3	11.2	5.6	0.3	2.8	0.3	2.8	5.6	8.4
Western	1.1	39.0	11.2	1.1	11.2	1.1	22.3	11.2	27.9
Kenya									
Coast	0.0	1.6	1.0	0.0	0.0	0.6	0.0	1.2	0.4
Rift Valley	0.1	1.7	1.4	0.1	0.1	0.6	0.1	2.2	1.4
West	0.1	7.7	4.7	0.1	0.6	1.2	0.1	1.2	0.6
East-Central	0.4	11.7	5.8	0.4	0.4	3.9	0.4	11.7	5.8
Nyanza	0.5	14.5	12.1	0.5	0.5	4.8	0.5	12.1	2.4
Malawi									
Malawi	5.7	40.9	29.2	13.6	0.6	0.3	7.2	7.2	17.2
Mozambique									
Southern	0.3	22.6	10.6	7.5	0.3	0.3	18.1	27.1	19.6
Northern	1.6	118.0	62.9	23.6	1.6	1.6	78.7	118.0	94.4
Central	1.8	132.8	106.3	35.4	1.8	1.8	79.7	97.4	132.8
Rwanda									
>1800 m	22.4	23.9	19.9	11.9	0.5	0.0	19.9	25.9	10.0
1500-1800 m	14.7	11.7	11.7	11.7	0.7	0.0	8.8	17.6	5.9
<1500 m	5.0	7.5	7.5	5.0	0.3	0.0	5.0	10.0	5.0
Tanzania									
Lake Zone	1.0	71.3	47.5	1.0	1.0	4.8	14.3	28.5	9.5
Western	0.1	10.5	5.6	0.7	0.1	1.4	2.1	7.0	1.4
Central	1.3	82.9	38.3	6.4	1.3	6.4	31.9	63.8	12.8
Eastern	3.1	19.9	12.2	3.1	0.3	0.3	4.6	9.2	3.1
Southern	0.5	35.2	20.1	5.0	0.5	5.0	10.1	7.5	5.0
Northern	0.2	15.3	7.0	1.2	0.2	1.2	5.9	11.7	2.3
Southern Highlands	0.7	52.9	28.2	3.5	0.7	7.1	10.6	35.3	7.1

[1] **N = nitrogen, P = phosphorus and K = potassium**

Sorghum production area	Acid soil	Nutrient deficiencies				Salinity	Water deficits		
		N	P	K	Other		Early	Mid-season	Late
Uganda									
Central and West	1.2	13.3	10.5	7.3	5.7	1.6	4.4	8.5	5.7
Karamoja	0.4	10.2	6.2	4.7	0.4	0.4	6.9	12.8	3.3
Northern	0.6	30.5	15.9	5.7	3.8	0.6	14.6	17.2	10.2
Southwest Highlands	0.3	17.5	6.9	3.8	7.2	0.3	6.9	11.6	6.9
Eastern	0.3	9.8	5.6	1.1	0.5	0.2	4.0	8.7	4.3
Zambia									
AEZ I	2.5	13.8	6.6	5.3	0.3	0.0	1.3	2.8	9.7
AEZ II	6.6	10.6	6.6	4.2	0.2	0.0	1.2	2.5	0.2
Zimbabwe									
Matabeleland	0.7	27.0	4.2	4.2	4.9	2.1	18.0	21.5	30.5
Masvingo	1.6	19.5	3.2	2.6	3.2	1.1	10.0	15.8	24.7
Shonaland, E.	0.2	5.4	2.6	1.0	1.0	0.0	1.0	1.0	3.4

[1] N = nitrogen, P = phosphorus and K = potassium

Table B5. Yield loss to other abiotic constraints.

Sorghum production area	Cold	Crusting	Flooding	Heat	Low radiation	Root barriers	Wind
Ethiopia							
Central Rift Valley	0.3	6.6	0.3	9.9	0.3	0.3	6.6
Eastern, >1500 m altitude	1.0	19.1	1.0	1.0	1.0	1.0	28.6
Eastern, <1500 m altitude	0.7	0.7	0.7	0.7	0.7	0.7	15.0
North Central Highlands	4.0	80.9	4.0	40.4	40.4	4.0	80.9
Northeast Mid-altitude	3.1	61.8	3.1	61.8	3.1	3.1	30.9
Tigrain Lowlands	1.7	1.7	1.7	51.0	1.7	1.7	34.0
Southern	0.7	14.8	0.7	14.8	0.7	0.7	14.8
Southwest Lowlands	1.3	25.7	25.7	38.6	1.3	1.3	19.3
Tigrain Highlands	5.6	5.6	0.3	0.3	5.6	2.8	5.6
Western	1.1	22.3	1.1	16.7	6.1	1.1	22.3
Kenya							
Coast	0.0	0.2	0.4	0.6	0.0	0.2	0.0
Rift Valley	0.8	0.8	0.8	2.2	0.1	0.1	0.3
West	0.1	1.8	3.0	1.8	0.1	1.2	0.6
East-Central	15.5	3.9	0.4	9.7	0.4	1.9	3.9
Nyanza	9.7	2.4	2.4	2.4	0.5	0.5	2.4
Malawi							
Malawi	0.6	0.6	7.9	0.6	1.2	0.3	0.6
Mozambique							
Southern	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Northern	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Central	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Rwanda							
>1800 m	2.0	0.0	0.0	0.0	0.0	2.0	11.9
1500-1800 m	0.0	14.7	5.9	0.0	0.0	2.9	29.3
<1500 m	0.0	2.5	0.3	1.2	0.0	0.0	5.0
Tanzania							
Lake Zone	1.0	4.8	1.0	1.0	1.0	1.0	1.0
Western	0.1	2.1	0.1	0.1	0.1	0.1	0.1
Central	1.3	12.8	1.3	1.3	1.3	12.8	1.3
Eastern	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Southern	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Northern	0.2	2.3	0.2	0.2	0.2	2.3	0.2
Southern Highlands	0.7	10.6	0.7	0.7	0.7	0.7	0.7

Sorghum production area	Cold	Crusting	Flooding	Heat	Low radiation	Root barriers	Wind
Uganda							
Central and West	0.4	0.4	1.6	8.5	0.4	0.8	1.6
Karamoja	0.3	2.2	1.1	0.3	0.3	1.8	2.2
Northern	0.9	0.9	2.5	4.5	0.9	7.6	6.4
Southwest Highlands	5.0	1.9	0.3	0.3	0.3	4.1	2.2
Eastern	0.2	0.2	0.5	0.2	0.2	1.9	0.2
Zambia							
AEZ I	0.2	0.2	1.3	1.9	0.0	0.0	0.2
AEZ II	0.2	0.2	3.9	0.2	0.5	0.0	0.2
Zimbabwe							
Matabeleland	11.8	0.7	2.4	9.0	0.0	2.8	3.5
Masvingo	3.7	0.5	1.3	11.0	0.0	0.0	2.1

Appendix C. Sorghum phenotypic preferences.

Table C1. Importance to producers of phenotypic preferences in cultivar choice. A larger score indicates more importance; no score indicates minor or no importance.

Sorghum production area	Grain color				Grain size, 100 seed		Panicle type			Panicle positioning	
	Brown	Red	Tan	White	<3g	>3g	Loose	Semi-compact	Compact	Crooked	Erect
Ethiopia											
Central Rift Valley	3		5			2		5	4		3
Eastern, >1500 m altitude	3		4			2	3		3	3	2
Eastern, <1500 m altitude			6			4		5			
North Central Highlands			2			2	4	2			3
Northeast Mid-altitude	3		4			2	3			3	
Tigrain Lowlands					2				6		3
Southern	3		5			3		5	3		3
Southwest Lowlands			5			5			3		
Tigrain Highlands					2	2	6				4
Western	3		5			3		5	3		3
Kenya											
Coast	3	1		3	2	1	1	2	1		2
Rift Valley	2	1		4	1	3	1	2	1		3
West	3	4		1	1		1	1	3	2	1
East-Central	1	2		2	1	2	2	1	1	1	2
Nyanza	4	2		1	2		4	1	1	1	2
Malawi											
Malawi	1	1		4		2	3	1	1		2
Mozambique											
Southern	1			3		6	3		5		
Northern	1			3		6	3		5		
Central	1			3		6	3		5		
Rwanda											
>1800 m		7		2		2	1	3	1	1	3
1500-1800 m	2	4	1	1		2		3			2
<1500 m	1	3		2	2	2	1	1	2	1	3
Tanzania											
Lake Zone	1	3		2		3	2	2	1	2	2
Western	1	3		2	1	2	3		3	1	3
Central	3			2	1	2	2	2	1	1	3

Sorghum production area	Grain color				Grain size, 100 seed		Panicle type			Panicle positioning	
	Brown	Red	Tan	White	<3g	>3g	Loose	Semi-compact	Compact	Crooked	Erect
Eastern	1	1	1	3		2	3	1	2		3
Southern	1	1	2	4		3	2	1	1	2	2
Northern	3			2		3	2	2		1	2
Southern Highlands	3	1		2		2	3	2			3
Uganda											
Central and West		4		6		4	1	1	2	1	1
Karamoja	2	3	1	1	1	4	1		3	2	1
Northern	1	4		1		3	3		1	1	
Southwest Highlands	2	2	2	1		3	2	2		1	
Eastern	3	3	2	1		3	1	1	3	1	1
Zambia											
AEZ I		2		6			2	2			1
AEZ II		1		5		2	1	3			3
Zimbabwe											
Matabeleland	1	1		4		1	1	1	2	1	1
Masvingo	1	1		3		1	1	2	2	1	1
Shonaland, E.	1	2		4		2	1	1	2	1	1

Table C2. Importance to producers of phenotypic preferences in cultivar choice. A larger score indicates more importance; no score indicates minor or no importance.

Sorghum production area	Photoperiod		Plant height			Seed tannin		Endosperm texture	Thresh-ability
	Insens.	Sens.	<1.5 m	> 2m	1.5-2 m	High	Low		
Ethiopia									
Central Rift Valley					6				2
Eastern, >1500 m altitude				7					
Eastern, <1500 m altitude	4				6		2		3
North Central Highlands	4	3		7	3				
Northeast Mid-altitude				7	3		2		3
Tigrain Lowlands	2				6		4		2
Southern					6				2
Southwest Lowlands	3				5		6		3
Tigrain Highlands	3	4		7		2			
Western					6				2
Kenya									
Coast				1	2	1	2	4	3
Rift Valley				1	2	1	2	3	2
West				2	1	3	1	2	3
East-Central				1	2	1	3	3	3
Nyanza				3	1	2	1	2	2
Malawi									
Malawi	2	2	2	4	5	1		1	1
Mozambique									
Southern	3		3	3	3				
Northern	3		3	3	3				
Central	3		3	3	3				
Rwanda									
>1800 m			1	1	5	4	2		
1500-1800 m			1	2	4	4	3		
<1500 m			1	1	2	2	1	1	1
Tanzania									
Lake Zone			2	2	1	3	1	1	2
Western			1	2	3	2	1		2
Central			1	3	3	2	2		2
Eastern				3	3	1	2	2	2
Southern				1	3	1	2	2	2
Northern			2	2	3	2	2	2	2
Southern Highlands			2	3	3	2	2		2

Sorghum production area	Photoperiod		Plant height			Seed tannin		Endosperm texture	Thresh-ability
	Insens.	Sens.	<1.5 m	> 2m	1.5-2 m	High	Low		
Uganda									
Central and West	1		1	1	2	2		2	3
Karamoja			2	2	1	1	4	1	3
Northern				4	4			1	3
Southwest Highlands				3	3	3		2	4
Eastern			4		2	1	2	1	3
Zambia									
AEZ I	1	3	2	1	4	3		3	1
AEZ II	3	1		1	4	3		2	2
Zimbabwe									
Matabeleland	1		4	0	2	3		1	3
Masvingo	1		4	1	1	3		1	3
Shonaland, E.	1		4	1	2	2		1	3

Appendix C. Sorghum utilization and cultivar phenotypic preferences.

Table C1. Major uses of sorghum as percent of total value given to the crop.

Sorghum production area	Brew-ing	Bak-ing	Boiled-grain	Njera	Boiled flour	Pop-ing	Bever-age[1]	Build-ing	Grain, animal	Fodder, animal[2]	Fuel	Mulch3
Ethiopia												
Central Rift Valley	17	10		13	10	3	3	10		16	13	3
Eastern, >1500 m altitude	13	13	7	20		7	7	10		10	10	3
Eastern, <1500 m altitude	13	7	7	23	7			10		20	13	
North Central Highlands	13	13	7	20	3	7		10		13	10	3
Northeast Mid-altitude	13	13	7	20		7	7	10		10	10	3
Tigrain Lowlands	13	7	7	23	7	7	7	10	3	7	7	3
Southern	10		7	20	7	10	3	13		13	13	3
Southwest Lowlands	10		10	10	17		10	17		10	13	3
Tigrain Highlands	13	13	7	20	3	7		7	10	10	10	
Western	12	7	7	20	5	8	2	12		14	12	3
Kenya												
Coast	13				17		27	7	7	10	7	14
Rift Valley	13	3			17		23	3	7	13	10	10
West	17				27		20	3	7	10	10	6
East-Central	20				20		17	3	7	23	3	6
Nyanza	13	3			23		17	7	7	10	13	6
Malawi												
Malawi	35		7		26		23	3	3	1	2	
Mozambique												
Southern	15				67		7	7	2	2		
Northern	25				55	3	12	3	2			
Central	29				49		12	8	2			
Rwanda												
>1800 m	40				10		40	13	3	17		10
1500-1800 m	17	3	3		27		20	3			3	
<1500 m	21				16		20	3	3			7
Tanzania												
Lake Zone	6		2		11			3	1	3	3	1
Western	7				10		2	3	1	3	2	2
Central	8				11		2			6	2	1
Eastern	10				6		2	2		3	1	3
Southern	6		6		9			3	1	1	2	2
Northern	7				10		2	3	1	3	2	2
Southern Highlands	9				12		1	1		1	2	4

Sorghum production area	Brewing	Baking	Boiled-grain	Njera	Boiled flour	Popping	Beverage[1]	Building	Grain, animal	Fodder, animal[2]	Fuel	Mulch[3]
Uganda												
Central and West	65				5			1	1	7	7	15
Karamoja	32		14		36			4		8	7	
Northern	31				41			8		8	6	3
Southwest Highlands	46				11		19	11		4	4	4
Eastern	21				50		1	5		11	6	6
Zambia												
AEZ I	19		7		39		18	11		7	2	
AEZ II	19		9		48		13	1	1	1	2	
Zimbabwe												
Matabeleland	18	2	2		34	2	7	3	2	18	4	2
Masvingo	24	1	4		35		5	4	4	21	2	2
Shonaland, E.	25		3		30		3		8	23		

[1]Beverage refers to non-alcoholic beverages, or at least beverages of very low alcohol content.
[2]Fodder for livestock includes feeding of green leaves and of stover.
[3]Mulch includes crop residues: used to mulch coffee, banana or another crop; used in thrash barriers for erosion control; or used *in situ* for ground cover.