International Center for Agricultural Research in the Dry Areas
ICARDA

Poverty Assessment and Mapping in Sudan Part 3

Poverty Assessment in Sudan: Mapping natural resource potential

Eddy De-Pauw, Weicheng Wu

Agricultural Economics and Policy Research Centre (AEPRC),
Agricultural Research Corporation (ARC), Sudan

Poverty Assessment in Sudan Mapping natural resource potential

Citation:
Eddy De-Pauw, Weicheng Wu 2012. Poverty Assessment in Sudan Mapping natural resource potential. ICARDA, Aleppo, Syria. vi + 33 pp.

ISBN: 92-9127-263-9

International Center for Agricultural Research in the Dry Areas (ICARDA) P.O.Box 5466, Aleppo, Syria
Tel: +963 21 2213433, 2213477, 2225012 E – mail: icarda@cgiar.org Website: www.icarda.org

Contents

EXECUTIVE SUMMARY

Mapping of agricultural resource potential of North and Southern Sudan – Part 3.

Sudan Rural Poverty Analysis

This is Part 3 of a study, presented in three reports that detail the results of a poverty assessment and mapping project in North and Southern Sudan. The study's objective was to produce a rural poverty analysis and poverty maps for North and Southern Sudan, and based on these findings, recommend agricultural interventions that can help reduce poverty.
These findings provided an input to the IFAD Sudan Country Program 2007–2012, that takes into consideration the new constitutional changes in Sudan resulting from the peace agreements with South/ East/West Sudan and to support peace, security and stability in Sudan.

- o Poverty assessment in Northern Sudan – Part 1
- o Poverty assessment in Southern Sudan – Part 2
- o Mapping of agricultural resource potential of North and Southern Sudan – Part 3.

Mapping of agricultural resource potential of North and Southern Sudan This section provides detailed maps of different agro – ecological, climatic, and soil indices. These have been combined into agricultural resource potential indices.

Key findings of the assessment: General state of the economy and agriculture

Sudan's economic structure has undergone a major shift over the past two decades (DTIS 2008), the main drivers of this change are the discovery of oil in the early 2000s and the expansion in services dominated by telecommunications, transport, and construction. Agriculture used to be the leading economic sector, forming typically more than 40% of GDP, but has lost much ground with a drop of its GDP share to 33% in 2007. A more dramatic trend has been the deterioration in the contribution of agriculture to the country's exports, declining to some 3% in 2007 down from an average of 74% in the 1996–1998 period. Both the relative share and the absolute value of agricultural exports has declined. Data from the Central Bank of Sudan reveals an annual trend value of $71,500.

Both income poverty and general human poverty are concerns for North and Southern Sudan. There is considerable deprivation in education and health, and poor households are particularly disadvantaged. Yet, despite the current fragile situation of Sudan's agriculture, this study found that the countries have enormous potential to raise crop yields by bridging at least part of its current 'yield gaps' – between actual and potential food production. These vary from 46% to as high as 566% between on – farm trials and prevailing commercial productivity. Irrigated crops can be improved by margins ranging from about 50% to > 140%. Even higher yield potential have been identified for rainfed crops – where potential margins ranged from twofold to over fivefold.

Prerequisites for achieving these levels of development and macroeconomic stability require an ambitious development plan that includes: creation of a sound financial system and an efficient federal system through more decentralization, coupled with adequate financial and technical resources and participatory mechanisms, and the just income and wealth distribution.

Northern Sudan assessment: Key findings and recommendations

(see Part 1) The results of the Northern Sudan Poverty Assessment show higher rural than urban poverty, in the six regions studied. This rural–urban disparity was mainly due to the rural–urban differences in food compositions and food prices. However, in absolute terms the number of rural poor was greater than of urban poor. Higher poverty incidence in rural areas is a due to chronic low productivity and low income in rural areas.

A targeting procedure conducive to poverty reduction in the Sudan is proposed in a chart (see the recommendation at the end of the Northern Sudan report), which suggests priority agricultural interventions in the 10 states with both highest income poverty and human poverty levels.

Southern Sudan Study – Key findings and recommendations (Part 2)

The survey estimates income poverty incidence at 99.6% in the states of Eastern Equatoria State, 88.6% in the Lakes State, and 54.0% in Central Equatoria State. The situation was especially serious in Eastern Equatoria and Lakes States. The study also showed acute shortfalls of the required caloric intake for about a third of both Eastern Equatoria and Central Equatoria States. Some 60% of the population in Lakes State faces a shortfall in the required daily caloric food intake.

This is an indication of deep poverty among a sizeable portion of the population. Lakes State had the lowest per capita income from both agricultural and non-agricultural sources. In all states, poverty was lower when expenditure estimates were used than when income estimates were used. This is a common feature in poverty analysis, and it is generally believed that expenditures are more easily recalled than incomes, but the ranking of relative poverty by province did not change.

To address this acute situation a set of 14 recommendations is proposed. The government will need to implement a long – term poverty reduction strategy that takes a broad perspective – focusing on strengthening its institutions, developing and implementing policies and legislation, investing in related areas of research and infrastructure to link rural communities to economic centers building capacity, systems, and structures for delivering services in the areas of health, education, and clean water. Actions for donors and other partners such as the private sector are also specified.

MAPPING AGRICULTURAL RESOURCE POTENTIAL OF SUDAN

Eddy De Pauw and Weicheng Wu

The maps listed in the following paragraphs have been prepared as part of the project. Each of these maps helps to characterize the potential and risks related to the natural resource base for agriculture in the different States of Sudan.

1. AGROCLIMATIC ZONES

A classification of climates in accordance with the UNESCO classification for the arid zones provides evidence that the climates of Sudan are very diverse, and differ mainly in their moisture characteristics, and less in their temperature regime. The explanation of the different climates is given in (Fig. 1), the agro climatic zones map is shown in (Fig. 2).

Agroclimatic zones

Symbol	Moisture regime	Aridity index	Winter temperature Regime	Winter temperature Range	Summer temperature Regime	Summer temperature Range
HA-W-VW	Hyper-arid	< 0.03	Warm	20° - 30°C	Warm	20° - 30°C
HA-M-VW	Hyper-arid	< 0.03	Mild	10° - 20°C	Very warm	> 30°C
HA-M-W	Hyper-arid	< 0.03	Mild	10° - 20°C	Warm	20° - 30°C
A-W-VW	Arid	0.03 - 0.2	Warm	20° - 30°C	Very warm	> 30°C
A-W-W	Arid	0.03 - 0.2	Warm	20° - 30°C	Warm	20° - 30°C
A-M-VW	Arid	0.03 - 0.2	Mild	10° - 20°C	Very warm	> 30°C
A-M-W	Arid	0.03 - 0.2	Mild	10° - 20°C	Warm	20° - 30°C
A-C-W	Arid	0.03 - 0.2	Cool	0° - 10°C	Warm	20° - 30°C
SA-W-VW	Semi-arid	0.2 - 0.5	Warm	20° - 30°C	Very warm	> 30°C
SA-W-W	Semi-arid	0.2 - 0.5	Warm	20° - 30°C	Warm	20° - 30°C
SA-M-W	Semi-arid	0.2 - 0.5	Mild	10° - 20°C	Warm	20° - 30°C
SA-M-M	Semi-arid	0.2 - 0.5	Mild	10° - 20°C	Mild	10° - 20°C
SA-C-W	Semi-arid	0.2 - 0.5	Cool	0° - 10°C	Warm	20° - 30°C
SA-C-M	Semi-arid	0.2 - 0.5	Cool	0° - 10°C	Mild	10° - 20°C
SH-W-VW	Sub-humid	0.5 - 0.75	Warm	20° - 30°C	Very warm	> 30°C
SH-W-W	Sub-humid	0.5 - 0.75	Warm	20° - 30°C	Warm	20° - 30°C
SH-M-W	Sub-humid	0.5 - 0.75	Mild	10° - 20°C	Warm	20° - 30°C
SH-M-M	Sub-humid	0.5 - 0.75	Mild	10° - 20°C	Mild	10° - 20°C
SH-C-M	Sub-humid	0.5 - 0.75	Cool	0° - 10°C	Mild	10° - 20°C
H-W-W	Humid	0.75 - 1	Warm	20° - 30°C	Warm	20° - 30°C
H-M-W	Humid	0.75 - 1	Mild	10° - 20°C	Warm	20° - 30°C
H-M-M	Humid	0.75 - 1	Mild	10° - 20°C	Mild	10° - 20°C
PH-M-W	Per-humid	> 1	Mild	10° - 20°C	Warm	20° - 30°C
PH-M-M	Per-humid	> 1	Mild	10° - 20°C	Mild	10° - 20°C
PH-C-M	Per-humid	> 1	Cool	0° - 10°C	Mild	10° - 20°C

Figure1. Legend of the agro climatic zones map

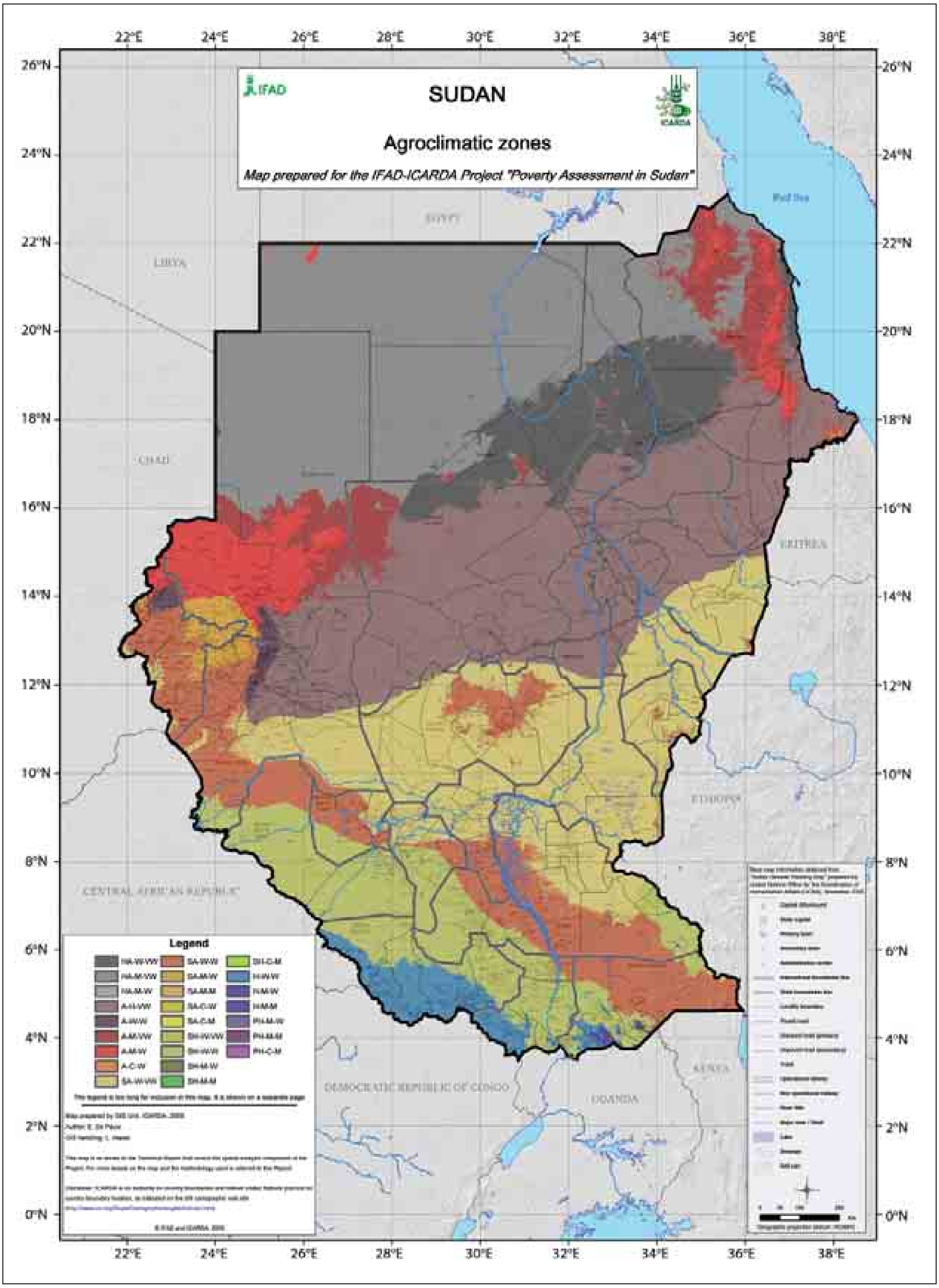


Figure2. Agroclimatic zones map

2. ANNUAL GROWING DEGREE DAYS

The map provides the mean temperature summed over the whole year. This value is an indicator of either the temperature adequacy or constraints for plant biomass production (> 10 000 growing degree – days poses serious risk of heat stress). Generally in Sudan, temperatures are high and do not show much spatial variation, due to Sudan's position within the tropics and the lack of high mountain areas. The distribution of annual growing degree – day classes by state is summarized in (Table 1). The map of annual growing degree days is shown in (Fig. 3).

Table 1: Annual growing degree days: percentage of the states of Sudan in each class

	Growing degree – day classes (°C.days)						
State	**<5000**	**5000 – 6000**	**6000 – 7000**	**7000 – 8000**	**8000 – 9000**	**9000 – 10000**	**10000 – 11000**
White Nile	0	0	0	0	0	0	100
South Kordofan	0	0	0	0	0	44	55
North Kordofan	0	0	0	0	0	48	52
Sennar	0	0	0	0	0	0	100
Red Sea	0	0	0	1	13	51	35
Northern	0	0	0	0	10	52	38
Nile	0	0	0	0	0	15	85
Khartoum	0	0	0	0	0	0	100
Kassala	0	0	0	0	0	1	99
Gedaref	0	0	0	0	0	1	99
Blue Nile	0	0	0	0	1	35	65
Gezira	0	0	0	0	0	0	100
West Darfur	0	0	0	2	27	70	0
South Darfur	0	0	0	1	8	84	8
North Darfur	0	0	0	0	19	80	0
Lakes	0	0	0	0	0	86	14
Bahr El Jabal	0	0	0	0	20	80	1
Eastern Equatoria	0	0	1	3	16	61	19
Upper Nile	0	0	0	0	0	3	97
Western Bahr El Jabal	0	0	0	0	3	97	0
Unity	0	0	0	0	0	2	98
Northern Bahr El Jabal	0	0	0	0	0	100	0
Jonglei	0	0	0	0	2	12	86
Warrab	0	0	0	0	0	43	57
Western Equatoria	0	0	0	0	2	98	0

[Note: in all tables pink color denotes where >10% of the given class occurs]

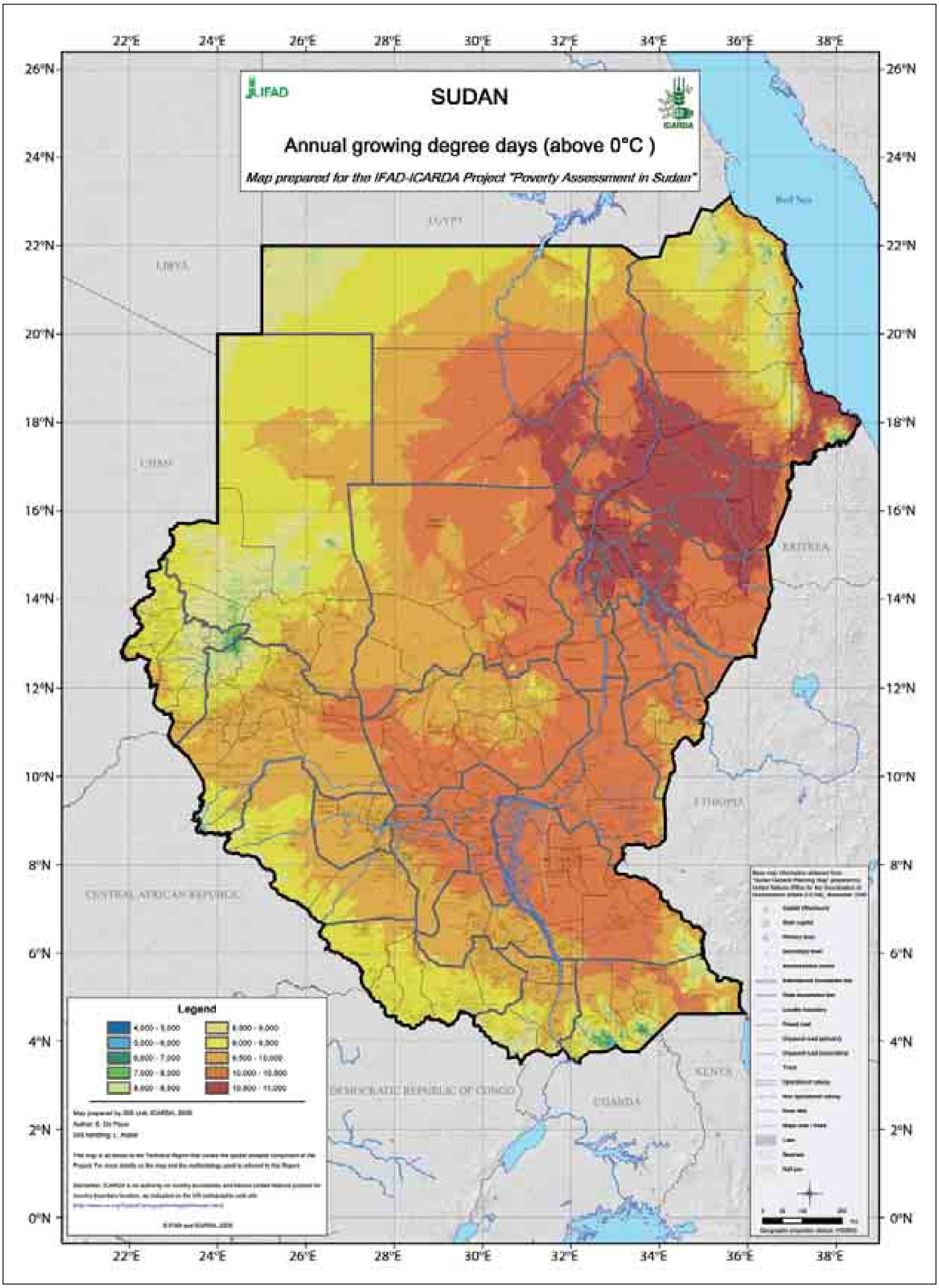


Figure3. Map of annual growing degree days

3. ANNUAL ARIDITY INDEX

The annual aridity index is the ratio of annual precipitation over the annual potential evapotranspiration. It provides a measure of the potential of climate to satisfy the water demand of plants by considering both the water supply from precipitation and the water demand by evapotranspiration. Sudan shows a very high range in aridity index, from hyper-arid to perhumid, and this is one of the key drivers in determining agricultural potential in rainfed agriculture. The distribution of aridity index classes by state is summarized in (Table 2). The map of the annual aridity index map is shown in (Fig. 4(.

Table 2: Annual Aridity Index: percentage of the States of Sudan in each class

	Aridity class					
State	**Hyper – arid**	**Arid**	**Semi – arid**	**Sub – humid**	**Humid**	**Per – humid**
South Kordofan	0	17	83	0	0	0
North Kordofan	0	73	27	0	0	0
Sennar	0	50	50	0	0	0
Red Sea	49	45	6	0	0	0
Northern	79	21	0	0	0	0
Nile	90	10	0	0	0	0
Khartoum	27	73	0	0	0	0
Kassala	0	100	0	0	0	0
Gedaref	0	44	56	0	0	0
Blue Nile	0	0	76	23	1	0
Gezira	0	100	0	0	0	0
West Darfur	0	15	85	0	0	0
South Darfur	0	3	84	13	0	0
North Darfur	35	49	16	0	0	0
Bahr El Jabal	0	0	12	65	24	0
Eastern Equatoria	0	2	39	54	5	0
Upper Nile	0	3	90	6	1	0
Western Bahr El Jabal	0	0	67	33	0	0
Unity	0	0	100	0	0	0
Northern Bahr El Jabal	0	0	50	50	0	0
Jonglei	0	0	87	13	0	0
Warrab	0	0	52	48	0	0
Western Equatoria	0	0	0	74	26	0

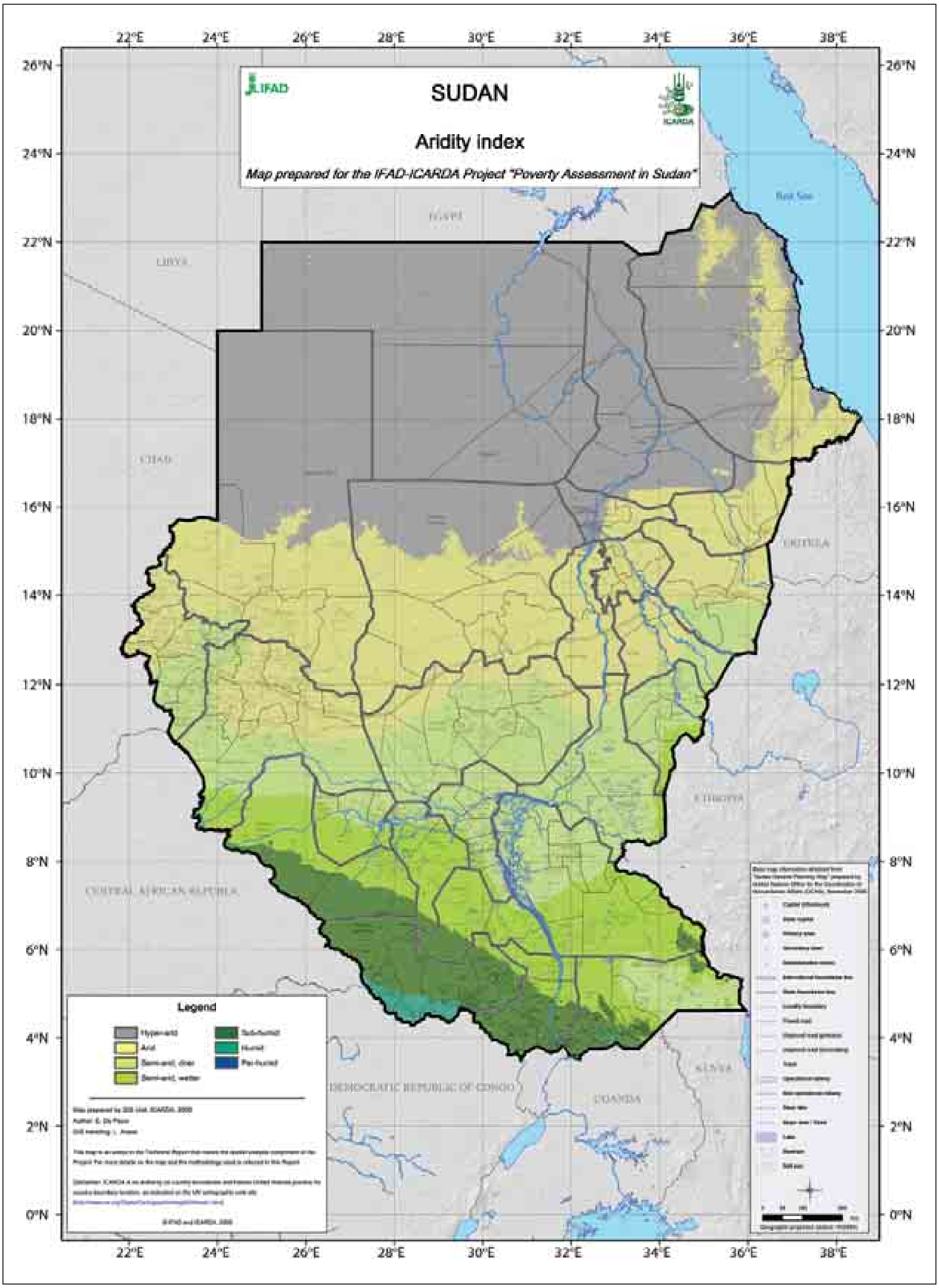


Figure 4. Map of the annual aridity index

4. BIOMASS

Vegetation biomass is obviously a very direct indicator of natural resource potential (Fig. 2). This map is the result of a new study to assess the amount of aboveground biomass by integrating the image analysis of satellite imagery at different resolutions (using MODIS, Landsat, and Google Earth) with the Land Cover map of Sudan. The biomass is expressed in metric tons/ha. The distribution of biomass classes by state is summarized in (Table 3). The biomass map is shown in (Fig. 5).

Table 3. Above-ground biomass: percentage of the states of Sudan in each class

	Biomass class (ton/ha)						
State	**0 – 0.5**	**0.5 – 1**	**1 -2**	**2 – 5**	**5 – 10**	**10 – 20**	**20 – 43**
White Nile	31	13	19	19	6	11	0
South Kordofan	3	3	4	14	24	52	0
North Kordofan	60	8	14	15	2	1	0
Sennar	47	7	3	9	14	20	0
Red Sea	99	0	0	0	0	0	0
Northern	100	0	0	0	0	0	0
Nile	99	1	0	0	0	0	0
Khartoum	93	5	2	1	0	0	0
Kassala	49	10	13	15	8	5	0
Gedaref	39	5	9	26	10	10	0
Blue Nile	13	6	0	5	43	32	0
Gezira	76	7	7	8	2	1	0
West Darfur	4	1	5	33	12	45	0
South Darfur	6	2	10	23	21	38	0
North Darfur	76	6	9	7	1	1	0
Lakes	0	2	0	7	6	82	3
Bahr El Jabal	0	4	1	4	6	81	4
Eastern Equatoria	0	1	2	18	15	61	2
Upper Nile	2	0	0	9	30	58	0
Western Bahr El Jabal	0	0	0	3	19	74	3
Unity	0	0	1	20	15	63	0
Northern Bahr El Jabal	3	1	0	2	17	75	2
Jonglei	0	0	1	10	8	80	0
Warrab	2	1	1	11	6	79	0
Western Equatoria	0	2	1	2	6	71	19

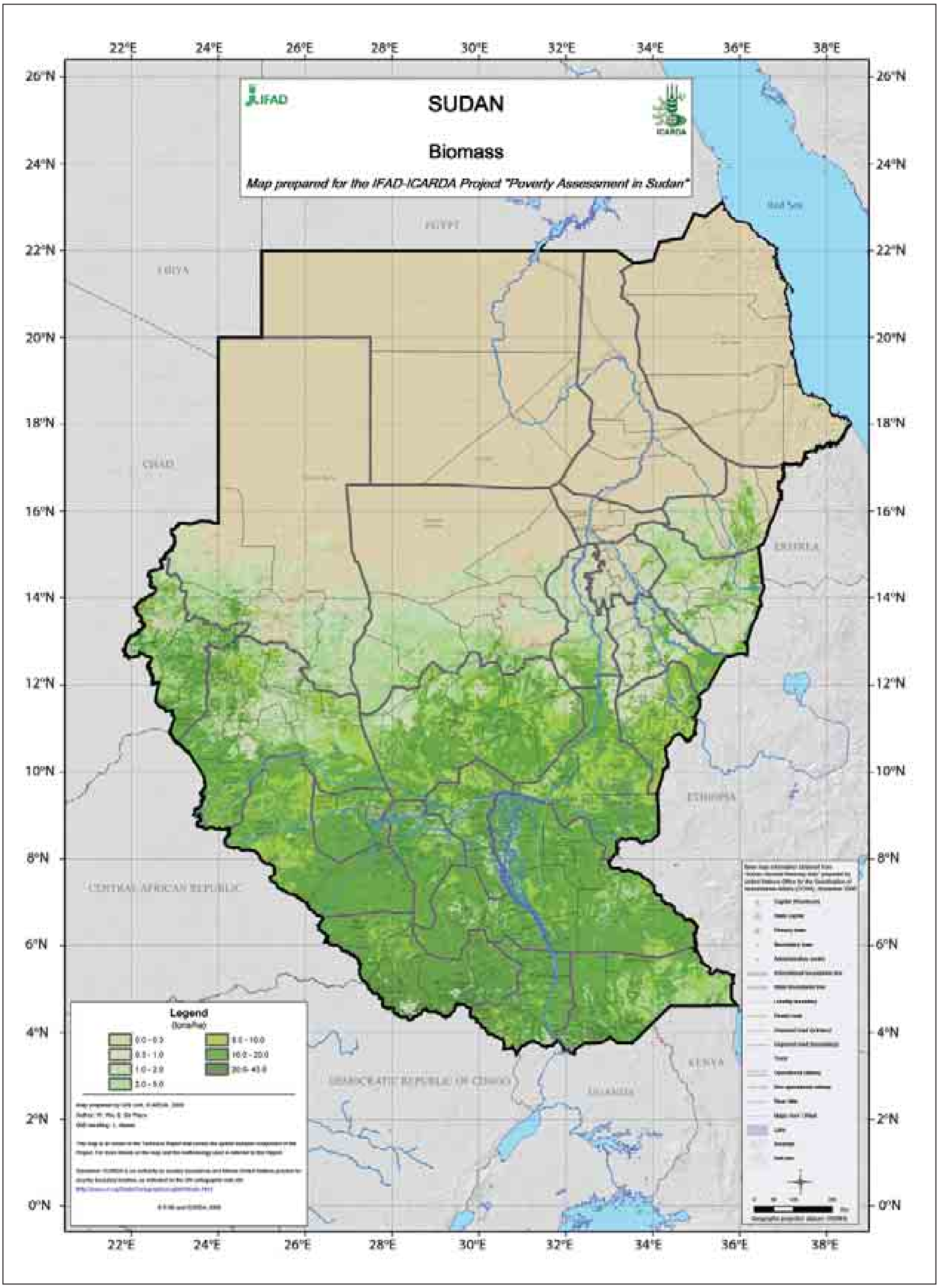


Figure 5. Biomass map

5. CLIMATICALLY DETERMINED BIOMASS PRODUCTIVITY INDEX (CDBPI)

While the vegetation biomass shows the actual totals, climate ultimately determines the potential to produce the biomass. For comparison of the climatic potential across large areas we use a very simple indicator, the product of the annual total growing degree – days (an indicator of temperature adequacy) with the aridity index (an indicator of moisture sufficiency). As the range in annual growing degree – days was 8000–11 000, the main factor that affects the productivity of climate for vegetation biomass production in Sudan is moisture. The distribution of CDBPI by state is summarized in (Table 4). The map of the Climatically Determined Biomass Productivity Index (CDBPI) is shown in (Fig. 6)

Table 4: Climatically determined biomass productivity index (CDBPI): percentage of the States of Sudan in each class

	CDBPI										
State	**0 – 100**	**100 – 200**	**200 – 500**	**500 – 1000**	**1000 – 2000**	**2000 – 3000**	**3000 – 4000**	**4000 – 5000**	**5000 – 6000**	**6000 – 7000**	**7000 – 8000**
White Nile	0	0	9	37	54	0	0	0	0	0	0
South Kordofan	0	0	0	0	27	65	8	0	0	0	0
North Kordofan	0	6	45	32	17	0	0	0	0	0	0
Sennar	0	0	0	1	66	30	2	0	0	0	0
Red Sea	11	19	57	12	1	0	0	0	0	0	0
Northern	80	18	2	0	0	0	0	0	0	0	0
Nile	34	22	42	2	0	0	0	0	0	0	0
Khartoum	0	7	59	34	0	0	0	0	0	0	0
Kassala	0	0	25	63	12	0	0	0	0	0	0
Gedaref	0	0	0	11	51	35	3	0	0	0	0
Blue Nile	0	0	0	0	0	51	46	4	0	0	0
Gezira	0	0	1	80	19	0	0	0	0	0	0
West Darfur	0	0	0	6	55	39	0	0	0	0	0
South Darfur	0	0	0	2	48	38	9	3	0	0	0
North Darfur	23	24	19	27	7	0	0	0	0	0	0
Lakes	0	0	0	0	0	0	22	57	20	0	0
Bahr El Jabal	0	0	0	0	0	0	0	39	43	19	0
Eastern Equatoria	0	0	0	0	0	15	42	25	16	2	0
Upper Nile	0	0	0	0	8	35	57	1	0	0	0
Western Bahr El Jabal	0	0	0	0	0	7	18	44	31	0	0
Unity	0	0	0	0	0	1	99	0	0	0	0
Northern Bahr El Jabal	0	0	0	0	0	4	75	21	0	0	0
Jonglei	0	0	0	0	0	1	77	21	1	0	0
Warrab	0	0	0	0	0	0	50	44	6	0	0
Western Equatoria	0	0	0	0	0	0	0	5	39	40	15

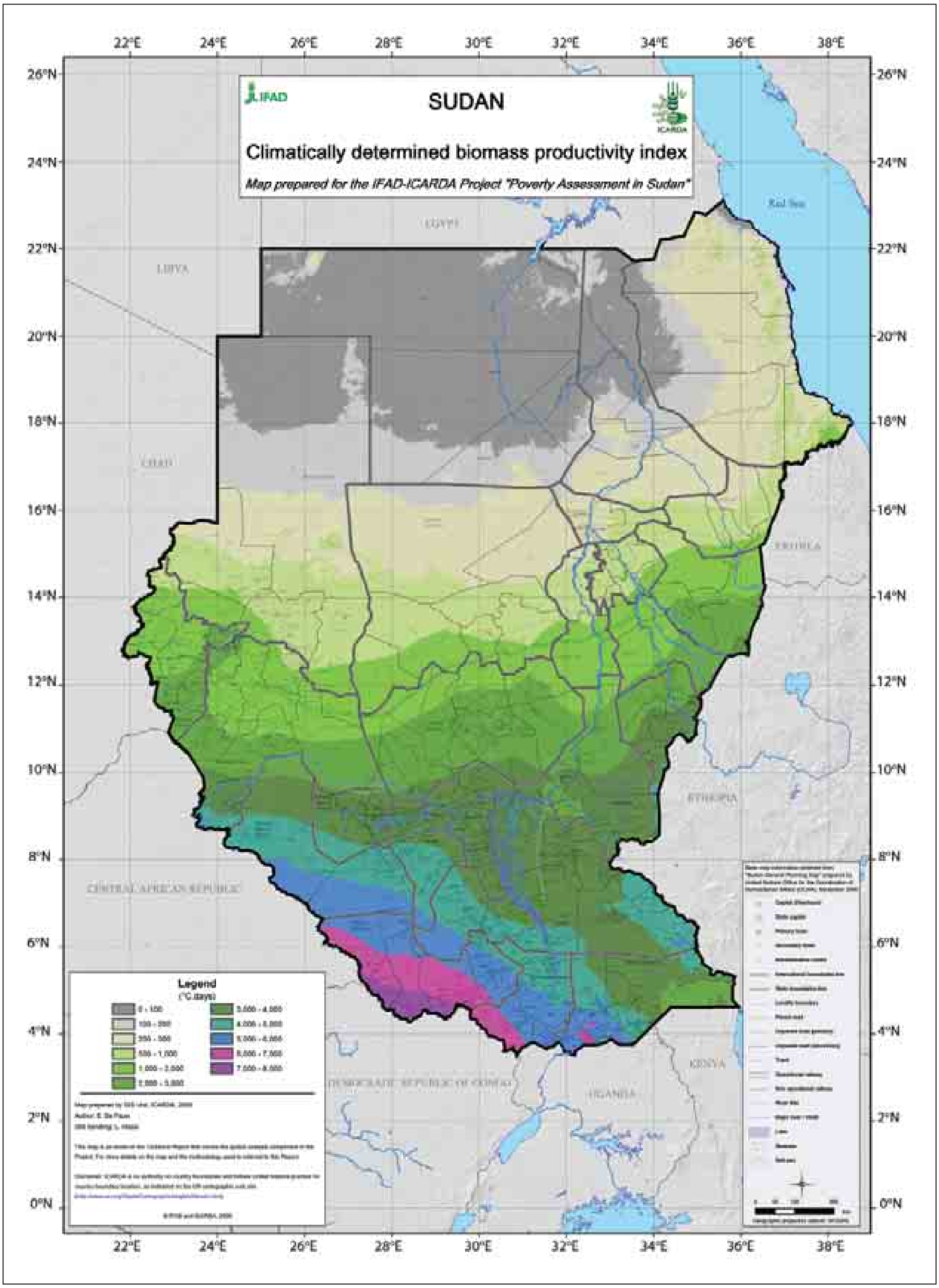


Figure6. Climatically Determined Biomass Productivity Index (CDBPI)

6. ELEVATION

This map is self – explanatory. In contrast with other countries in the region, e.g. Ethiopia or Eritrea, Sudan has limited differences in elevation, except for a few mountain areas such as Jebel Marra, Nuba, Red Sea, and Imatong Mountains, which explains the limited range in temperature. Higher elevations are useful in this context, especially when moisture is not too limiting; as this would be a factor enabling some biodiversity or special crops, such as fruit trees, to thrive. An elevation map is shown in (Fig. 7).

7. SLOPES

The slopes were determined from the Shuttle Radar Topographic Mission (SRTM) digital elevation model. Sudan is generally flat, with slopes < 5%, except in the few mountain areas of Jebel Marra, Red Sea, Nuba, and Imatong Mountains in the south. A slope map is shown in (Fig. 8).

8. LANDFORMS

Using elevation and slope as differentiating criteria, a 15-class landform classification was established (see legend in Fig. 9). These were condensed into four simplified landforms. The distribution of these simplified landforms (plains, low hills, steep hills, and mountains) is summarized in (Table 5). A map of the landforms is shown in (Fig. 9).

Table 5: Major landforms: percentage of the States of Sudan in each class

	Landform classes			
State	**Plains**	**Low hills**	**Steep hills**	**Mountains**
South Kordofan	100	0	0	0
North Kordofan	100	0	0	0
Sennar	98	1	1	0
Red Sea	81	3	9	7
Northern	96	3	2	0
Nile	94	4	2	0
Khartoum	97	2	0	0
Kassala	85	6	6	3
Gedaref	96	3	1	0
Blue Nile	78	9	12	2
Gezira	100	0	0	0
West Darfur	91	4	4	0
South Darfur	81	10	7	3
North Darfur	93	4	3	0
Bahr El Jabal	87	10	3	0
Eastern Equatoria	72	11	11	7
Upper Nile	92	2	4	1
Western Bahr El Jabal	94	2	4	0
Unity	100	0	0	0
Northern Bahr El Jabal	100	0	0	0
Jonglei	93	3	5	0
Warrab	100	0	0	0
Western Equatoria	97	2	0	0

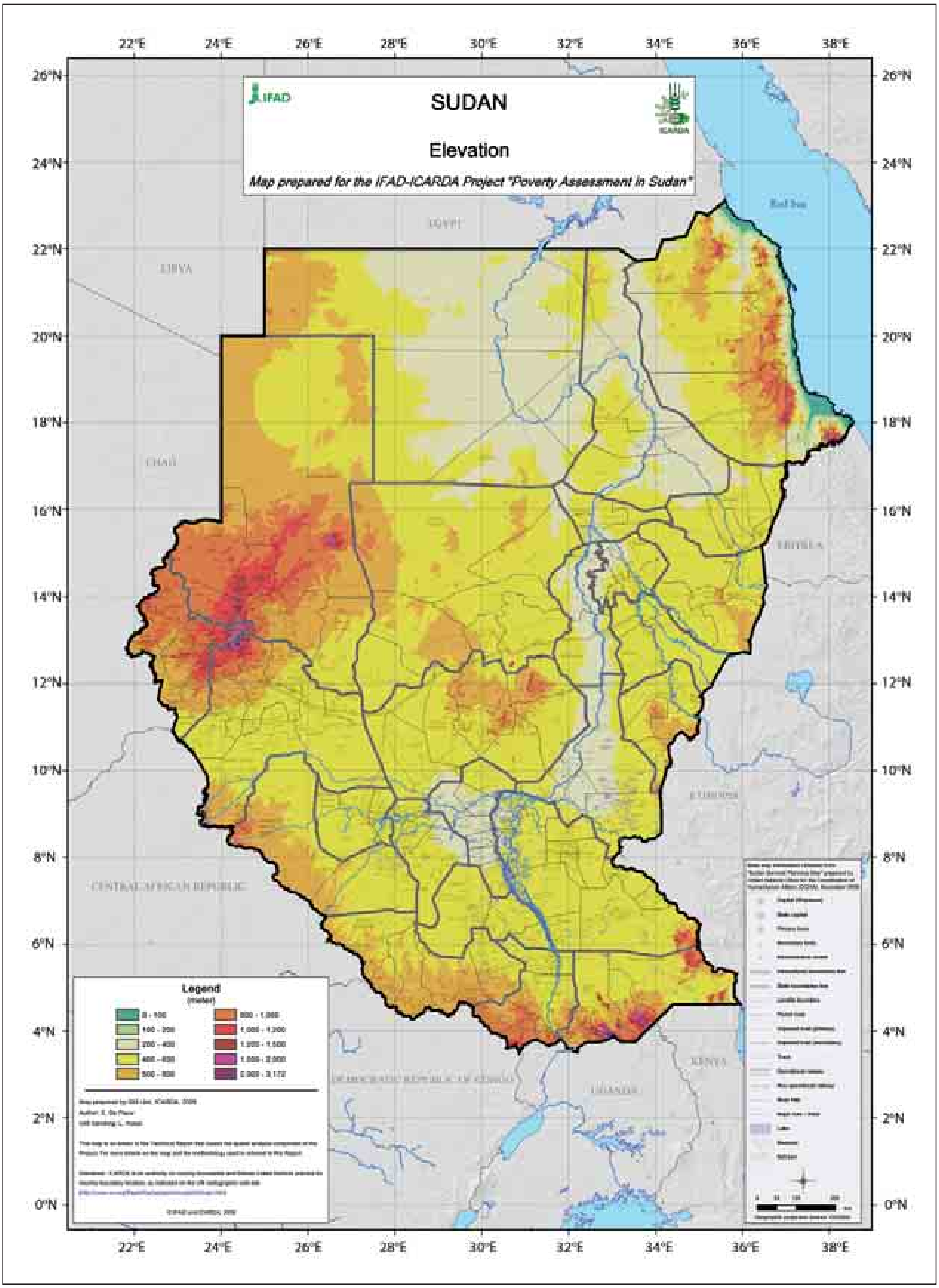


Figure7. Elevation map

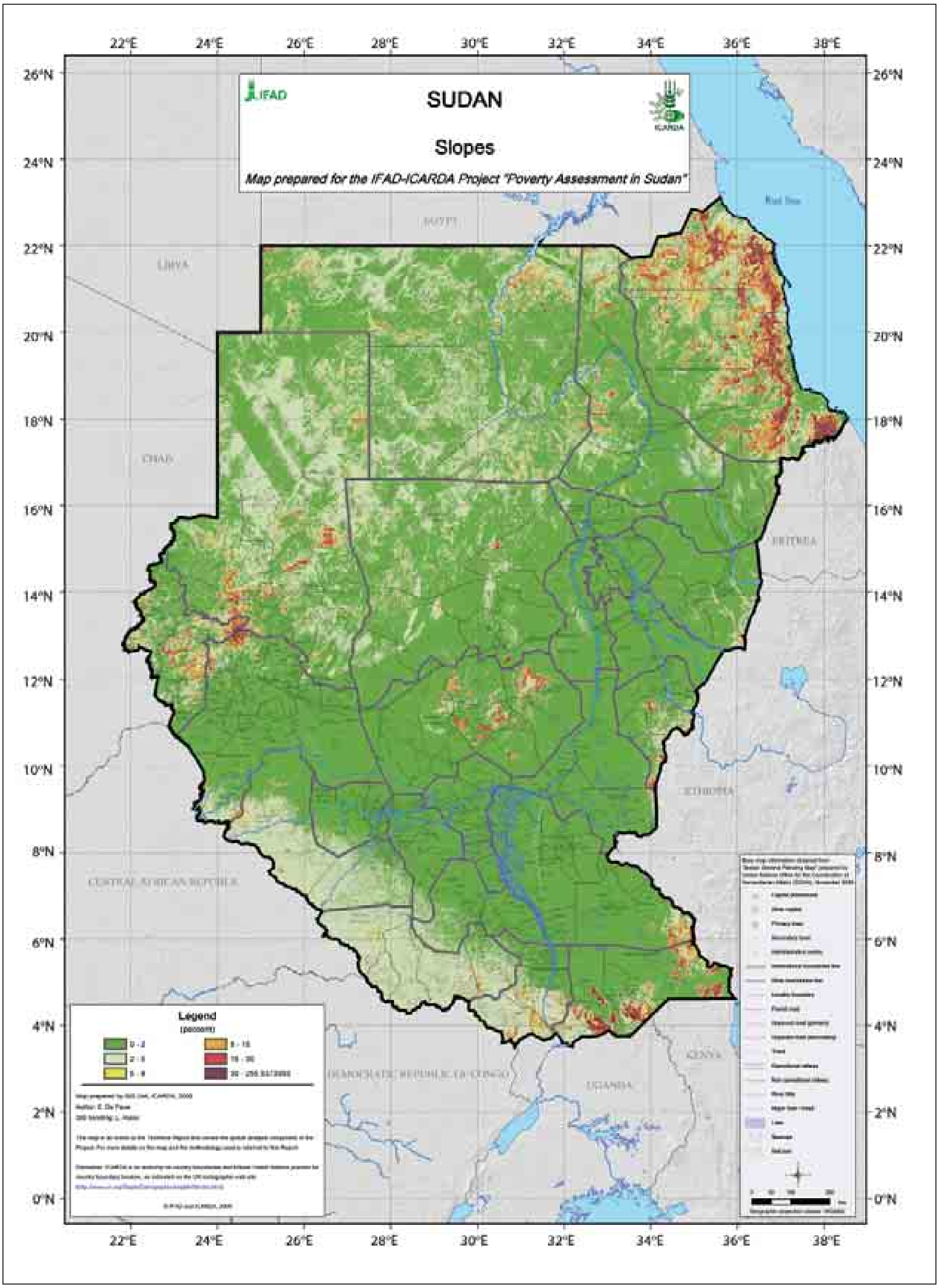


Figure8. Slope map

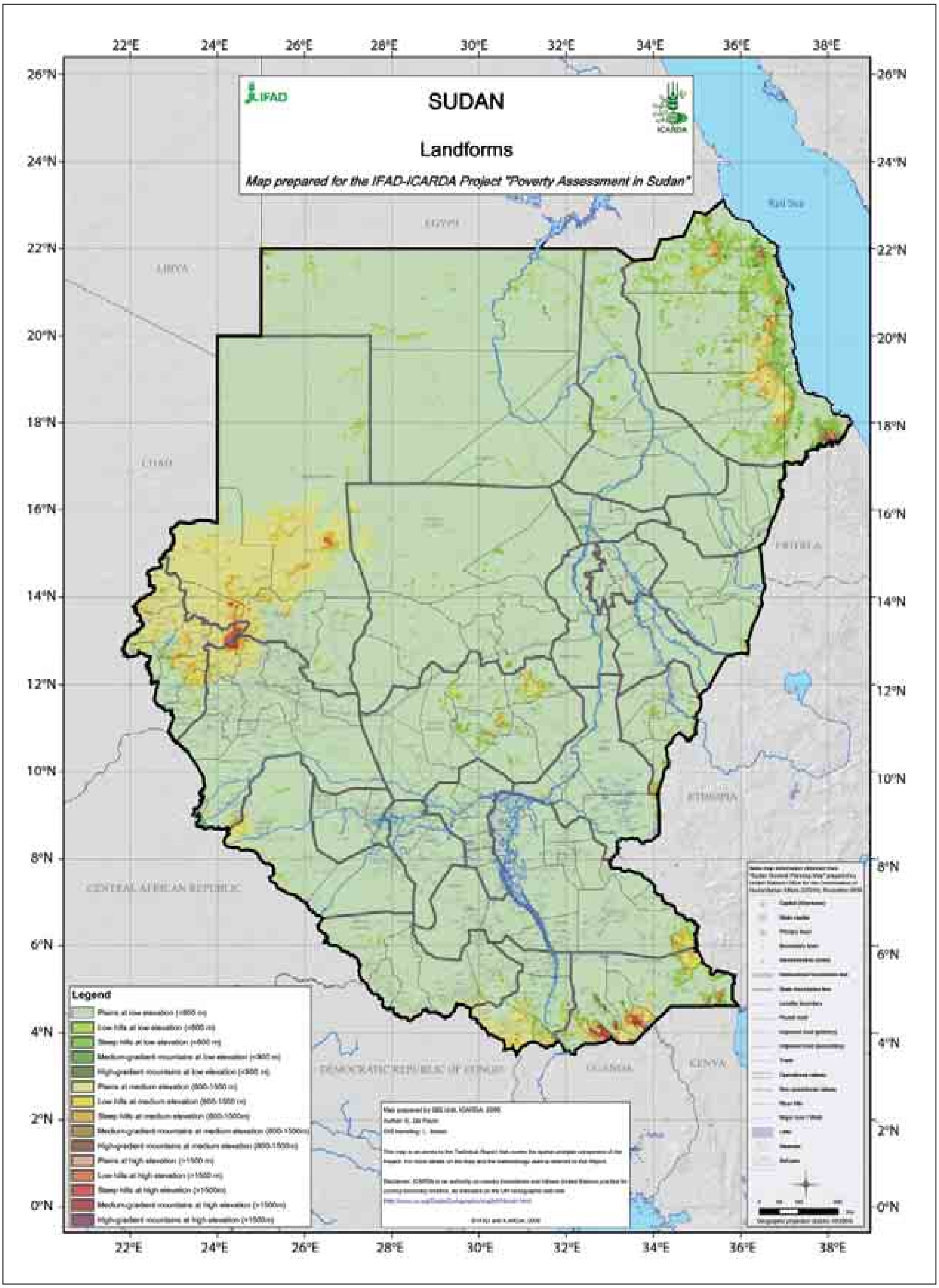


Figure9. Map of landforms

9. ANNUAL PRECIPITATION

This map is self-explanatory, with units of millimeters. The distribution of precipitation classes by state is summarized in (Table 6). An annual precipitation map is shown in (Fig. 10).

Table 6: Annual precipitation: percentage of the States of Sudan in each class

	Annual precipitation class (mm)										
State	**0–50**	**50–100**	**100–200**	**200–300**	**300–400**	**400–500**	**500–600**	**600–800**	**800–1000**	**1000–1200**	**1200–1400**
White Nile	0	3	37	45	15	0	0	0	0	0	0
South Kordofan	0	0	0	1	17	30	38	14	0	0	0
North Kordofan	6	32	37	22	3	0	0	0	0	0	0
Sennar	0	0	0	18	38	24	13	6	0	0	0
Red Sea	32	45	21	1	0	0	0	0	0	0	0
Northern	98	2	0	0	0	0	0	0	0	0	0
Nile	58	37	5	0	0	0	0	0	0	0	0
Khartoum	7	43	50	0	0	0	0	0	0	0	0
Kassala	0	10	77	14	0	0	0	0	0	0	0
Gedaref	0	0	9	22	26	19	20	5	0	0	0
Blue Nile	0	0	0	0	0	18	29	48	5	0	0
Gezira	0	0	55	44	0	0	0	0	0	0	0
West Darfur	0	0	1	15	26	41	16	1	0	0	0
South Darfur	0	0	0	20	22	24	22	11	2	0	0
North Darfur	46	13	28	9	2	1	0	0	0	0	0
Lakes	0	0	0	0	0	0	0	57	37	6	0
Bahr El Jabal	0	0	0	0	0	0	0	15	45	32	9
Eastern Equatoria	0	0	0	0	0	1	11	52	20	15	0
Upper Nile	0	0	0	0	7	13	20	60	1	0	0
Western Bahr El Jabal	0	0	0	0	0	0	5	22	64	9	0
Unity	0	0	0	0	0	0	0	100	0	0	0
Northern Bahr El Jabal	0	0	0	0	0	0	1	85	14	0	0
Jonglei	0	0	0	0	0	0	2	87	10	1	0
Warrab	0	0	0	0	0	0	0	69	31	0	0
Western Equatoria	0	0	0	0	0	0	0	0	19	59	22

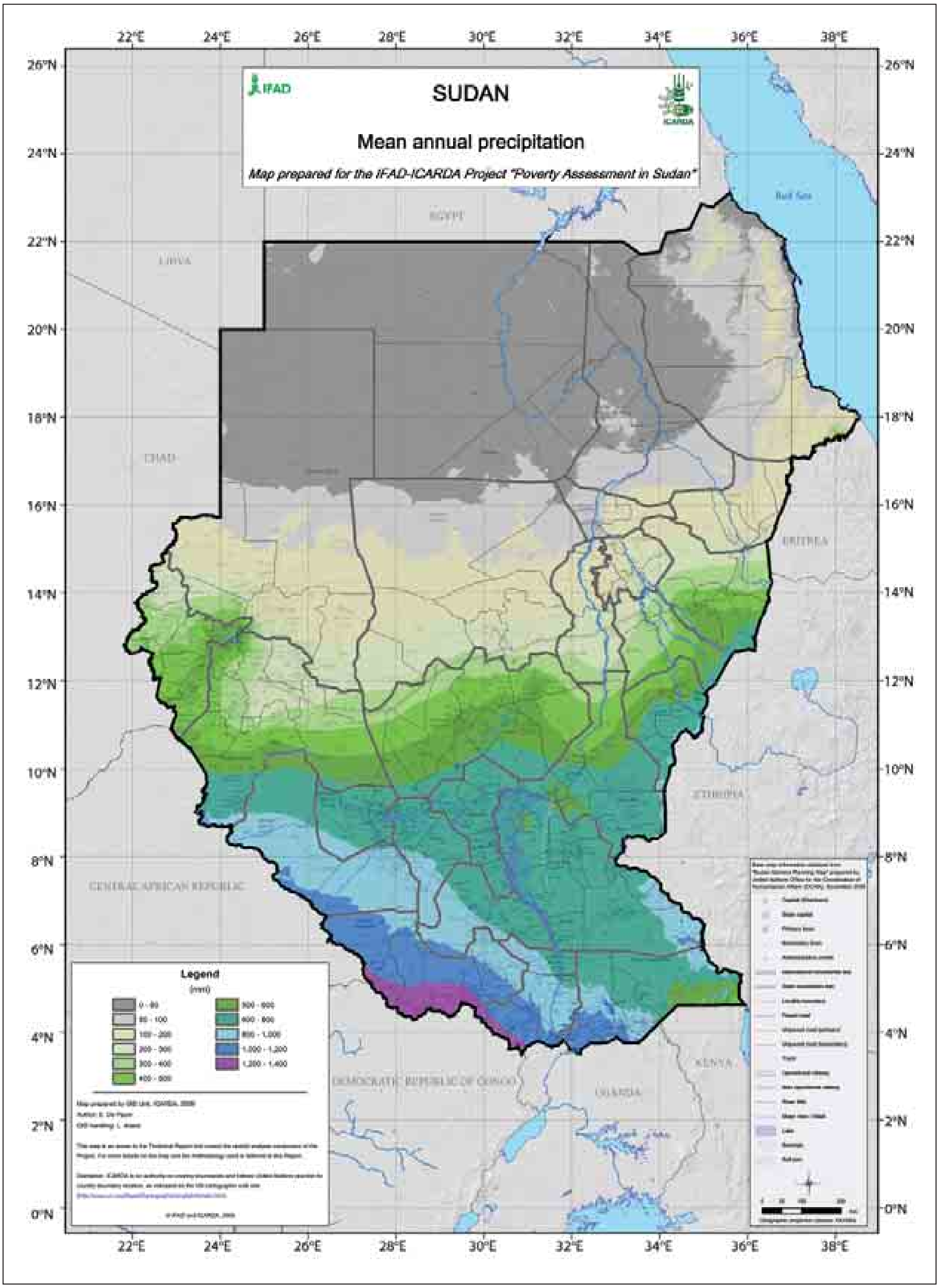


Figure10. Annual precipitation map

10. ANNUAL POTENTIAL EVAPOTRANSPIRATION (PET)

This map shows the water demand of a reference crop (grass) on an annual basis, calculated according to the Penman–Monteith method (expressed in mm). The distribution of PET classes by state is summarized in (Table 7). An annual potential evapotranspiration map is shown in (Fig. 11).

Table 7: Annual potential evapotranspiration (PET): percentage of the States of Sudan in each class

	Annual PET (mm)								
State	**1000–1200**	**1200–1400**	**1400–1600**	**1600–1800**	**1800–2000**	**2000–2200**	**2200–2400**	**2400–2600**	**2600–2750**
White Nile	0	0	0	0	0	36	54	10	0
South Kordofan	0	0	0	0	0	87	13	0	0
North Kordofan	0	0	0	0	0	1	62	37	0
Sennar	0	0	0	0	0	49	51	0	0
Red Sea	0	0	0	0	2	30	30	38	0
Northern	0	0	0	0	0	0	11	47	42
Nile	0	0	0	0	0	0	0	83	17
Khartoum	0	0	0	0	0	0	0	98	2
Kassala	0	0	0	0	0	18	38	44	0
Gedaref	0	0	0	0	0	23	72	5	0
Blue Nile	0	0	0	0	9	89	2	0	0
Gezira	0	0	0	0	0	0	53	47	0
West Darfur	0	0	0	0	16	72	11	0	0
South Darfur	0	0	0	6	20	58	16	0	0
North Darfur	0	0	0	0	1	24	48	27	0
Lakes	0	0	0	33	67	0	0	0	0
Bahr El Jabal	0	0	1	96	4	0	0	0	0
Eastern Equatoria	0	1	4	28	51	15	0	0	0
Upper Nile	0	0	0	0	3	97	0	0	0
Western Bahr El Jabal	0	0	0	47	49	4	0	0	0
Unity	0	0	0	0	60	40	0	0	0
Northern Bahr El Jabal	0	0	0	0	93	7	0	0	0
Jonglei	0	0	0	3	83	15	0	0	0
Warrab	0	0	0	14	85	1	0	0	0
Western Equatoria	0	0	10	90	0	0	0	0	0

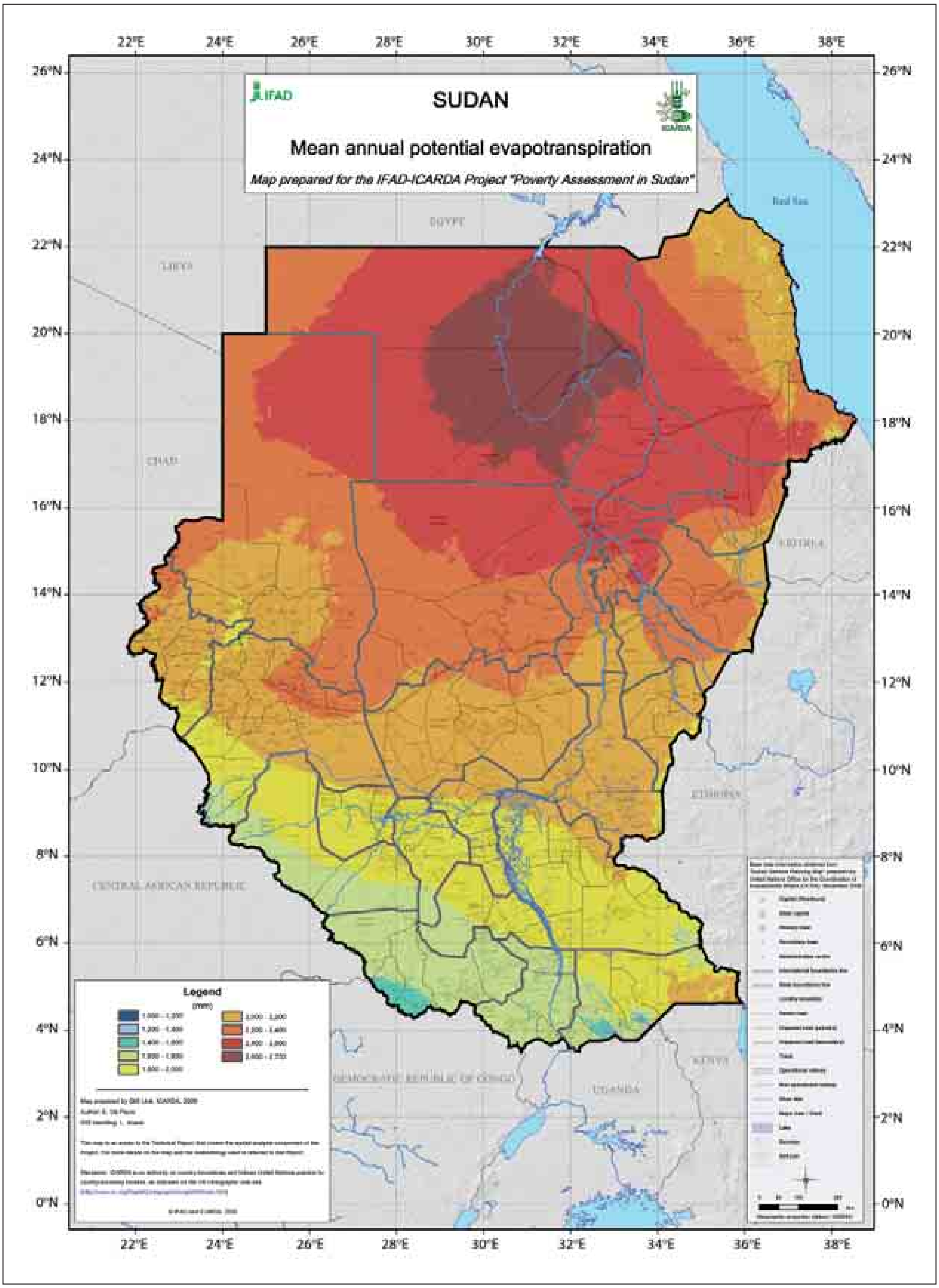


Figure11. Annual potential evapotranspiration map

11. LENGTH OF GROWING PERIOD (LGP)

The LGP is the period of the year (in days) in which neither moisture nor temperature constrains plant growth. As temperature is not a limiting factor in Sudan (except at high temperatures), moisture availability is the key constraint. The moisture – limited growing period is calculated as the contiguous period in which the ratio of actual to potential evapotranspiration, as calculated by simple water balance, is > 50%. The distribution of LGP classes by state is summarized in (Table 8). The map of the length of growing period is shown in (Fig. 12).

Table 8: Length of growing period: percentage of the States of Sudan in each class

	LGP (days)											
State	**0–30**	**30–60**	**60–90**	**90–120**	**120–150**	**150–180**	**180–210**	**210–240**	**240–270**	**270–300**	**300–330**	**330–365**
White Nile	35	35	30	0	0	0	0	0	0	0	0	0
South Kordofan	0	0	10	34	40	16	0	0	0	0	0	0
North Kordofan	67	20	13	0	0	0	0	0	0	0	0	0
Sennar	0	9	34	38	15	4	0	0	0	0	0	0
Red Sea	100	0	0	0	0	0	0	0	0	0	0	0
Northern	100	0	0	0	0	0	0	0	0	0	0	0
Nile	100	0	0	0	0	0	0	0	0	0	0	0
Khartoum	100	0	0	0	0	0	0	0	0	0	0	0
Kassala	89	11	0	0	0	0	0	0	0	0	0	0
Gedaref	12	14	30	27	13	2	0	0	0	0	0	0
Blue Nile	0	0	0	11	32	47	9	0	0	0	0	0
Gezira	59	41	0	0	0	0	0	0	0	0	0	0
West Darfur	0	5	16	38	40	0	0	0	0	0	0	0
South Darfur	0	2	24	26	27	20	2	0	0	0	0	0
North Darfur	78	15	5	2	0	0	0	0	0	0	0	0
Lakes	0	0	0	0	0	2	62	29	6	0	0	0
Bahr El Jabal	0	0	0	0	0	0	14	32	51	2	0	0
Eastern Equatoria	13	14	3	0	1	16	19	10	23	1	0	0
Upper Nile	0	0	2	12	15	63	8	0	0	0	0	0
Western Bahr El Jabal	0	0	0	0	1	24	44	31	0	0	0	0
Unity	0	0	0	0	0	92	8	0	0	0	0	0
Northern Bahr El Jabal	0	0	0	0	0	69	31	0	0	0	0	0
Jonglei	0	0	0	0	0	43	51	4	1	0	0	0
Warrab	0	0	0	0	0	43	44	13	0	0	0	0
Western Equatoria	0	0	0	0	0	0	0	23	73	5	0	0

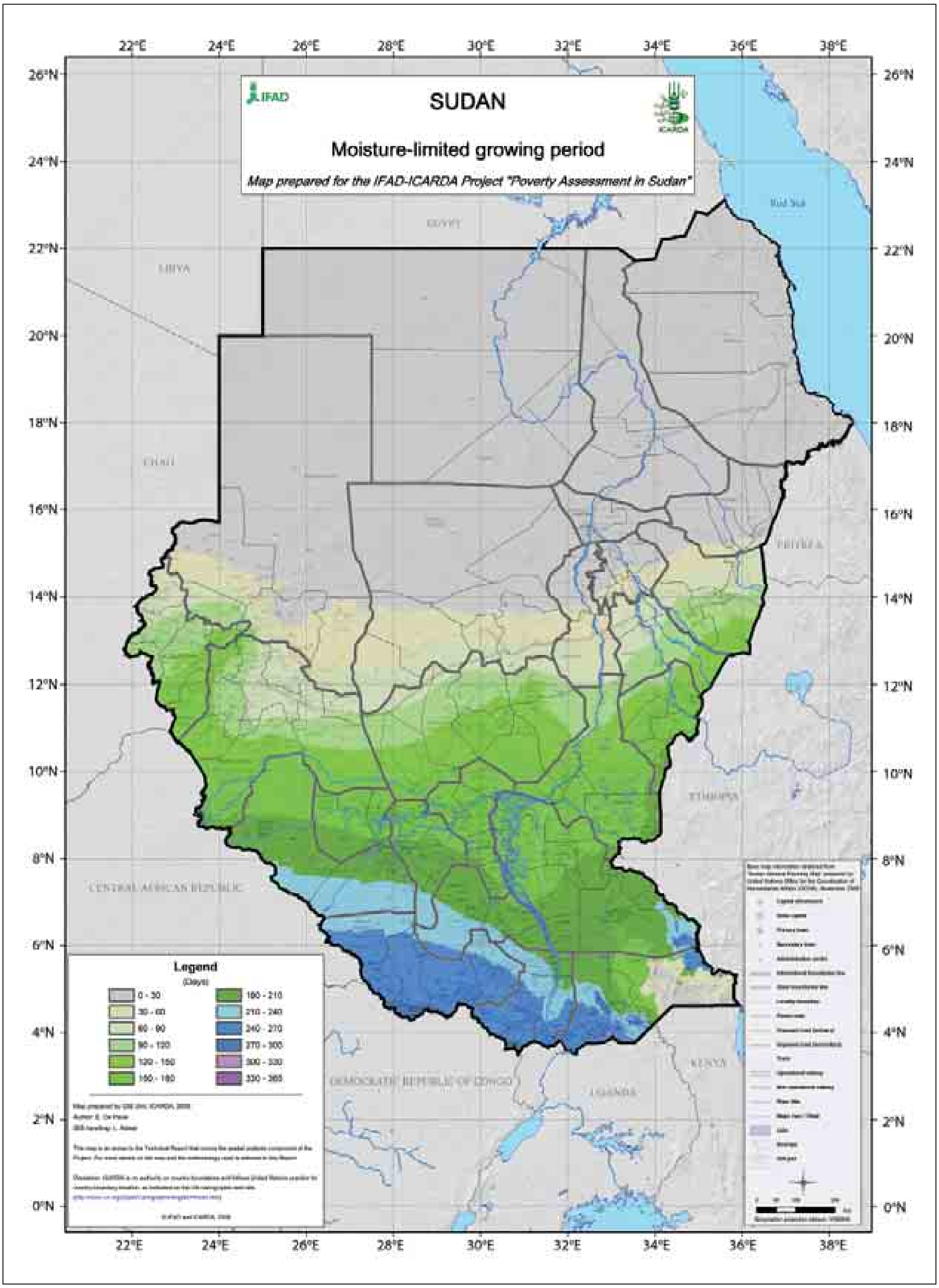


Figure12. Length of growing period map

12. CLIMATIC RESOURCE INDEX (CRI)

The CRI is an index of scale 0–100 for capturing the climatic potential for biomass production. It is based on the CDBPI. The distribution of CRI classes by state is summarized in (Table 9). The climatic resource index map is shown in (Fig. 13).

Table 9: Climatic Resource Index under Rainfed and Irrigated conditions (CRI – RF/IR): percentage of the States of Sudan in each class

	CRI (0 – 100)									
State	**0 – 10**	**10–20**	**20–30**	**30–40**	**40–50**	**50–60**	**60–70**	**70–80**	**80–90**	**90–100**
White Nile	24	53	16	0	0	0	0	0	6	0
South Kordofan	0	2	30	46	19	0	0	0	3	1
North Kordofan	65	32	2	0	0	0	0	0	1	1
Sennar	0	17	56	14	5	0	0	0	8	0
Red Sea	95	4	0	0	0	0	0	0	0	0
Northern	100	0	0	0	0	0	0	0	0	0
Nile	98	0	0	0	0	0	0	0	1	0
Khartoum	95	2	0	0	0	0	0	0	3	0
Kassala	58	37	0	0	0	0	0	0	5	0
Gedaref	1	27	37	28	5	0	0	0	2	0
Blue Nile	0	0	0	40	37	20	2	0	1	0
Gezira	19	57	0	0	0	0	0	0	25	0
West Darfur	0	23	44	32	0	0	0	0	0	1
South Darfur	0	23	30	29	10	5	1	0	1	1
North Darfur	77	20	2	0	0	0	0	0	0	0
Lakes	0	0	0	0	1	39	38	17	5	0
Bahr El Jabal	0	0	0	0	0	3	32	30	26	9
Eastern Equatoria	0	0	0	9	27	29	16	11	9	0
Upper Nile	0	0	9	18	63	8	0	0	1	0
Western Bahr El Jabal	0	0	0	3	12	14	33	34	3	0
Unity	0	0	0	0	72	28	0	0	0	0
Northern Bahr El Jabal	0	0	0	0	46	43	11	0	0	0
Jonglei	0	0	0	0	38	51	10	1	0	0
Warrab	0	0	0	0	13	52	27	9	0	0
Western Equatoria	0	0	0	0	0	0	3	18	41	38

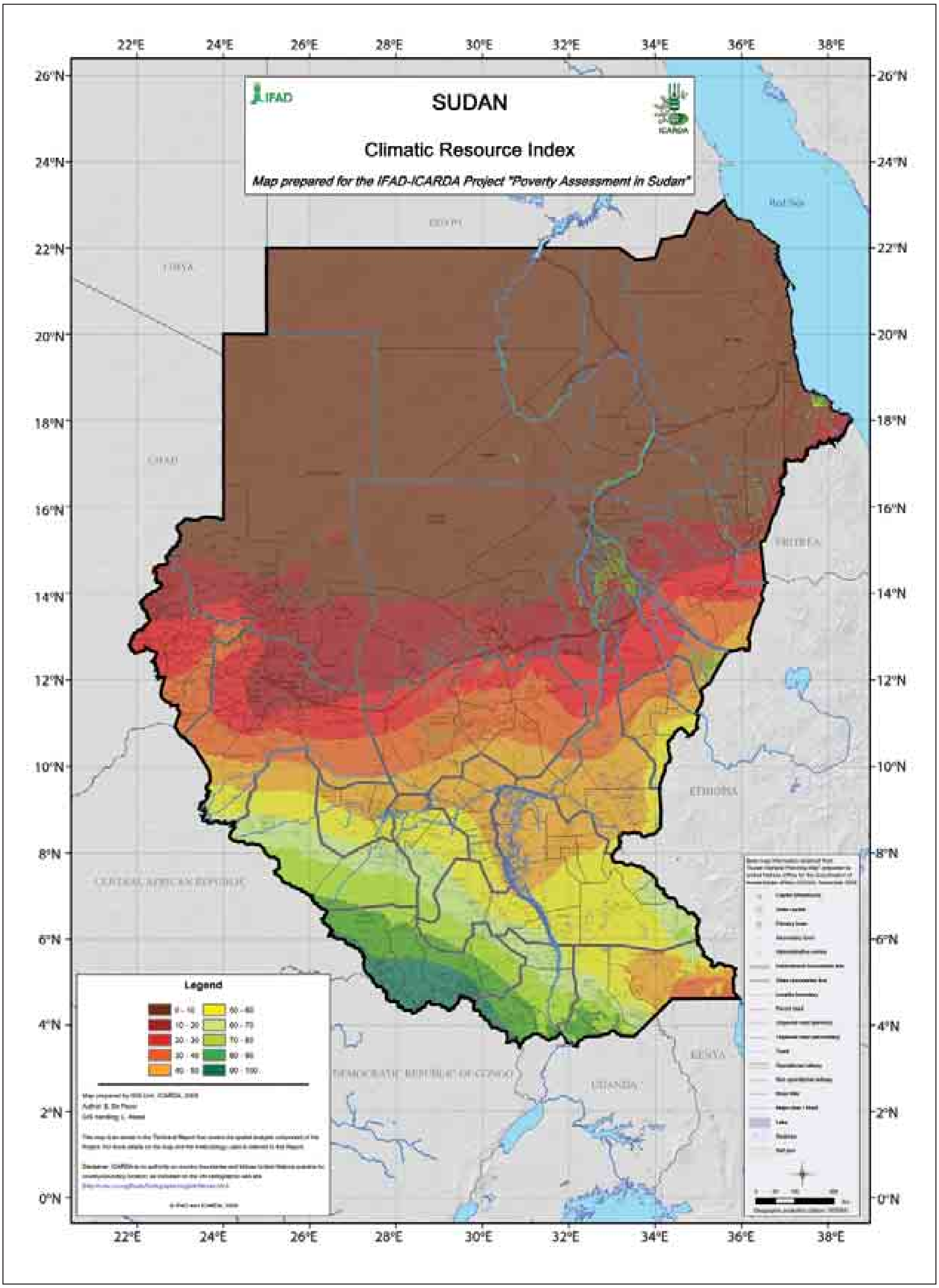


Figure13. Climatic Resource Index (CRI) map

13. SOIL RESOURCE INDEX (SRI)

The SRI is the proportion of a pixel on a GIS map without problematic soil types. Problematic soils are those that are either unsuitable for agricultural production due to severe physical limitations, or soils that are very expensive to reclaim for production. The distribution of SRI classes by state is summarized in (Table 10). The soil resource index map is shown in (Fig. 14).

Table 10: Soil Resource Index (SRI): percentage of the States of Sudan in each class

	SRI (0 – 100)									
State	**0–10**	**10–20**	**20–30**	**30–40**	**40–50**	**50–60**	**60–70**	**70–80**	**80–90**	**90–100**
White Nile	34	0	0	9	2	0	0	0	9	46
South Kordofan	23	0	0	0	17	0	0	20	0	41
North Kordofan	15	4	0	39	38	0	0	3	0	2
Sennar	0	0	0	0	0	0	0	0	7	93
Red Sea	2	20	0	31	2	0	25	3	7	10
Northern	11	75	0	7	1	0	5	0	1	0
Nile	4	42	0	0	39	0	8	1	4	2
Khartoum	16	0	0	0	49	0	0	0	7	29
Kassala	0	0	0	0	4	0	0	0	3	93
Gedaref	0	0	0	0	0	0	0	0	31	68
Blue Nile	2	0	0	0	0	0	4	0	23	71
Gezira	0	0	0	0	0	0	0	0	8	92
West Darfur	4	1	0	4	52	0	17	0	0	21
South Darfur	24	0	16	13	4	0	22	18	0	3
North Darfur	39	28	0	3	26	0	1	1	0	1
Lakes	0	0	0	30	0	0	0	25	0	45
Bahr El Jabal	0	0	37	31	0	0	0	1	2	29
Eastern Equatoria	1	0	1	0	6	0	13	1	13	65
Upper Nile	0	0	0	0	0	0	1	0	3	96
Western Bahr El Jabal	0	0	0	47	0	0	0	51	0	2
Unity	0	0	0	0	0	0	0	11	0	89
Northern Bahr El Jabal	0	0	0	0	0	0	0	91	0	9
Jonglei	0	0	1	0	0	0	0	0	2	96
Warrab	1	0	0	11	0	0	0	26	0	62
Western Equatoria	4	0	14	82	0	0	0	0	0	1

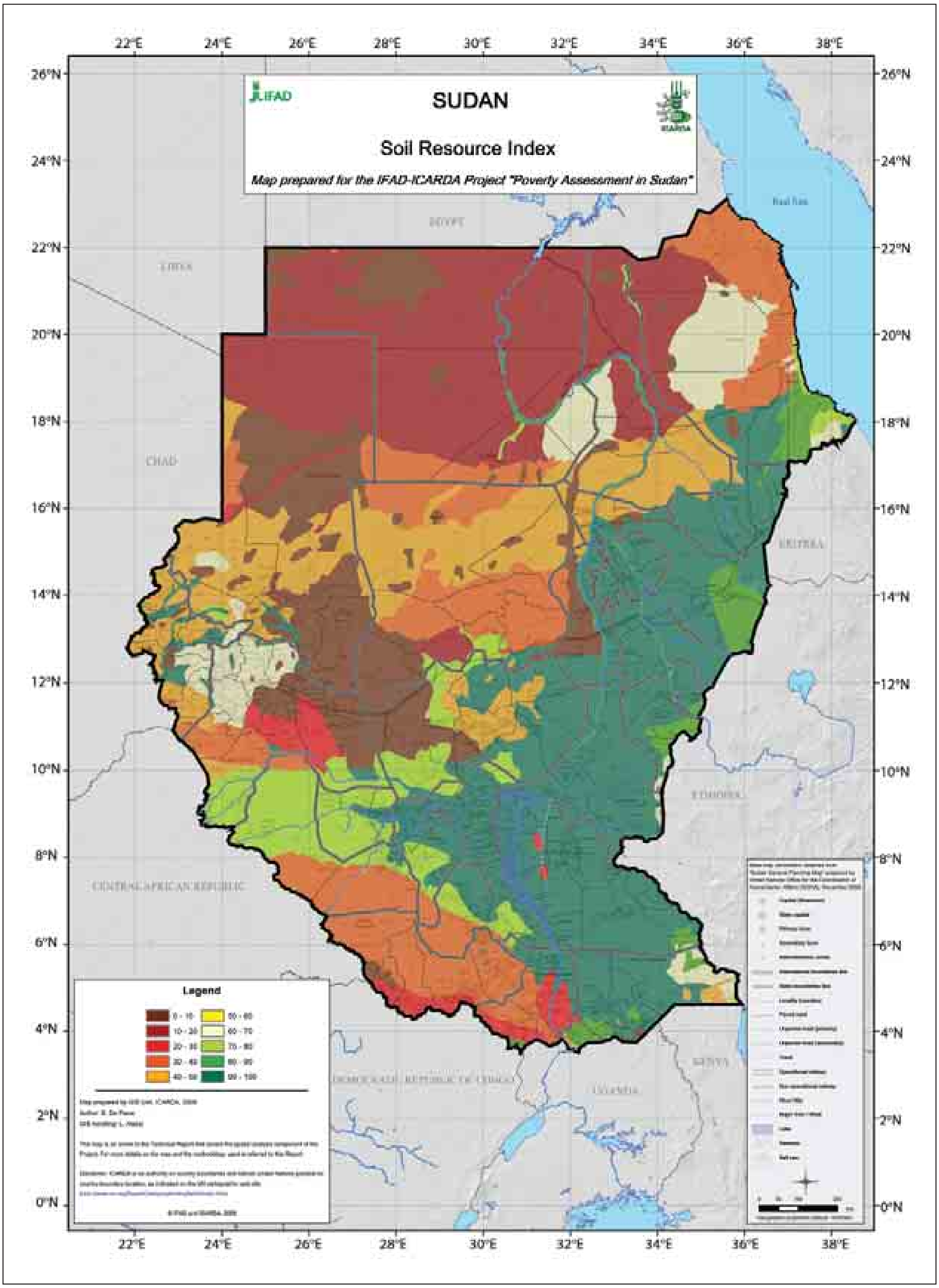


Figure14. Soil Resource Index (SRI) map

14. TOPOGRAPHIC RESOURCE INDEX (TRI)

The TRI is the proportion of the pixel without problematic soil types. The TRI was derived from a Shuttle Radar Topographic Mission Digital Elevation Model (CGIAR–CSI online database) by calculating the slope for each 90 – m pixel. To match the resolution of the other datasets used to calculate the CRI and SRI, the slope pixels were aggregated to a pixel – size 100 Times larger. TRI was then calculated as the percentage of SRTM pixels with slope ≥ 15%, which corresponds well with the slope – limit delineating what constitutes sustainable agriculture without resorting to use of terracing. The distribution of TRI classes by state is summarized in (Table 11). The Topographic Resource Index (TRI) map is shown in (Fig. 15).

Table 11: Topographic Resource Index (TRI): percentage of the States of Sudan in each class

	TRI (0 – 100)									
State	**0–10**	**10–20**	**20–30**	**30–40**	**40–50**	**50–60**	**60–70**	**70–80**	**80–90**	**90–100**
White Nile	0	0	0	0	0	0	0	0	0	100
South Kordofan	0	0	0	1	1	1	1	1	1	95
North Kordofan	0	0	0	0	0	0	0	0	0	99
Sennar	0	0	0	0	0	0	0	0	0	100
Red Sea	4	3	3	3	3	3	3	4	5	70
Northern	0	0	0	0	0	0	0	1	1	98
Nile	0	0	0	0	0	0	0	1	1	97
Khartoum	0	0	0	0	0	0	0	0	0	99
Kassala	0	0	0	0	0	0	0	0	0	98
Gedaref	0	0	0	0	0	0	0	0	0	99
Blue Nile	1	1	1	1	1	1	1	1	1	93
Gezira	0	0	0	0	0	0	0	0	0	100
West Darfur	0	1	1	1	1	1	2	2	3	87
South Darfur	0	0	0	0	0	0	0	0	1	97
North Darfur	0	0	0	0	0	0	1	1	1	96
Lakes	0	0	0	0	0	0	0	0	0	100
Bahr El Jabal	0	0	0	0	0	1	1	1	2	94
Eastern Equatoria	4	2	2	1	1	1	1	2	2	83
Upper Nile	0	0	0	0	0	0	0	0	0	99
Western Bahr El Jabal	0	0	0	0	0	0	0	0	0	99
Unity	0	0	0	0	0	0	0	0	0	100
Northern Bahr El Jabal	0	0	0	0	0	0	0	0	0	100
Jonglei	0	0	0	0	0	0	0	0	0	98
Warrab	0	0	0	0	0	0	0	0	0	100
Western Equatoria	0	0	0	0	0	0	0	0	1	98

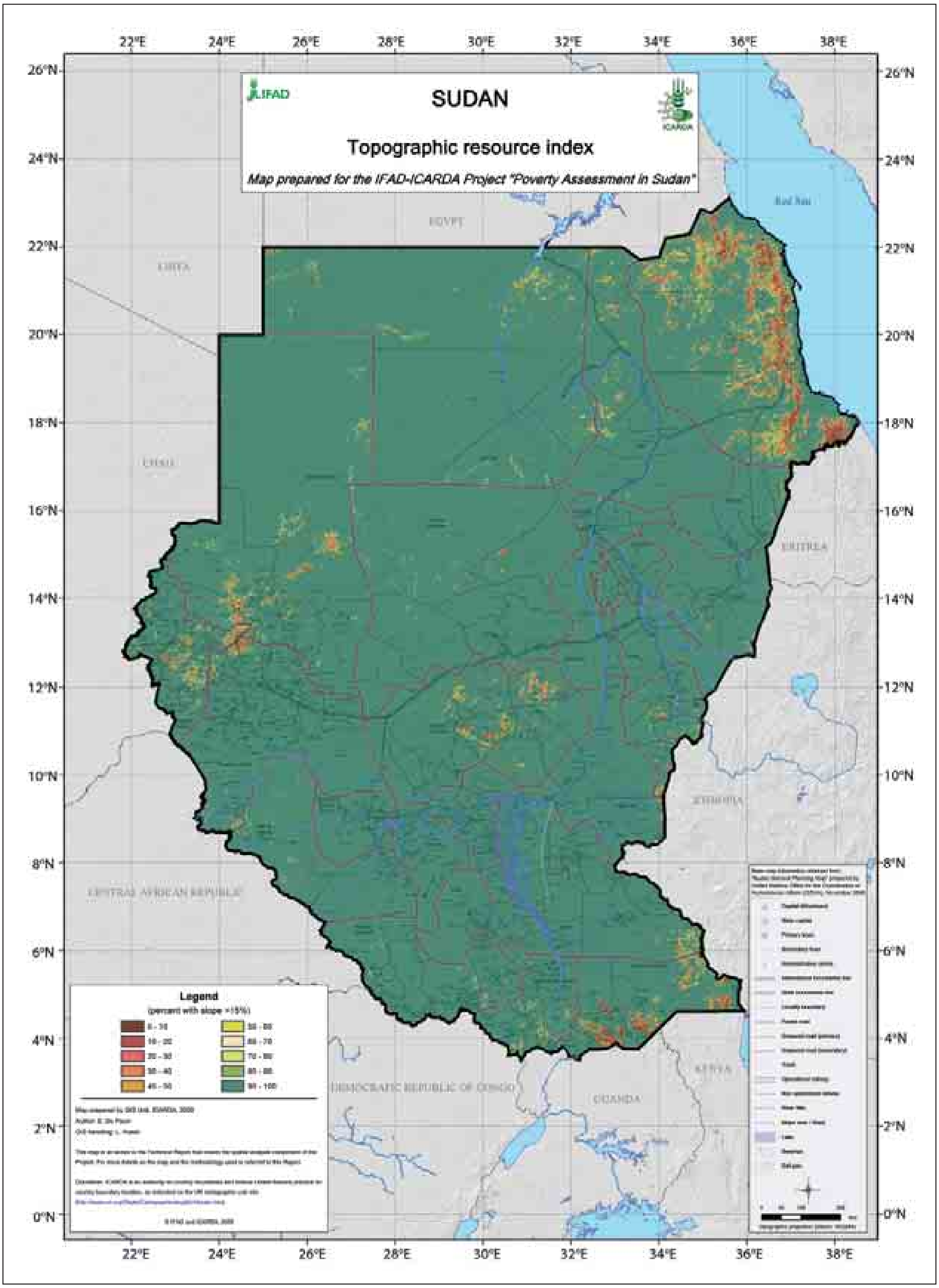


Figure15. Topographic Resource Index (TRI) map

15. AGRICULTURAL RESOURCE POTENTIAL INDEX (ARI)

The thematic indices (CRI, SRI, and TRI) were combined as raster themes in GIS, with the same spatial scope and resolution, into the ARI. The ARI is an integrated index based on the climatic, soil, topographic, and water resources and is calculated as the lowest value of CRI, SRI, and TRI for rainfed areas. If, however, a fraction of the pixel is irrigated, only CRI is considered for the irrigated fraction in the ARI calculation, assuming that irrigation takes place where soil and topographic conditions are not severely constraining. The distribution of ARI classes by state is summarized in (Table 12). The map of the agricultural resource potential index is shown in (Fig. 16).

Table 12: Agricultural Resource Potential Index (ARI): percentage of the States of Sudan in each class

	ARI (0 – 100)									
State	**0–10**	**10–20**	**20–30**	**30–40**	**40–50**	**50–60**	**60–70**	**70–80**	**80–90**	**90–100**
White Nile	53	26	16	0	0	0	0	0	4	0
South Kordofan	23	2	20	36	18	0	0	1	0	0
North Kordofan	76	23	1	0	0	0	0	0	0	0
Sennar	0	17	56	14	5	0	0	0	8	0
Red Sea	97	2	0	0	0	0	0	0	0	0
Northern	100	0	0	0	0	0	0	0	0	0
Nile	98	0	0	0	1	0	0	0	1	0
Khartoum	96	2	0	0	0	0	0	0	3	0
Kassala	58	37	0	0	0	0	0	0	5	0
Gedaref	1	27	37	28	5	0	0	0	2	0
Blue Nile	3	1	1	39	35	19	1	0	1	0
Gezira	19	57	0	0	0	0	0	0	25	0
West Darfur	5	24	40	31	0	0	0	0	0	0
South Darfur	24	11	28	20	10	5	2	0	0	0
North Darfur	90	8	2	0	0	0	0	0	0	0
Lakes	0	0	0	30	1	39	31	0	0	0
Bahr El Jabal	0	0	37	31	0	3	26	2	2	0
Eastern Equatoria	5	2	3	10	28	28	13	6	6	0
Upper Nile	0	0	9	18	62	8	0	0	1	0
Western Bahr El Jabal	0	0	0	47	11	14	26	1	0	0
Unity	0	0	0	0	72	28	0	0	0	0
Northern Bahr El Jabal	0	0	0	0	46	43	11	0	0	0
Jonglei	0	0	1	0	37	51	9	1	0	0
Warrab	1	0	0	11	13	51	24	0	0	0
Western Equatoria	4	0	14	82	0	0	0	0	0	0

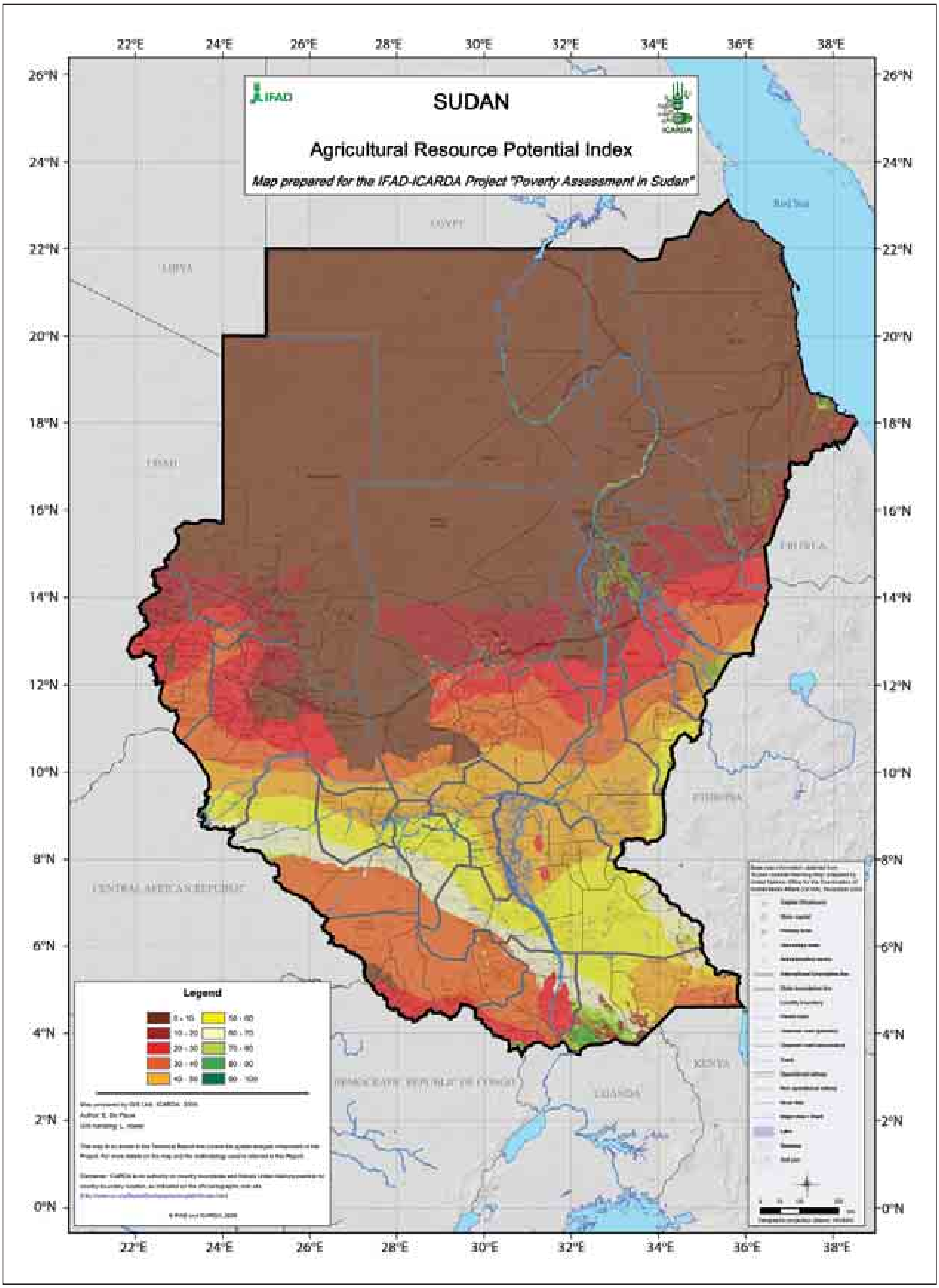
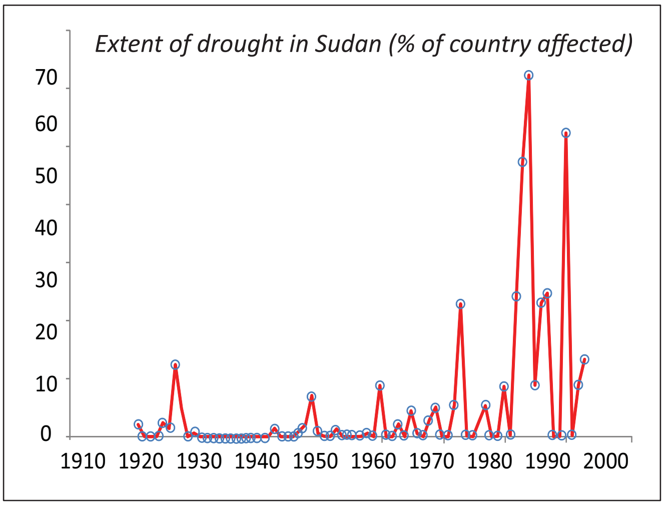


Figure16. Agricultural Resource potential Index (ARI) map

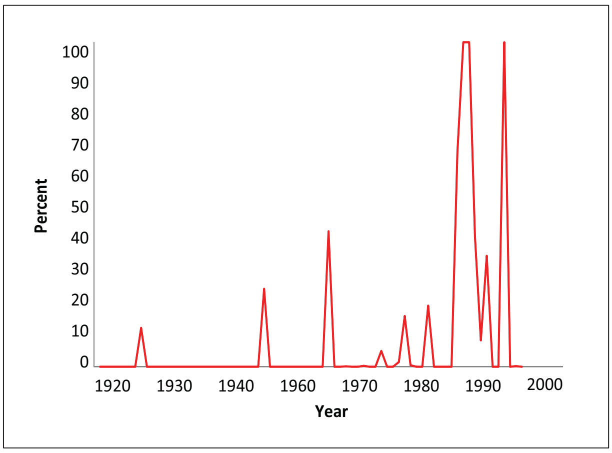
16. DROUGHT IN SUDAN

The Standardized Precipitation Index (SPI) is a tool for monitoring drought and anomalously wet events based on a cumulative probability distribution of precipitation time series. Using a time series of monthly precipitation data from Sudan, the annual SPI has been calculated from 1921 to 1993, a period in which the number of meteorological stations in the country expanded from 50 to 120 and declined afterwards to 30. By interpolating station SPI values and using a mask to cover hyper-arid areas, 73 annual SPI maps were created which allow to characterize historical drought patterns and to compare the extent of drought in the different states of Sudan. The Drought Extent Index, defined as the average percentage area that would be affected by drought each year, varies between States between 5-11%, a surprisingly narrow range indicating that drought is a feature of all States, with Southern and Western Darfur the most vulnerable ones. SPI trend analysis indicates that droughts became both more extensive and severe towards the end of the period and that wetness anomalies have declined. Droughts during the mid-1920s, particularly in southern Sudan, were followed between 1930 and 1960 by a period characterized by normal or even above normal precipitation across the country, interrupted by local and scattered drought events. This period of relative climatic stability was followed by an uptick in droughts during the 1960s-70s and culminated in a new state of the climate characterized by multi-year regional droughts from 1982 onwards.

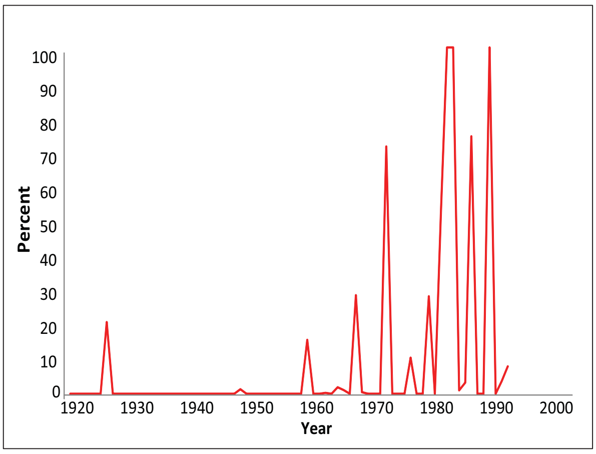


The drought patterns of the period 1921-1993 are indicative of the increases in precipitation variability to be expected under global warming. The SPI mapping is in agreement with field and satellite data and can be a useful tool for comparing longer-term vulnerability to drought within countries.

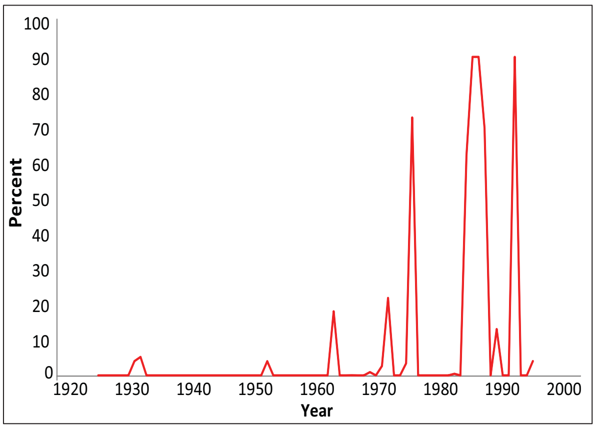
DROUGHT PATTERNS BY STATE



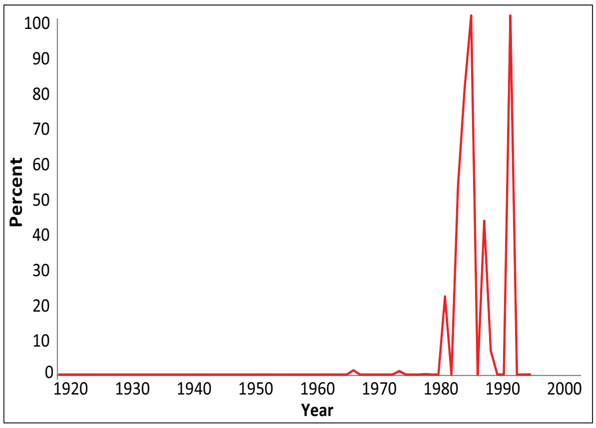
Area (%) affected by drought in White Nile State



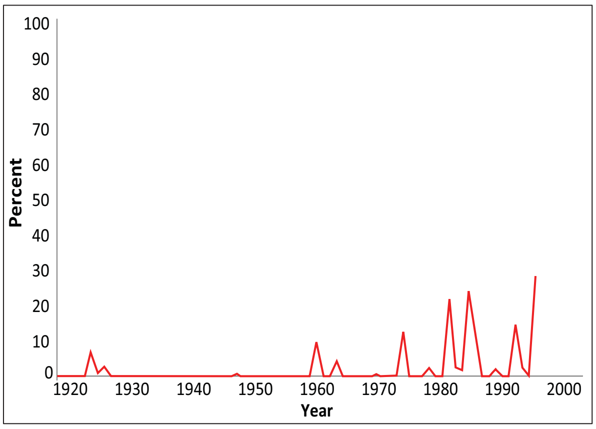
Area (%) affected by drought in South Kordofan State



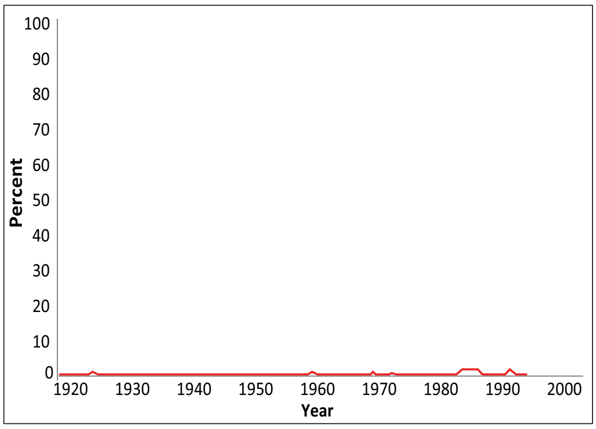
Area (%) affected by drought in North Kordofan State



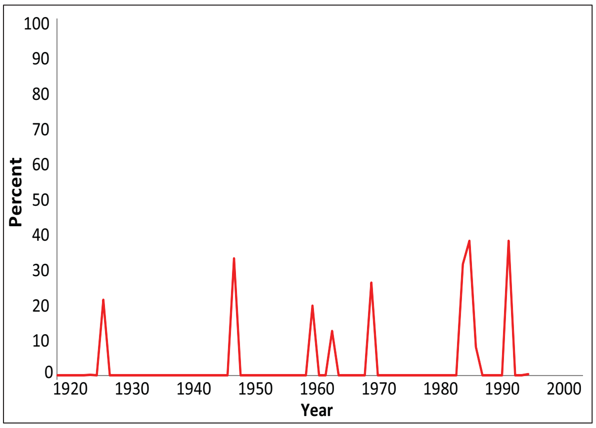
Area (%) affected by drought in Sennar State



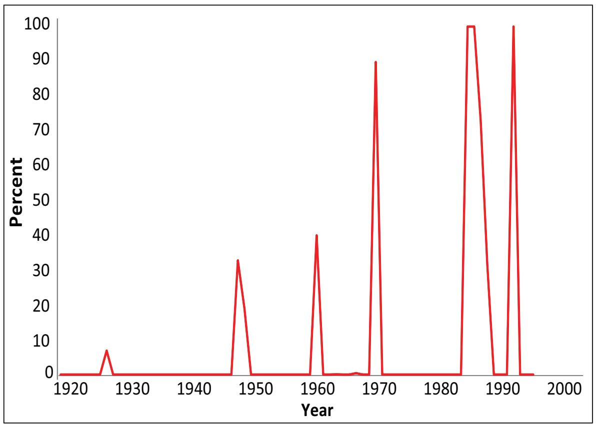
Area (%) affected by drought in Red Sea State



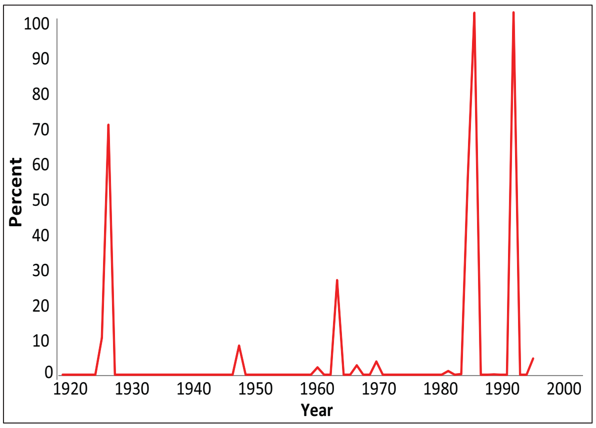
Area (%) affected by drought in Northern State



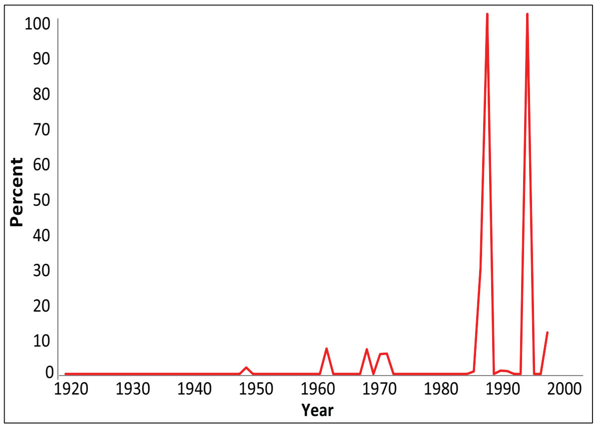
Area (%) affected by drought in Nile State



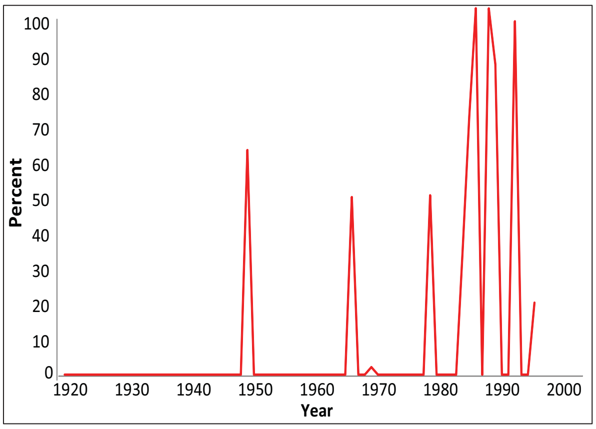
Area (%) affected by drought : Khartoum State



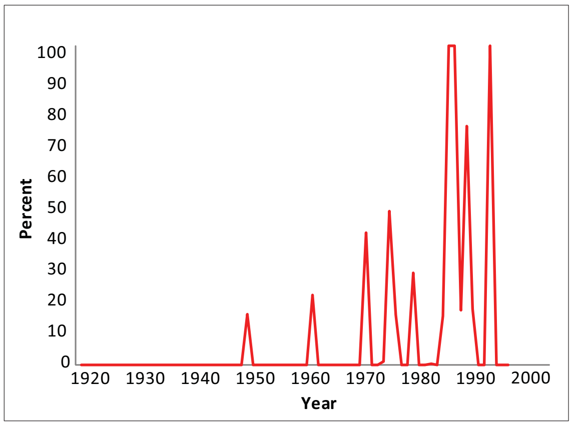
Area (%) affected by drought : Kassala State



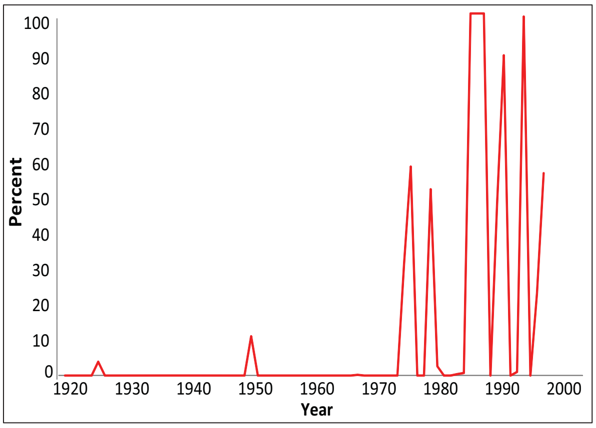
Area (%) affected by drought : Gedaref State



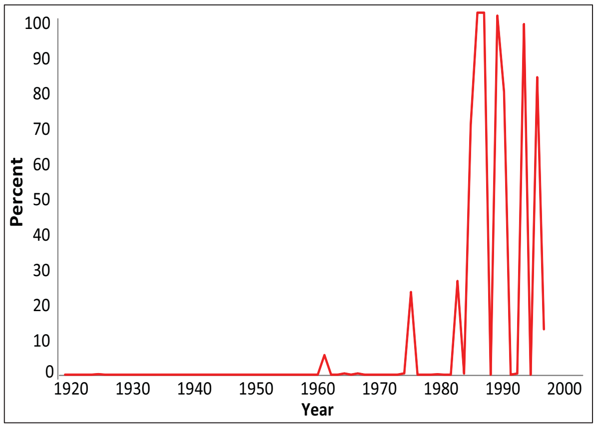
Area (%) affected by drought : Blue Nile State



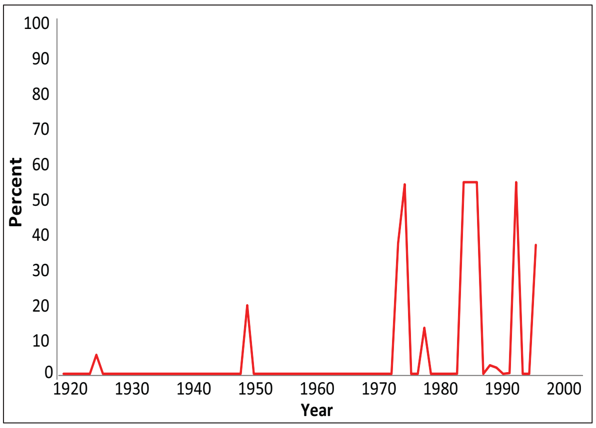
Area (%) affected by drought : Gezira State



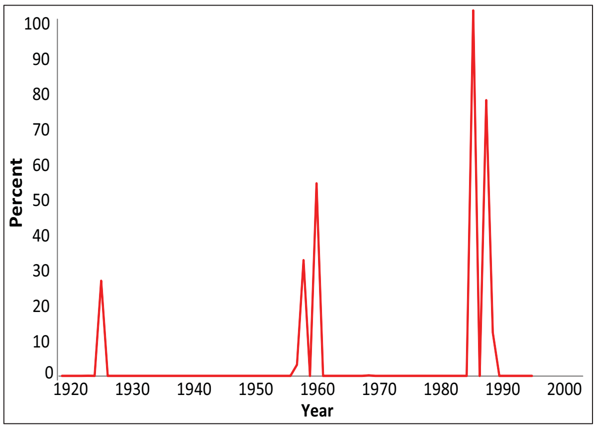
Area (%) affected by drought : Western Darfur State



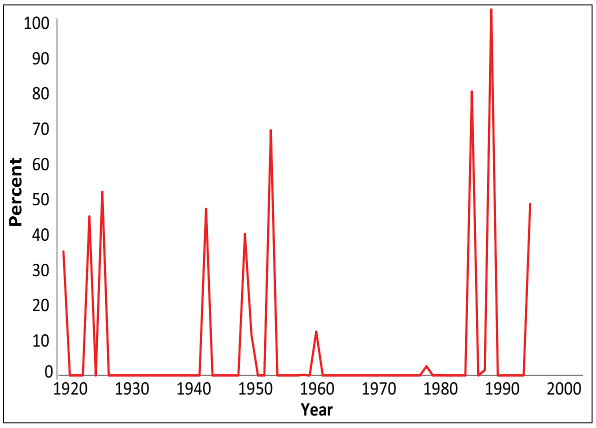
Area (%) affected by drought : South Darfur State



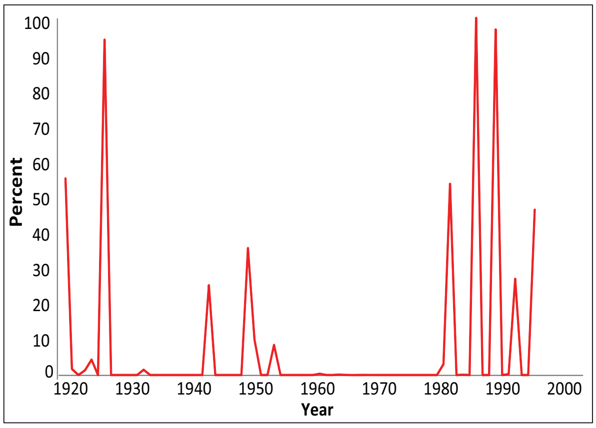
Area (%) affected by drought : North Darfur State



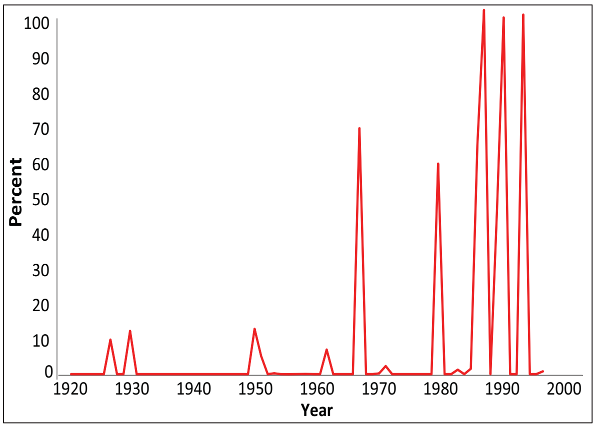
Area (%) affected by drought : Lakes State



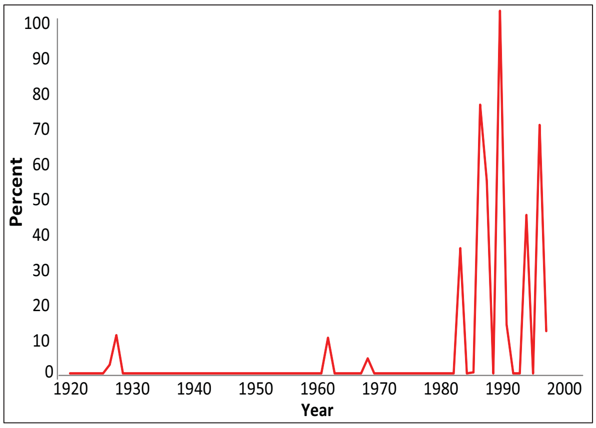
Area (%) affected by drought : Bahr el Jabal State



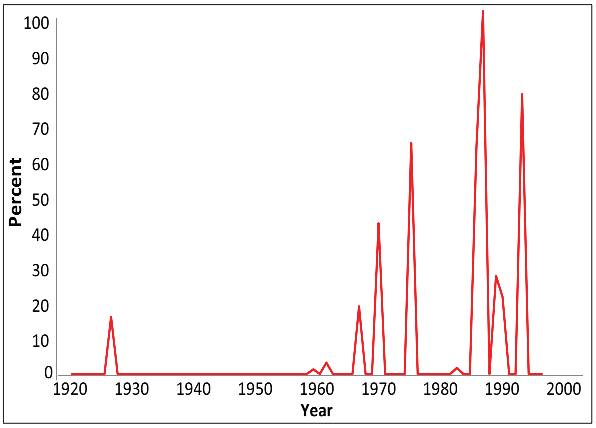
Area (%) affected by drought : Eastern Equatoria State



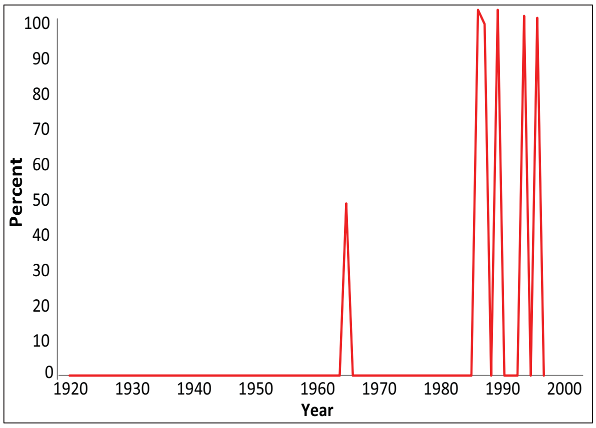
Area (%) affected by drought : Upper Nile State



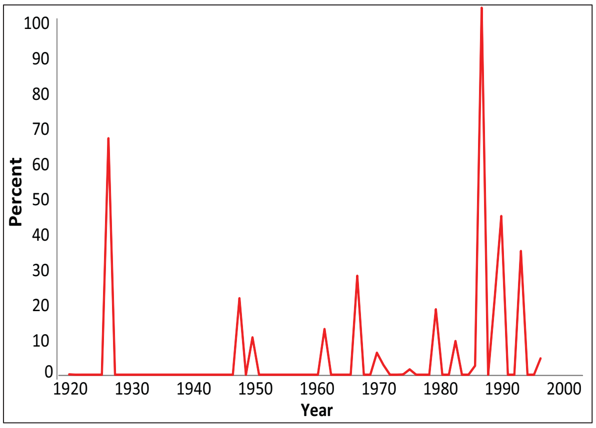
Area (%) affected by drought : Western Bahr el Ghazal State



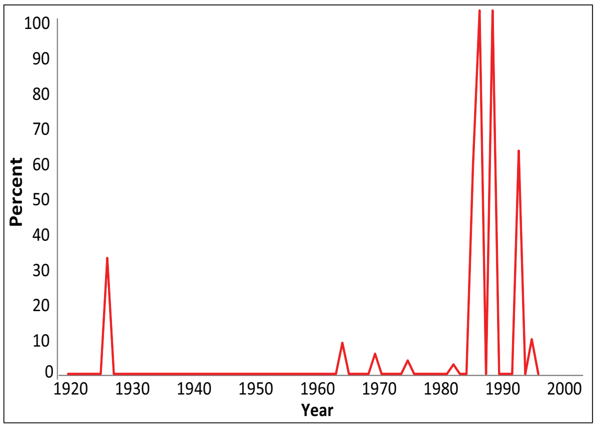
Area (%) affected by drought : Unity State



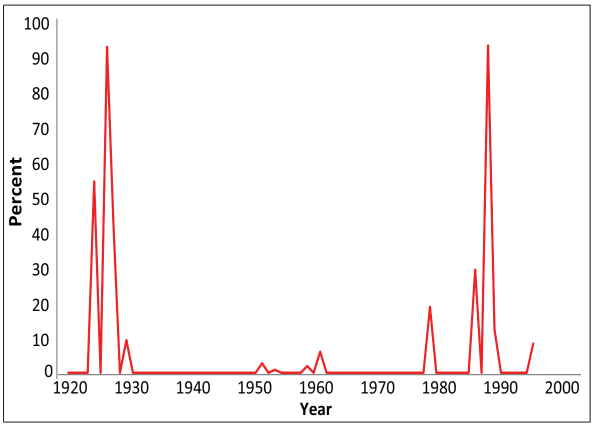
Area (%) affected by drought : Northern Bahr el Ghazal State



Area (%) affected by drought : Jonglei State



Area (%) affected by drought : Warrab State



Area (%) affected by drought : Western Equatoria State

About ICARDA and the CGIAR

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is one of 15 centers supported by the CGIAR. ICARDA's mission is to contribute to the improvement of livelihoods of the resource-poor in dry areas by enhancing food security and alleviating poverty through research and partnerships to achieve sustainable increases in agricultural productivity and income, while ensuring the efficient and more equitable use and conservation of natural resources.

ICARDA has a global mandate for the improvement of barley, lentil and faba bean, and serves the non-tropical dry areas for the improvement of on-farm water use efficiency, rangeland and small-ruminant production. In the Central and West Asia and North Africa region, ICARDA contributes to the improvement of bread and durum wheats, kabuli chickpea, pasture and forage legumes, and associated farming systems. It also works on improved land management, diversification of production systems, and value-added crop and livestock products. Social, economic and policy research is an integral component of ICARDA's research to better target poverty and to enhance the uptake and maximize impact of research outputs.

CGIAR is a global research partnership that unites organizations engaged in research for sustainable development. CGIAR research is dedicated to reducing rural poverty, increasing food security, improving human health and nutrition, and ensuring more sustainable management of natural resources. It is carried out by the 15 centers who are members of the CGIAR Consortium in close collaboration with hundreds of partner organizations, including national and regional research institutes, civil society organizations, academia, and the private sector. WWW.cgiar.org