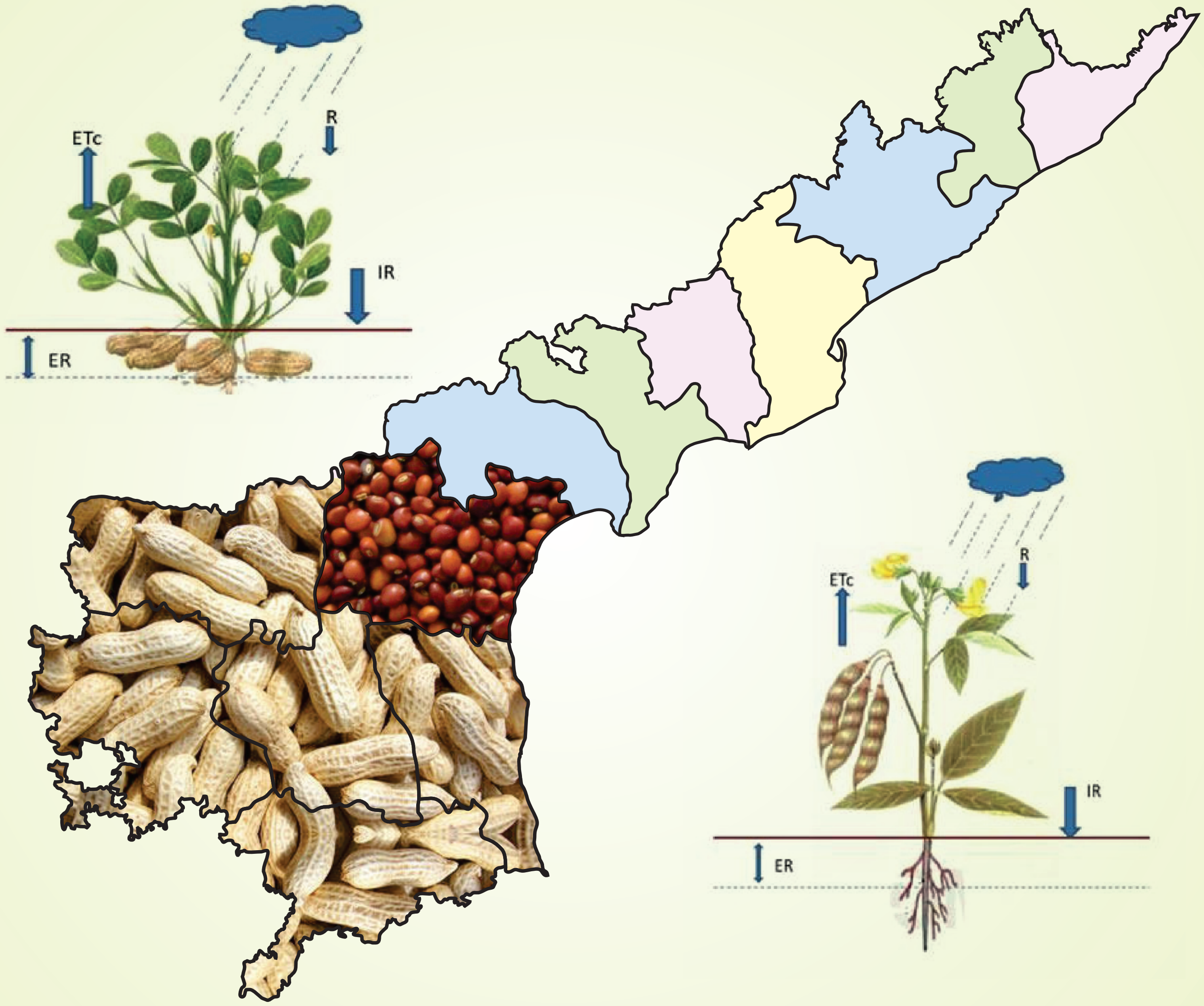
ATLAS on

Climate Change Impacts on Crop Water Balance of Groundnut (*Arachis hypogaea*) and Pigeon pea (*Cajanus cajan*) in Rainfed Districts of Andhra Pradesh



K S Reddy, M Kumar, V Maruthi, N Ravi Kumar, M Maheswari,
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National Innovations on Climate Resilient Agriculture

ICAR-Central Research Institute for Dryland Agriculture

Hyderabad - 500059, India

CRIDA

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Citation:

Reddy K S, Kumar M, Maruthi V, Ravi Kumar N, Maheswari M, Sikka A K, Lakshminarayana P, Vijayalakshmi, Umesha B and Reddy Y V K (2015). Atlas on Climate Change Impacts on Crop Water Balance of Groundnut (*Arachis hypogaea*) and Pigeon pea (*Cajanus cajan*) in Rainfed districts of Andhra Pradesh. ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, PP:100

Copies : 200

Published by

The Director

ICAR-Central Research Institute for Dryland Agriculture

Hyderabad - 500059, India

Ph: 040-24530177 Fax: 040-24531802

Website : http://www.crida.in

Email: director@crida.in

ISBN No: 978-93-80883-33-5

Cover page by K S Reddy and P Lakshminarayana

Printed at

Heritage Print Services Pvt Ltd.

B-11/9, Modern Bread Lane, IDA, Uppal, Hyderabad - 500 039   Phone : 040-27201927

सत्यमेव जयते

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कृषि अनुसंधान और शिक्षा विभाग एवं
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FOREWORD

Enhancing climate resilience in rainfed production systems through effective water resource planning and management is of paramount importance for achieving desirable goals of food production and sustainability. Among several other crops, India is the major producer of groundnut and pigeon pea in the world, of which 80% groundnut and 90% pigeon pea area is rainfed. These crops severely suffer from early, mid-season and terminal droughts resulting in low yields and poor productivity. These adverse impacts are likely to be aggravated amidst anticipated climate change and variability as these climatic effects will result in drastic changes in crop water balance. Since, the productivity enhancement of rainfed groundnut and pigeon pea crops is the main concern; there is a need to understand the dynamic relationship between crop water balance and climate change for effective water resource planning and development.

Andhra Pradesh is the key producer of groundnut and pigeon pea within India. Owing to its diversity in agro ecological situations, location specific requirements and land use, the crop water balance varies, affecting the crop production in rainfed districts. Therefore, the problem of climate change may need to be addressed first at regional level and later at national level as a part of adaptation and mitigation strategies. Increased frequency of untimely high intensity rains upset the soil-water balance for which rainwater harvesting can act as a technology stopgap in placing appropriate crops and cropping systems at farm level in Andhra Pradesh where Groundnut and pigeon pea are grown primarily as rainfed crops. For efficient use of harvested rain water or for managing ground water, documenting the components of water balance will come in handy in saving crops from extreme weather events. Besides these, documentation would also help in effective water resources planning and management. In this context, this Atlas with Geospatial maps is brought out which deals with the issues pertaining to crop water balance and mapping the dynamics of its components in rainfed areas of the state of Andhra Pradesh.

The present analysis of crop water balance in the form of rain fall, effective rainfall (green water), crop evapotranspiration and irrigation water requirements for six rainfed districts of Andhra Pradesh was attempted by taking the downscaled long term climate data of ECHam5 GCM model for A1b scenario considering the decadal variations in the form of geospatial maps. This study would be helpful in implementing Integrated Crop Management Technologies (ICMT) for improved natural resource use and also in formulating policies for adaptation strategies in the context of climate change/variability for managing extreme weather events.

I congratulate all the authors in bringing out such detailed maps on various components of crop water balance which could be utilized for developing water foot print for Andhra Pradesh.

(S. Ayyappan)

Dated the 9th June, 2015
New Delhi

PREFACE

Rainfed agricultural production systems are primarily dependent on climate parameters including rainfall, temperature, wind velocity, sunshine hours/solar radiation etc among which rainfall is the critical input resource. It significantly varies over time and space with erratic distribution having coefficient of variation (CV) in the range of 30 to 80% in all the semi arid regions. The other crop water balance parameters effective rainfall, crop evapotranspiration, irrigation water requirement during crop seasons, have dynamic relationship with the quantity and distribution pattern of rainfall.

IPCC AR5 report indicated the decrease in rainfall in southern part of the country with extreme events of drought, and its frequency, decrease in rainy days which are primarily concerns of rainfed agriculture. The two states of Andhra Pradesh and Telangana have maximum area (67%) under rainfed agriculture with major crops of maize, cotton, groundnut and pigeon pea grown in the 16 districts of two states. Therefore an attempt is made to analyze the decadal variation of crop water balance parameters in 16 districts of Telangana and Andhra Pradesh. The data and its variation are shown in the geospatial maps of Telangana and Andhra Pradesh for easy understanding to the readers in the form of atlas for each state.

The atlas is the outcome of the work related to modeling of crop water balance for groundnut and Pigeon pea in rainfed districts of Andhra Pradesh state. It was an important activity on potential of rainwater harvesting and utilization under NICRA project of ICAR-CRIDA. We thank Dr. S. Ayyappan , Director General, ICAR and Secretary, DARE and Dr. A.K. Sikka, DDG (NRM) for their keen interest, guidance and constant support. We also express our sincere thanks to Director, CRIDA and Principal Investigator, NICRA for extending necessary support and encouragement.

We take this opportunity to thank "Climate Change, Agriculture and Food Security (CCAFS)" for providing base data (1961-1990) and ECHam5 data as open source from Marksim DSSAT. We are also thankful to FAO, Rome for providing CROPWAT V8.0 simulation software.

We also extend thanks to Dr. Abdul Islam for critically evaluating the findings and suggestions to improve upon. We recognize the help rendered by students of College of Agricultural Engineering, Madakasira and Sangareddy.

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1 Introduction

The productive characteristics and agricultural potential of a region are strongly related to its climate conditions, and these have changed in an unprecedented way world wide in the last 70 years(de la Casa and Ovando, 2014). Climate projections show that atmospheric concentration of GHG would reach almost 685 parts per million (ppm) CO_2 equivalents by 2050. It is well above the concentration level of 450 ppm required to have at least a 50% chance of stabilising the climate at a 2°C global average temperature increase, the goal set at the 2010 United Nations Framework Convention on Climate Change (CRIDA, 2013). Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties that persists for an extended period of time. Climate change is caused by factors such as biotic processes, variations in solar radiation, volcanic eruptions, the industrial and air pollution caused by CO_2 and other GHG emissions affecting the climate parameters of temperature, rainfall, crop evapotranspiration and green water within the root zone in various agriculture production systems. Global temperature rise, ultimately results in warming of oceans, shrinking ice sheets influencing the changes in hydrologic components of climate. The potential future effects of global climate change include more frequent wildfires; longer periods of drought in some regions; increase in frequency of droughts, increase in duration and intensity of tropical storms (IPCC, 2007). These impacts would have paramount influence in the crop water balance of rainfed agriculture which contributes 40% of food basket in the country (CRIDA, 2013). Fischer et al. (2007) analysed the climate change impacts on irrigation requirements based on daily water balance and concluded that mitigation strategies of climate can reduce by about 40% in agricultural water requirements as comparison to unmitigated climate.

According to recent IPCC report (IPCC, 2014), the global-scale precipitation is projected to gradually increase in the 21st century. Many subtropical arid and semi-arid regions are likely to experience less precipitation, affecting the crop production. The model predictions indicated, runoff may increase in Northern latitudes and decrease in Southern regions (IPCC, 2014). On a global scale, there are many indications that climate change will continue and could result in major shifts in biomes by the turn of the century (Bergengren et al., 2011; Tebaldi et al., 2006; Oreskes., 2004).

Asian agriculture is responsible for two thirds of global agricultural GDP (Mendelsohn, 2014) with the most populous continent on earth accounting for 63% of the global population. With the green revolution, they contribute 67% of global agricultural productivity. Agriculture requires 70%, industrial 19% and domestic sector 11% of the total utilisable water (Bruinsma., 2003). The impacts of climate change upon crop yield and food security are significant, with a projected range, between 5 and 200 million additional people at risk of hunger by 2100 (Schmidhuber and Tubiello., 2007). Climate change and climate variability have been impacting Indian agriculture by changing the rainfall which is likely to decline by 5 to 10% over southern parts of India whereas, 10 to 20% increase is likely over other regions (CRIDA, 2013). Gosain et al. (2006) studied the climate change effects on Indian river basins and concluded that the flows may be reduced in Krishna river with catchments from both Andhra Pradesh and Telangana causing droughts. Chowdhury et al. (2013) has made sensitivity analysis of crop growing seasons and found that the shift of wheat growing season might conserve significant amount of groundwater. There are many studies exploring how climate change may affect crops and farmers in China (Wang et al., 2009, 2014; Chen et al., 2014; Holst et al., 2013) and India (Kumar and Parikh., 1998; Sanghi and Mendelsohn., 2008) as well as other Asian countries (Seo et al., 2005).

In India, around 68% of the country is prone to drought in varying degrees and 35% of which receives rainfall between 750 mm and 1125 mm is considered drought prone while 33% receiving less than 750 mm is chronically drought prone (MoWR, 2014). Climate change will cause increased frequency of extreme events such as floods and droughts. India will lose more than 20% of their crop net revenue due to temperature rise of 1.5°C and it is two thirds of the net revenue loss in Asia (Mendelsohn., 2014). Impact of climate change on crops grown in India is more on winter crops in central and south-central zones but in south-west zone, climate change effect is more on monsoon crops (Srivastava et al., 2010).

As per the India's Second National Communication submitted to the United Nations Framework Convention on Climate Change (UNFCCC), it is projected that the annual mean surface air temperature rise by the end of the century ranges from 3.5 ^{0}C to 4.3 ^{0}C whereas the sea level along the Indian coast has been rising at the rate of about 1.3 mm/year on an average (Anonymous., 2012). These climate change projections are likely to impact human health, agriculture, water resources, natural ecosystems, and biodiversity. India's first National Action Plan on Climate Change (NAPCC) emphasized the need for assessing the existing and future policies and programs addressing climate mitigation and adaptation. In the report, the key issues identified are reduction in winter rainfall and temperature fluctuations affecting rabi crops in the rainfed areas. Similarly, it is reported that there is a decrease in cropped area in south-west monsoon due to insufficient rainfall.

The Food and Agriculture Organization (FAO) developed CROPWAT model for estimating the crop evapotranspiration, effective rainfall and irrigation requirement during the crop growth period. Several researchers have used CROPWAT in their estimations for its reliability in estimating the crop water balance and irrigation scheduling (Kuo et al., 2006 and Stancalie et al., 2010). CROPWAT software has been widely used for predicting CWR, irrigation rescheduling, reference evapotranspiration, deficit irrigation scheduling and cropping patterns in countries like Greece, Taiwan, Africa, USA, Morocco, Turkey, Zimbabwe and Pakistan (George et al., 2000, Anadranistakis et al., 2000, Kuo et al., 2006, Wahaj et al., 2007, Kang et al., 2009, Nazeer, 2009, Mimi and Jamous, 2010, Stancalie et al., 2010). Kuo et al. 2006 found that CWR predicted by CROPWAT was accurate for scheduling irrigation under different water management systems.

Estimates of crop water balance for different crops provide valuable information for efficient water resource management (Zhang et al., 2010). Pleban and Israeli (1989) advocated on-farm water balance as the normal method for deciding how much water to apply per irrigation. Arora and Gajri (2000) combined a crop growth simulator (SUCROS) with a water balance model (WBM) to forecast maize growth and yield in a subtropical environment. Anadranistakis et al. (2000) estimated and validated Crop Water Requirement (CWR) for cotton, wheat and maize in Greece. Bocchiola et al. (2012) studied the effect of prospective climate change (considered climate variations with focus upon temperature, precipitation, and CO_2) upon crop yield, and related water footprint of maize (Zea mays L.) in Po valley of Northern Italy using CropSyst model. Assessment of crop water balance components like rainfall, crop evapotranspiration, effective rainfall (Green water) and irrigation water requirement are very important for future foot print estimations in rainfed agriculture in the context of climate change in southern region of country. In the event of climate change impacts on rainfall shifts in the region, it is essential to consider different sowing windows of the crops. In Andhra Pradesh, two crops namely pigeon pea (Cajanus cajan) and groundnut (Arachis hypogaea) are grown extensively in rainfed districts of Andhra Pradesh. These crops were selected for crop water balance analysis in the report and for preparing the Atlas.

2 Materials and Methods

2.1 Study area

Andhra Pradesh which has two Agro climatic regions/zones (ACR), southern plateau and hills (I) and East coast plains and hills (II) comprising the sub regions of southern zone (700-1100 mm) and scarce rainfall zones (500-750 mm) (Prasad et al. 2012). The sub regions of ACR lies in the Rayalaseema region of Andhra Pradesh covering the districts of Nellore, Chittoor, Kadapa, Anantapur, Kurnool and part of Prakasam. All these districts are rainfed in which groundnut (Arachis hypogaea) is grown as major kharif crop except in Prakasam district where pigeon pea (Cajanus cajan) is predominant crop. Both Nellore and Prakasam have coast line but the majority of the area is under rainfed agriculture, having mixture of influence from south west and north east monsoons on production systems. The major soils in the area are red sandy soils. The location map of the study area is given in Fig.2.1.

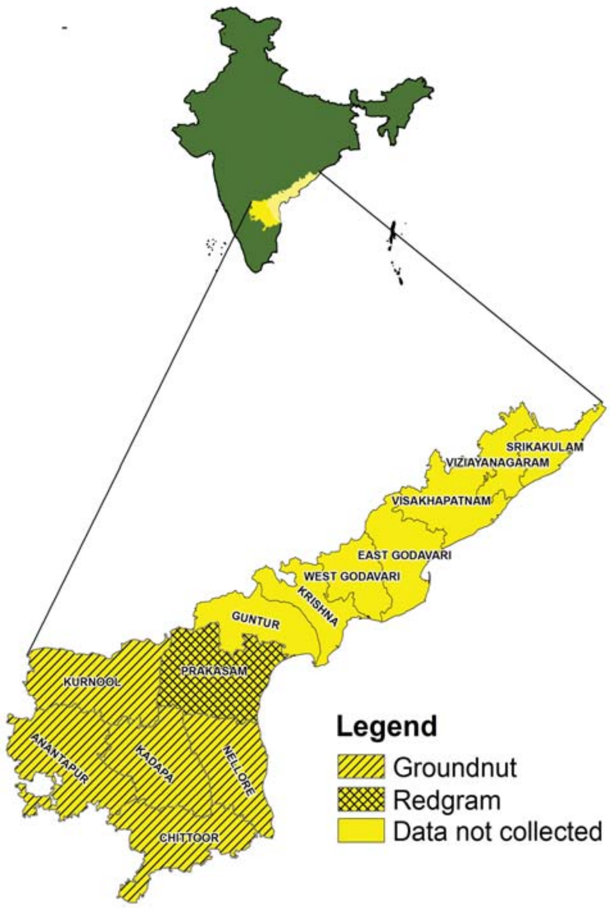

Fig 2.1 Location map of the study area

2.2 Input data

Daily climate data used in this study were obtained from CCAFS-MarkSim™ DSSAT weather file generator (web: http://gismap.ciat.cgiar.org/MarkSimGCM/) which uses the well-known MarkSim™ application (Jones & Thornton 2000, Jones et al 2002) working off a 30 arc-second climate surface derived from WorldClim (Hijmans et al., 2005). MarkSim was developed in the 1980 and 1990 to simulate weather from known sources of monthly climate data from around the world. It divides the world into 720 clusters of climate that were all distinct from one another and fitted a third order Markov model to the precipitation data. The temperature data simulation was derived from SIMMETEO model (Geng et al., 1988). The radiation data were based on the model of Donatelli and Campbell (1997). The data has been compared with observed weather data from Gunegal Research Farm (Telangana) for validation. There is a good agreement between MarkSim base period data and those of observed values. MarkSim DSSAT data are from globally valid models that does not need recalibration every time. Data of Base Period (1961-1990) and Projected Period (2011- 2050) were downloaded for ECHam5 model (Roeckner et al. 2003), A1b scenario (As usual scenario). Though there are several GCM models providing downscale geospatial climate data from the MarkSim DSSAT, the ECHam5 for A1b scenario was preferred due to its more prominent use in climate change analysis (Kumar et al.2013; Kolli et al. 2006; Almazroui. 2013; Gerten et al., 2011; Bouwer et al. 2006; Kazmi et al. 2014; Park et al.2011; Conde et al. 2011; Ines and Hansen. 2006; Dobler and Ahrens. 2010; Henriksson et al.2011) in irrigation water management. A1b scenario represent medium atmospheric CO_2 concentration, based on the assumptions of future population and economic growth (IPCC, 2007). A1b scenario in which CO_2 level are in the range of 445-535 ppm. The DSSAT provides the climate data of rainfall, max and min temperatures and solar radiation on daily basis. These climate files downloaded for the period from 2011 to 2050 were used as input for estimating crop water balance.

The information on different crops and their sowing windows were collected from Contingency manual of peninsular India by Prasad et al (2012). The summary of the input data given to the CROPWAT model is given in Table 2.1 to 2.3.

2.3 Estimation of crop water balance parameters

Crop water balance parameters include the effective rainfall, crop evapotranspiration and irrigation requirement and calculated using CROPWAT Model. The inputs rainfall, temperature(min, max), solar radiation and crop parameters were given to CROPWAT model to calculate crop water balance parameters during crop growth period.

Table 2.1. Climate data and crop parameter sources

Parameters	Source	Model
Precipitation, minimum and maximum temperature, solar radiation	CCAFS-MarksimTM DSSAT weather file generator	ECHam5-A1b Scenario
Crop type, crop sowing dates	Contingency Plan, CRIDA	–
Crop Parameters (K_c, stage, rooting depth, crop height, and growth period)	FAO-CROPWAT model	CROPWAT v8.0

Table 2.2. Crop coefficients used in CROPWAT model

Crop	Parameter	Season					Total days
		Initial	Development	Mid	Late	Harvest	
Groundnut	K_c values	0.4	–	1.15	–	0.6	–
	Stage (Days)	25	35	45	25	–	130
	Rooting Depth (m)	0.3	–	–	0.8	–	–
	Crop height (m)		–	0.4	–	–	–
Pigeon pea	K_c values	0.4	–	1.15	–	0.35	–
	Stage (Days)	20	30	40	20	–	110
	Rooting Depth (m)	0.3	–	–	1	–	–
	Crop height (m)		–	0.4	–	–	–

Source: FAO, 2008

Table 2.3. Crop sowing windows selected for groundnut and pigeon pea

District	Groundnut		Pigeon pea	
	Normal Sowing	Late Sowing	Normal Sowing	Late Sowing
Prakasam	–	–	Jul-25	Aug-15
Anantapur	Jul-10	Aug-10	–	–
Kadapa	Jun-10	Jul-10	–	–
Kurnool	Jul-10	Aug-10	–	–
Chittoor	Jun-10	Jul-10	–	–
Nellore	May-10	Jun-10	–	–

Source: Prasad et al. 2012

2.3.1 CROPWAT model

CROPWAT is a decision support tool developed by the Land and Water Development Division of FAO for calculation of crop water requirements (CWR) and irrigation requirements based on soil, climate and crop data. In addition to this, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. All calculation procedures used in CROPWAT model is based on the FAO publications of the Irrigation and Drainage Series, namely, No. 56: Crop evapotranspiration -Guidelines for computing crop water requirements and No. 33: Yield response to water.

CROPWAT is a collection of modules that integrates the several models necessary to predict CWR, irrigation water management and crop scheduling (Smith, 1992). CWR represent the amount of water to be supplied and ET_c represents the amount of water that crop loses due to evapotranspiration into atmosphere. Crop water balance estimation require data on Climate (minimum and maximum temperature,^{0}C; humidity,%; wind, km/day; Sunshine, hours; and Radiation, MJ/m^2/day;) rainfall (to calculate effective rainfall), crop type and crop parameters (K_c values, Stage days, critical depletion factor, Yield response factor, crop height).

2.3.2 Reference evapotranspiration

The FAO Penman-Monteith method is used for determining reference evapotranspiration (ET_o) due to its accuracy and reliable estimate. The method has been selected because it provides very consistent estimate with actual crop water use data worldwide, as it has been demonstrated through many years in the scientific literature. This method overcomes the shortcoming of previously recommended methods, and explicitly incorporates both physiological and aerodynamic parameters. Moreover, procedures have been developed for using this method even with limited climatic data, as used in the present study. The equation for Reference Evapotranspiration is given by:

$$\mathbf{ET_o} = \frac{0.408\Delta(R_n - G) + \gamma(900/(T+273))U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34\ U_2)} \quad \text{——————(1)}$$

Where,

$\mathbf{ET_o}$	=	Reference evapotranspiration [mm day^{-1}],
$\mathbf{R_n}$	=	Net radiation at the crop surface [MJ m^{-2} day^{-1}],
G	=	Soil heat flux density [MJ m^{-2} day^{-1}],
T	=	Mean daily air temperature at 2 m height [°C],
$\mathbf{U_2}$	=	Wind speed at 2 m height [m s^{-1}],
$\mathbf{e_s}$	=	Saturation vapour pressure [kPa],
$\mathbf{e_a}$	=	Actual vapour pressure [kPa],
$\mathbf{e_s - e_a}$	=	Saturation vapour pressure deficit [kPa],
Δ	=	Slope vapour pressure curve [kPa °C^{-1}],
γ	=	Psychrometric constant [kPa °C^{-1}].

2.3.3 Crop evapotranspiration

The crop evapotranspiration (ET_c) is calculated by multiplying reference evapotranspiration (ET_o) with appropriate crop coefficients (K_c) at different growth stages. The first step in the CROPWAT software gives the output on decadal days (10 days interval) for the entire crop growth period. ET_c is obtained by the following equaiton:

$$ET_c = K_c * ET_o \quad \text{————————(2)}$$

where,

ET_c = Crop evapotranspiration (mm/day),

ET_o = Reference evapotranspiration (mm/day);

K_c = Crop coefficient at a specific growth stage.

K_c depends on the type of crop (e.g., height of crop, resistance of canopy, albedo), soil and climatic parameters, such as, soil surface, evaporation and wind speed and direction (FAO, 1998; Smith and Kivumbi, 2006).

2.3.4 Effective rainfall

In assessing CWR for a crop, it is essential to understand the effective rainfall (ER) over the cultivated area. The effective rainfall can be calculated using the Soil Conservation Service method of USDA(1967). Effective rainfall is the portion of rainfall that infiltrates into the root zone during growth period of a crop and is available to meet consumptive water requirements. The effective rainfall is calculated by the following formulae:

$$P_{eff(dec)} = \frac{P_{dec} * (125 - 0.6 * P_{dec})}{125} \quad \text{if } P_{dec} <= (250 / 3) \text{ mm} \quad \text{————————(3)}$$

$$P_{eff(dec)} = \left(\frac{125}{3}\right) + 0.1 * P_{dec} \quad \text{if } P_{dec} > (250 / 3) \text{ mm} \quad \text{————————(4)}$$

Where,

$P_{eff(dec)}$ = 10 days effective rainfall,

P_{dec} = 10 days rainfall

2.3.5 Irrigation requirement

The irrigation requirement (IR), expressed in mm and computed over a certain period of time, expresses the difference between the crop evapotranspiration (ET_c) under standard conditions and the effective rainfall (ER) contributions over the same time step. Irrigation requirement indicatively represents the fraction of the crop water requirements that needs to be satisfied through irrigation contributions in order to achieve optimal crop growing conditions.

2.4 Decadal averages

The year wise calculated crop water balance parameters for crop growth period during normal and late sowing windows were used to calculate the decadal averages. The average of 10 years data is called decadal average. The decadal average is calculated for 2011 to 2020, 2021 to 2030, 2031 to 2040 and 2041 to 2050.

2.5 Decadal percent deviation

Decadal percent deviation of each decade over base period (1961-1990) was calculated using the formula as given below.

$$\text{Decadal percent deviation} = \frac{\text{Decadal average value} - \text{Base period value}}{\text{Base period value}} \times 100 \text{ ————(5)}$$

Where,

Base period = 1961-1990,

Decadal average value = average of period 2011-2020(D_1), 2021-2030(D_2), 2031-2040(D_3) and 2041-2050(D_4).

2.6 Spatial maps

The base period, decadal and decadal percent deviation spatial maps for rainfall (R), effective rainfall(ER), crop evapotranspiration (ET_c) and irrigation requirement (IR) were prepared by using software Arc GIS 9.3.

2.7 Limitations of the present study

(a) The CCAFS-MarkSim DSSAT model data has been compared with observed weather data of one location of Ranga Reddy district due to non-availability of weather data for the base period for other districts.

(b) The present analysis is based on the downscaled ECHam5 GCM model data for A1b scenario. For changed scenario, the results may be further corroborated.

(c) Since the relationship between CO_2 concentration and its effect of evapotranspiration for various crops in the region under consideration is not available, the present study considered the medium CO_2 concentration of 445-535 ppm. Some correction factor may be devised in future when such information are available for region and crops.

(d) The time horizon in different scenario usually are 30 years period, the present study deals with the decadal changes in the different parameters of crop water balance.

3 Climate change impacts on crop water balance of groundnut and pigeon pea

The results on crop water balance (rainfall, effective rainfall, crop evapotranspiration and irrigation requirement) for normal(NS) and late sowing(LS) windows of each district were given below. The results included the projected crop water balance (D_1: 2011-2020, D_2: 2021-2030, D_3: 2031-2040 and D_4: 2041-2050) and the their percent deviation from the base period 1961-1990. The number of prepared spatial maps are given in Table.3.1.

Table 3.1. Number of spatial maps for crop water balance parameters

Data Type	Sowing period	Rainfall	Effective Rainfall	Crop Evapo transpiration	Irrigation Requirement	Total
Base Period (1961-1990)	Normal	1	1	1	1	4
	Late	1	1	1	1	4
Decadal Period	Normal	4	4	4	4	16
(D_1, D_2, D_3 and D_4)	Late	4	4	4	4	16
Decadal percent	Normal	4	4	4	4	16
Deviation over base period	Late	4	4	4	4	16
Total		18	18	18	18	72

The modelled data on decadal average crop water balance parameters of groundnut and pigeon pea in rainfed districts of Andhra Pradesh during crop growth period are given in Table 3.2. The decadal percent deviation of crop water balance parameters of groundnut and pigeon pea with respect to base period is given in Table 3.3. The summary of climate change impacts on crop water balance of groundnut and pigeon pea is given in Table 3.4.

The spatial maps on projected decades 2011-2020, 2021-2030, 2031-2040 and 2041-2050 for rainfall, effective rainfall, crop evapotranspiration and irrigation requirement for normal and late sowing windows are given in Figures 3.1 to 3.40. The spatial maps on percent deviation of rainfall, effective rainfall, crop evapotranspiration and irrigation requirement with respect to base period for normal and late sowing windows are given in Figures 3.41 to 3.72.

Table 3.2. Decadal crop water balance in rainfed districts of Andhra Pradesh during crop growth period

A. PRAKASAM; Crop: Pigeon pea

Normal Sowing(NS): Jul- 25; Late Sowing(LS): Aug-15;

Crop Growth Period (CGP):110 days

Parameter	BP		Decadal average of crop water balance (mm)							
			D_1		D_2		D_3		D_4	
	NS	LS	NS	LS	NS	LS	NS	LS	NS	LS
Rainfall(R)	397.60	344.20	467.21	386.98	437.90	352.33	450.02	373.99	456.89	379.39
Reference	Fig.3.1	Fig.3.5	Fig.3.9	Fig.3.13	Fig.3.17	Fig.3.21	Fig.3.25	Fig.3.29	Fig.3.33	Fig.3.37
Effective Rainfall (ER)	223.90	179.60	333.34	274.76	323.92	265.01	334.89	286.14	340.43	289.69
Reference	Fig.3.2	Fig.3.6	Fig.3.10	Fig.3.14	Fig.3.18	Fig.3.22	Fig.3.26	Fig.3.30	Fig.3.34	Fig.3.38
Crop Evapotranspiration (ET_c)	376.70	350.90	348.55	303.96	351.02	305.21	353.08	306.25	355.26	307.40
Reference	Fig.3.3	Fig.3.7	Fig.3.11	Fig.3.15	Fig.3.19	Fig.3.23	Fig.3.27	Fig.3.31	Fig.3.35	Fig.3.39
Irrigation Requirement(IR)	205.40	197.50	106.55	106.25	111.51	105.94	98.93	92.10	100.07	86.27
Reference	Fig.3.4	Fig.3.8	Fig.3.12	Fig.3.16	Fig.3.20	Fig.3.24	Fig.3.28	Fig.3.32	Fig.3.36	Fig.3.40

BP: Base Period (1961-1990); D_1: 2011-2020; D_2: 2021-2030; D_3:2031-2040; D_4:2041-2050

B. ANANTAPUR; Crop: Groundnut

Normal Sowing(NS): Jul-10; Late Sowing(LS):Aug-10;

Crop Growth Period (CGP):130 days

Parameter	BP		Decadal average of crop water balance (mm)							
			D_1		D_2		D_3		D_4	
	NS	LS	NS	LS	NS	LS	NS	LS	NS	LS
Rainfall(R)	251.60	204.60	407.16	359.98	398.77	370.43	388.20	369.26	407.85	387.28
Reference	Fig.3.1	Fig.3.5	Fig.3.9	Fig.3.13	Fig.3.17	Fig.3.21	Fig.3.25	Fig.3.29	Fig.3.33	Fig.3.37
Effective Rainfall (ER)	194.40	152.10	313.49	268.41	307.56	279.07	299.89	282.75	306.12	294.27
Reference	Fig.3.2	Fig.3.6	Fig.3.10	Fig.3.14	Fig.3.18	Fig.3.22	Fig.3.26	Fig.3.30	Fig.3.34	Fig.3.38
Crop Evapotranspiration (ET_c)	468.20	441.80	488.45	403.20	485.86	398.22	485.85	395.11	489.08	395.89
Reference	Fig.3.3	Fig.3.7	Fig.3.11	Fig.3.15	Fig.3.19	Fig.3.23	Fig.3.27	Fig.3.31	Fig.3.35	Fig.3.39
Irrigation Requirement (IR)	304.70	312.00	203.93	206.98	200.61	187.26	206.02	178.99	207.29	173.49
Reference	Fig.3.4	Fig.3.8	Fig.3.12	Fig.3.16	Fig.3.20	Fig.3.24	Fig.3.28	Fig.3.32	Fig.3.36	Fig.3.40

BP: Base Period (1961-1990); D_1: 2011-2020; D_2: 2021-2030; D_3:2031-2040; D_4:2041-2050

C. KADAPA; Crop: Groundnut

Normal Sowing(NS): Jun-10; Late Sowing(LS):Jul-10;
Crop Growth Period (CGP):130 days

Parameter	BP		Decadal average of crop water balance (mm)							
			D_1		D_2		D_3		D_4	
	NS	LS	NS	LS	NS	LS	NS	LS	NS	LS
Rainfall(R)	330.90	302.40	675.10	567.58	674.67	610.44	633.97	537.23	580.46	522.42
Reference	Fig.3.1	Fig.3.5	Fig.3.9	Fig.3.13	Fig.3.17	Fig.3.21	Fig.3.25	Fig.3.29	Fig.3.33	Fig.3.37
Effective Rainfall (ER)	249.90	236.70	359.85	297.41	358.17	309.60	315.45	283.90	324.27	288.14
Reference	Fig.3.2	Fig.3.6	Fig.3.10	Fig.3.14	Fig.3.18	Fig.3.22	Fig.3.26	Fig.3.30	Fig.3.34	Fig.3.38
Crop Evapotranspiration (ET_c)	492.60	461.50	470.93	418.84	498.04	430.42	501.22	431.79	510.28	437.85
Reference	Fig.3.3	Fig.3.7	Fig.3.11	Fig.3.15	Fig.3.19	Fig.3.23	Fig.3.27	Fig.3.31	Fig.3.35	Fig.3.39
Irrigation Requirement(IR)	285.50	267.10	162.77	169.54	172.60	156.42	208.86	188.98	216.45	203.09
Reference	Fig.3.4	Fig.3.8	Fig.3.12	Fig.3.16	Fig.3.20	Fig.3.24	Fig.3.28	Fig.3.32	Fig.3.36	Fig.3.40

BP: Base Period (1961-1990); D_1: 2011-2020; D_2: 2021-2030; D_3:2031-2040; D_4:2041-2050

D. KURNOOL; Crop: Groundnut

Normal Sowing(NS): Jul-10; Late Sowing(LS):Aug-10;
Crop Growth Period (CGP):130 days

Parameter	BP		Decadal average of crop water balance (mm)							
			D_1		D_2		D_3		D_4	
	NS	LS	NS	LS	NS	LS	NS	LS	NS	LS
Rainfall(R)	350.60	173.50	540.93	442.41	535.50	445.31	532.62	435.47	561.32	468.62
Reference	Fig.3.1	Fig.3.5	Fig.3.9	Fig.3.13	Fig.3.17	Fig.3.21	Fig.3.25	Fig.3.29	Fig.3.33	Fig.3.37
Effective Rainfall (ER)	234.80	127.50	369.89	292.37	371.80	298.05	364.68	292.28	380.57	313.01
Reference	Fig.3.2	Fig.3.6	Fig.3.10	Fig.3.14	Fig.3.18	Fig.3.22	Fig.3.26	Fig.3.30	Fig.3.34	Fig.3.38
Crop Evapotranspiration (ETc)	466.00	451.10	481.30	406.22	480.02	404.41	480.61	404.58	482.01	405.42
Reference	Fig.3.3	Fig.3.7	Fig.3.11	Fig.3.15	Fig.3.19	Fig.3.23	Fig.3.27	Fig.3.31	Fig.3.35	Fig.3.39
Irrigation Requirement (IR)	300.90	356.70	161.47	208.61	149.81	202.12	165.12	205.40	151.49	188.43
Reference	Fig.3.4	Fig.3.8	Fig.3.12	Fig.3.16	Fig.3.20	Fig.3.24	Fig.3.28	Fig.3.32	Fig.3.36	Fig.3.40

BP: Base Period (1961-1990); D_1: 2011-2020; D_2: 2021-2030; D_3:2031-2040; D_4:2041-2050

E. CHITTOOR; Crop: Groundnut

Normal Sowing(NS): Jun-10; Late Sowing(LS):Jul-10;
Crop Growth Period (CGP):130 days

Parameter	BP		Decadal average of crop water balance (mm)							
			D_1		D_2		D_3		D_4	
	NS	LS	NS	LS	NS	LS	NS	LS	NS	LS
Rainfall(R)	551.70	435.30	468.38	420.96	485.45	494.77	528.31	554.52	536.06	531.71
Reference	Fig.3.1	Fig.3.5	Fig.3.9	Fig.3.13	Fig.3.17	Fig.3.21	Fig.3.25	Fig.3.29	Fig.3.33	Fig.3.37
Effective Rainfall (ER)	360.70	290.90	365.20	323.73	370.82	357.54	385.49	384.69	394.47	381.10
Reference	Fig.3.2	Fig.3.6	Fig.3.10	Fig.3.14	Fig.3.18	Fig.3.22	Fig.3.26	Fig.3.30	Fig.3.34	Fig.3.38
Crop Evapotranspiration (ETc)	499.80	469.80	481.68	410.56	481.83	408.15	483.61	406.36	479.21	406.75
Reference	Fig.3.3	Fig.3.7	Fig.3.11	Fig.3.15	Fig.3.19	Fig.3.23	Fig.3.27	Fig.3.31	Fig.3.35	Fig.3.39
Irrigation Requirement(IR)	210.70	251.40	158.53	150.73	152.60	129.58	142.82	116.61	141.51	116.12
Reference	Fig.3.4	Fig.3.8	Fig.3.12	Fig.3.16	Fig.3.20	Fig.3.24	Fig.3.28	Fig.3.32	Fig.3.36	Fig.3.40

BP: Base Period (1961-1990); D_1: 2011-2020; D_2: 2021-2030; D_3:2031-2040; D_4:2041-2050

F. NELLORE; Crop: Groundnut

Normal Sowing(NS): May-10; Late Sowing(LS):Jun-10;
Crop Growth Period (CGP):130 days

Parameter	BP		Decadal average of crop water balance (mm)							
			D_1		D_2		D_3		D_4	
	NS	LS	NS	LS	NS	LS	NS	LS	NS	LS
Rainfall(R)	541.70	514.50	518.54	487.36	535.18	519.38	492.95	473.92	504.37	479.48
Reference	Fig.3.1	Fig.3.5	Fig.3.9	Fig.3.13	Fig.3.17	Fig.3.21	Fig.3.25	Fig.3.29	Fig.3.33	Fig.3.37
Effective Rainfall (ER)	380.40	361.80	380.72	357.28	383.88	377.49	360.72	349.50	366.39	350.08
Reference	Fig.3.2	Fig.3.6	Fig.3.10	Fig.3.14	Fig.3.18	Fig.3.22	Fig.3.26	Fig.3.30	Fig.3.34	Fig.3.38
Crop Evapotranspiration (ET_c)	530.10	501.00	560.58	518.50	563.54	520.19	568.65	527.84	574.43	527.90
Reference	Fig.3.3	Fig.3.7	Fig.3.11	Fig.3.15	Fig.3.19	Fig.3.23	Fig.3.27	Fig.3.31	Fig.3.35	Fig.3.39
Irrigation Requirement(IR)	155.90	197.80	191.02	203.50	190.38	199.52	216.59	216.51	224.04	222.64
Reference	Fig.3.4	Fig.3.8	Fig.3.12	Fig.3.16	Fig.3.20	Fig.3.24	Fig.3.28	Fig.3.32	Fig.3.36	Fig.3.40

BP: Base Period (1961-1990); D_1: 2011-2020; D_2: 2021-2030; D_3:2031-2040; D_4:2041-2050

Table 3.3. Decadal percent deviation of crop water balance from base period (1961-1990) in rainfed districts of Andhra Pradesh

A. PRAKASAM; Crop: Pigeon pea

Normal Sowing(NS): Jul- 25; Late Sowing(LS): Aug-15;

Crop Growth Period (CGP):110 days

Parameter	Decadal percent deviation from BP, %							
	D_1		D_2		D_3		D_4	
	NS	LS	NS	LS	NS	LS	NS	LS
Rainfall(R)	17.60	12.43	10.22	2.36	13.27	8.65	15.00	10.22
Reference	Fig.3.41	Fig.3.45	Fig.3.49	Fig.3.53	Fig.3.57	Fig.3.61	Fig.3.65	Fig.3.69
Effective Rainfall(ER)	48.88	52.98	44.67	47.56	49.57	59.32	52.05	61.30
Reference	Fig.3.42	Fig.3.46	Fig.3.50	Fig.3.54	Fig.3.58	Fig.3.62	Fig.3.66	Fig.3.70
Crop Evapotranspiration (ET_c)	-7.47	-13.38	-6.82	-13.02	-6.27	-12.72	-5.69	-12.40
Reference	Fig.3.43	Fig.3.47	Fig.3.51	Fig.3.55	Fig.3.59	Fig.3.63	Fig.3.67	Fig.3.71
Irrigation Requirement(IR)	-48.13	-46.20	-45.71	-46.36	-51.84	-53.37	-51.28	-56.32
Reference	Fig.3.44	Fig.3.48	Fig.3.52	Fig.3.56	Fig.3.60	Fig.3.64	Fig.3.68	Fig.3.72

D_1: 2011-2020; D_2: 2021-2030; D_3:2031-2040; D_4:2041-2050

B. ANANTAPUR; Crop: Groundnut

Normal Sowing(NS): Jul-10; Late Sowing(LS):Aug-10;
Crop Growth Period (CGP):130 days

Parameter	Decadal percent deviation from BP, %							
	D_1		D_2		D_3		D_4	
	NS	LS	NS	LS	NS	LS	NS	LS
Rainfall(R)	61.83	75.94	58.49	81.05	54.29	80.48	62.10	89.28
Reference	Fig.3.41	Fig.3.45	Fig.3.49	Fig.3.53	Fig.3.57	Fig.3.61	Fig.3.65	Fig.3.69
Effective Rainfall(ER)	61.26	76.47	58.21	83.48	54.56	85.90	57.47	93.47
Reference	Fig.3.42	Fig.3.46	Fig.3.50	Fig.3.54	Fig.3.58	Fig.3.62	Fig.3.66	Fig.3.70
Crop Evapotranspiration (ET_c)	4.53	-8.44	3.77	-8.86	3.77	-10.57	4.56	-10.39
Reference	Fig.3.43	Fig.3.47	Fig.3.51	Fig.3.55	Fig.3.59	Fig.3.63	Fig.3.67	Fig.3.71
Irrigation Requirement(IR)	-33.07	-33.66	-34.16	-39.98	-32.39	-42.63	-31.97	-44.39
Reference	Fig.3.44	Fig.3.48	Fig.3.52	Fig.3.56	Fig.3.60	Fig.3.64	Fig.3.68	Fig.3.72

D_1: 2011-2020; D_2: 2021-2030; D_3:2031-2040; D_4:2041-2050

C. KADAPA;   Crop: Groundnut

Normal Sowing(NS): Jun-10; Late Sowing(LS):Jul-10;
Crop Growth Period (CGP):130 days

Parameter	Decadal percent deviation from BP, %							
	D_1		D_2		D_3		D_4	
	NS	LS	NS	LS	NS	LS	NS	LS
Rainfall(R)	104.02	87.69	103.89	101.87	91.59	77.66	75.42	72.76
Reference	Fig.3.41	Fig.3.45	Fig.3.49	Fig.3.53	Fig.3.57	Fig.3.61	Fig.3.65	Fig.3.69
Effective Rainfall(ER)	44.00	25.65	43.33	30.80	26.23	19.94	29.76	21.73
Reference	Fig.3.42	Fig.3.46	Fig.3.50	Fig.3.54	Fig.3.58	Fig.3.62	Fig.3.66	Fig.3.70
Crop Evapotranspiration (ET_c)	-4.40	-8.24	1.10	-6.73	1.75	-6.44	3.59	-5.12
Reference	Fig.3.43	Fig.3.47	Fig.3.51	Fig.3.55	Fig.3.59	Fig.3.63	Fig.3.67	Fig.3.71
Irrigation Requirement(IR)	-42.99	-36.53	-39.54	-41.44	-26.84	-29.25	-24.19	-23.96
Reference	Fig.3.44	Fig.3.48	Fig.3.52	Fig.3.56	Fig.3.60	Fig.3.64	Fig.3.68	Fig.3.72

D_1: 2011-2020; D_2: 2021-2030; D_3:2031-2040; D_4:2041-2050

D. KURNOOL; Crop: Groundnut

Normal Sowing(NS): Jul-10; Late Sowing(LS):Aug-10;
Crop Growth Period (CGP):130 days

Parameter	Decadal percent deviation from BP, %							
	D_1		D_2		D_3		D_4	
	NS	LS	NS	LS	NS	LS	NS	LS
Rainfall(R)	104.02	87.69	103.89	101.87	91.59	77.66	75.42	72.76
Reference	Fig.3.41	Fig.3.45	Fig.3.49	Fig.3.53	Fig.3.57	Fig.3.61	Fig.3.65	Fig.3.69
Effective Rainfall(ER)	44.00	25.65	43.33	30.80	26.23	19.94	29.76	21.73
Reference	Fig.3.42	Fig.3.46	Fig.3.50	Fig.3.54	Fig.3.58	Fig.3.62	Fig.3.66	Fig.3.70
Crop Evapotranspiration (ET_c)	-4.40	-8.24	1.10	-6.73	1.75	-6.44	3.59	-5.12
Reference	Fig.3.43	Fig.3.47	Fig.3.51	Fig.3.55	Fig.3.59	Fig.3.63	Fig.3.67	Fig.3.71
Irrigation Requirement(IR)	-42.99	-36.53	-39.54	-41.44	-26.84	-29.25	-24.19	-23.96
Reference	Fig.3.44	Fig.3.48	Fig.3.52	Fig.3.56	Fig.3.60	Fig.3.64	Fig.3.68	Fig.3.72

D_1: 2011-2020; D_2: 2021-2030; D_3:2031-2040; D_4:2041-2050

E. CHITTOOR; Crop: Groundnut

Normal Sowing(NS): Jun-10; Late Sowing(LS):Jul-10;
Crop Growth Period (CGP):130 days

Parameter	Decadal percent deviation from BP, %							
	D_1		D_2		D_3		D_4	
	NS	LS	NS	LS	NS	LS	NS	LS
Rainfall(R)	-15.10	-3.29	-12.01	13.66	-4.24	27.39	-2.83	22.15
Reference	Fig.3.41	Fig.3.45	Fig.3.49	Fig.3.53	Fig.3.57	Fig.3.61	Fig.3.65	Fig.3.69
Effective Rainfall(ER)	1.25	11.29	2.81	23.91	6.87	32.24	9.36	31.01
Reference	Fig.3.42	Fig.3.46	Fig.3.50	Fig.3.54	Fig.3.58	Fig.3.62	Fig.3.66	Fig.3.70
Crop Evapotranspiration (ET_c)	-3.63	-12.61	-3.60	-13.12	-3.24	-13.50	-4.12	-13.42
Reference	Fig.3.43	Fig.3.47	Fig.3.51	Fig.3.55	Fig.3.59	Fig.3.63	Fig.3.67	Fig.3.71
Irrigation Requirement(IR)	-24.76	-40.04	-27.57	-48.46	-32.22	-53.62	-32.84	-53.81
Reference	Fig.3.44	Fig.3.48	Fig.3.52	Fig.3.56	Fig.3.60	Fig.3.64	Fig.3.68	Fig.3.72

D_1: 2011-2020; D_2: 2021-2030; D_3:2031-2040; D_4:2041-2050

F. NELLORE; Crop: Groundnut

Normal Sowing(NS): May-10; Late Sowing(LS):Jun-10;
Crop Growth Period (CGP):130 days

Parameter	Decadal percent deviation from BP, %							
	D_1		D_2		D_3		D_4	
	NS	LS	NS	LS	NS	LS	NS	LS
Rainfall(R)	-4.27	-5.28	-1.20	0.95	-9.00	-7.89	-6.89	-6.81
Reference	Fig.3.41	Fig.3.45	Fig.3.49	Fig.3.53	Fig.3.57	Fig.3.61	Fig.3.65	Fig.3.69
Effective Rainfall(ER)	0.08	-1.25	0.91	4.34	-5.17	-3.40	-3.68	-3.24
Reference	Fig.3.42	Fig.3.46	Fig.3.50	Fig.3.54	Fig.3.58	Fig.3.62	Fig.3.66	Fig.3.70
Crop Evapotranspiration (ET_c)	5.75	3.49	6.31	3.83	7.27	5.36	8.36	5.37
Reference	Fig.3.43	Fig.3.47	Fig.3.51	Fig.3.55	Fig.3.59	Fig.3.63	Fig.3.67	Fig.3.71
Irrigation Requirement(IR)	22.53	2.88	22.12	0.87	38.93	9.46	43.71	12.56
Reference	Fig.3.44	Fig.3.48	Fig.3.52	Fig.3.56	Fig.3.60	Fig.3.64	Fig.3.68	Fig.3.72

D_1: 2011-2020; D_2: 2021-2030; D_3:2031-2040; D_4:2041-2050

Table 3.4. Summary of climate change impacts on crop water balance of groundnut and pigeon pea in rainfed districts of Andhra Pradesh

District	Rainfall		Effective Rainfall		Crop Evapotranspiration		Irrigation Requirement	
	NS	LS	NS	LS	NS	LS	NS	LS
Prakasam	↓	↓	↓	↓	↑	↑	↑	↑
Anantapur	↓	↓	↓	↓	↑	↑	↑	↑
Kadapa	↓	↓	↓	↓	↑	↑	↑	↑
Kurnool	↓	↓	↓	↓	↑	↑	↑	↑
Chittoor	↓	↓	↓	↓	↑	↑	↑	↑
Nellore	↓	↓	↓	↓	↑	↑	↑	↑

Note : ↓ - Increase over base period; ↑ - Decrease over base period; NS - Normal sowing; LS - Late sowing

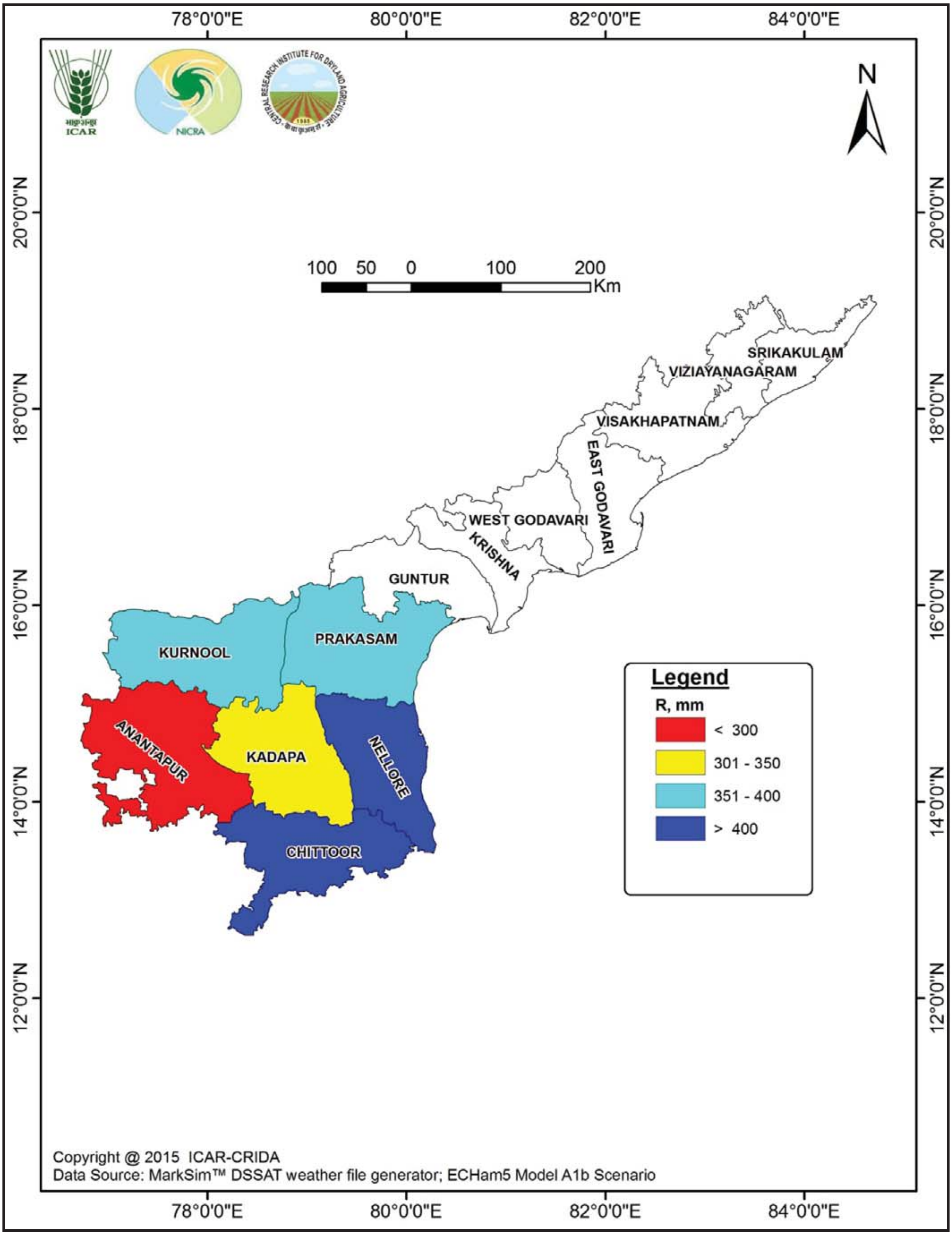

Fig.3.1 Rainfall (R) during crop growth period of groundnut and pigeon pea under normal sowing for the base period (1961-1990) in rainfed districts of Andhra Pradesh

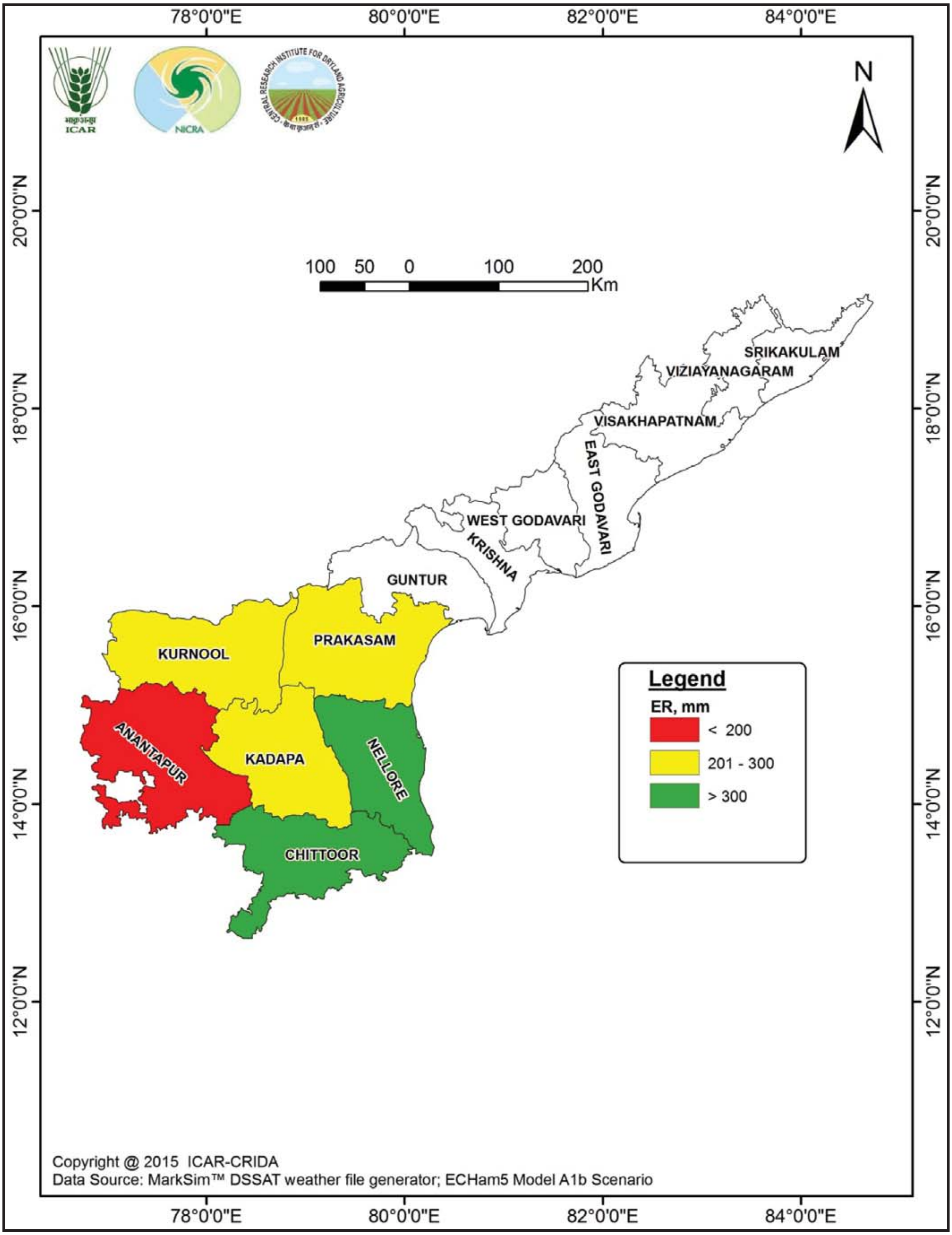

Fig.3.2 Effective rainfall (ER) during crop growth period of groundnut and pigeon pea under normal sowing for the base period (1961-1990) in rainfed districts of Andhra Pradesh

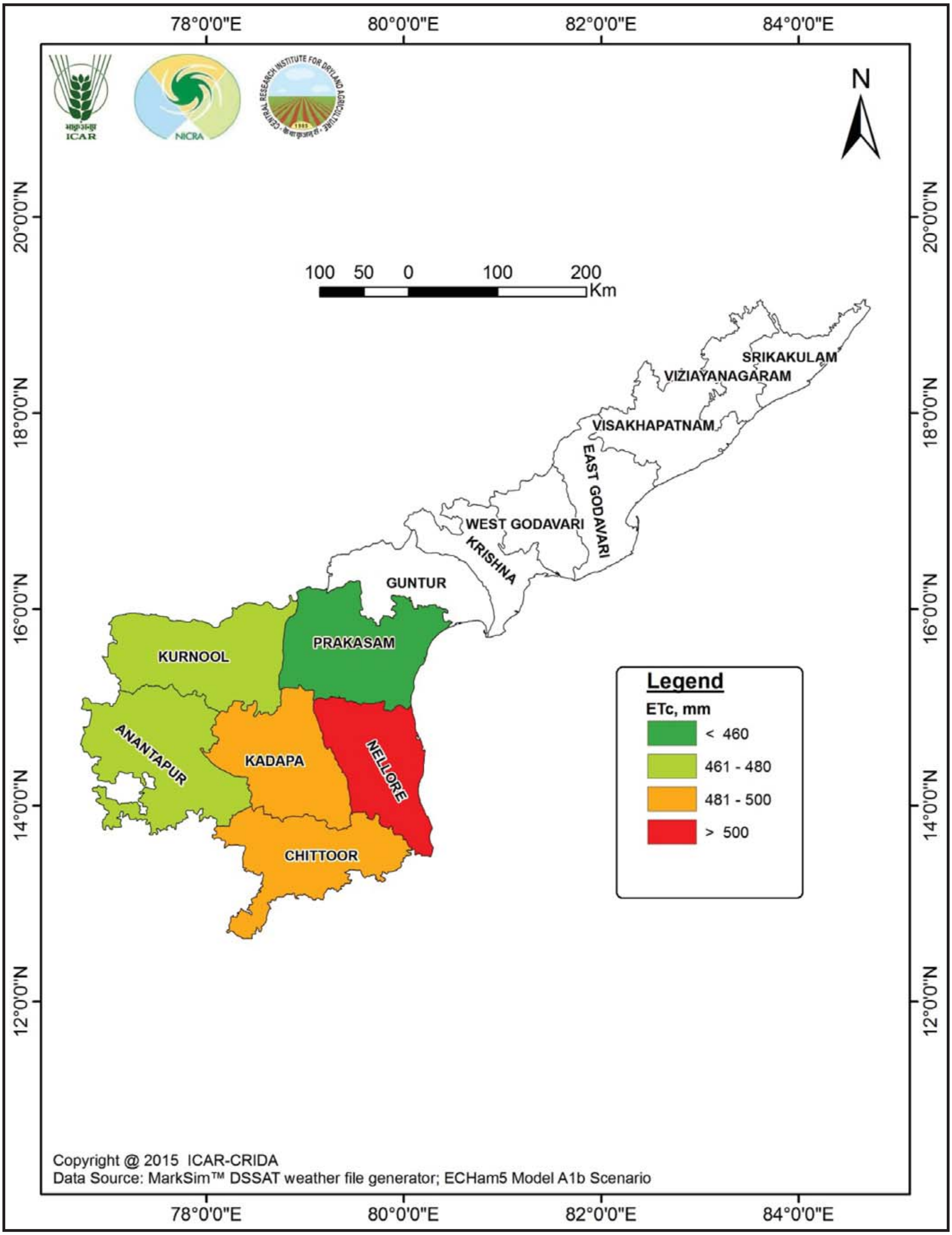

Fig.3.3 Crop evapotranspiration (ETc) during crop growth period of groundnut and pigeon pea under normal sowing for the base period (1961-1990) in rainfed districts of Andhra Pradesh

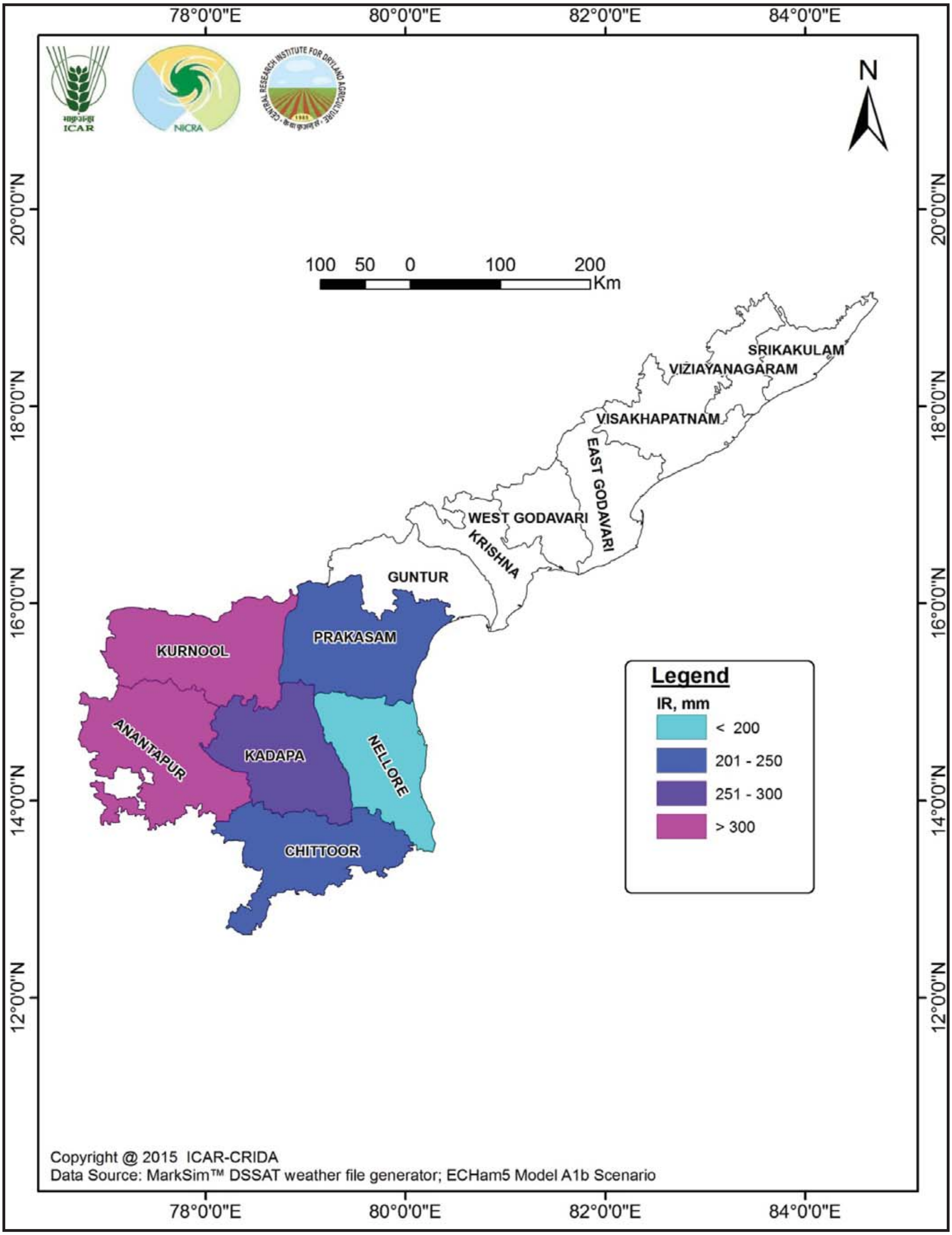

Fig.3.4 Irrigation requirement (IR) during crop growth period of groundnut and pigeon pea under normal sowing for the base period (1961-1990) in rainfed districts of Andhra Pradesh

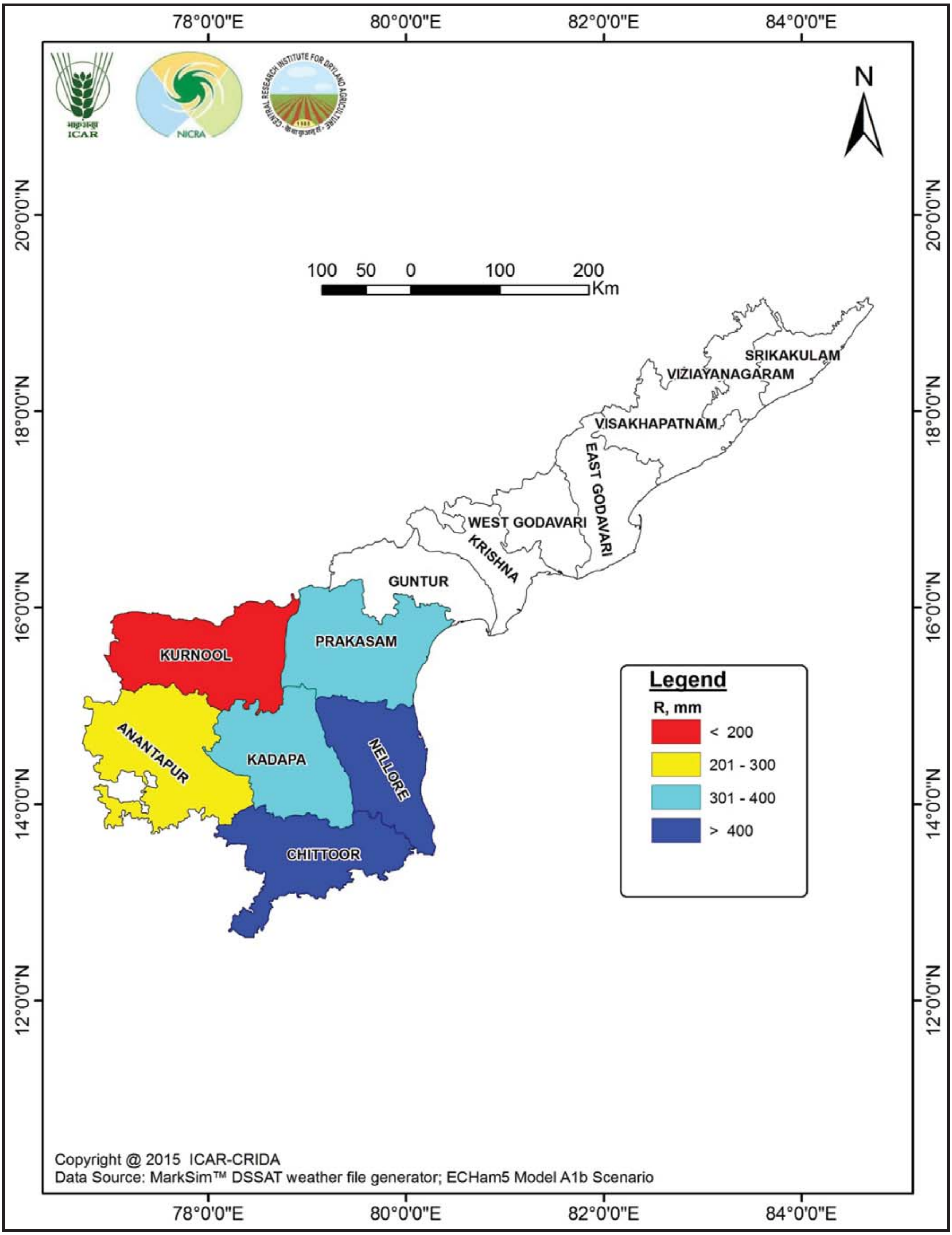

Fig.3.5 Rainfall (R) during crop growth period of groundnut and pigeon pea under late sowing for the base period (1961-1990) in rainfed districts of Andhra Pradesh

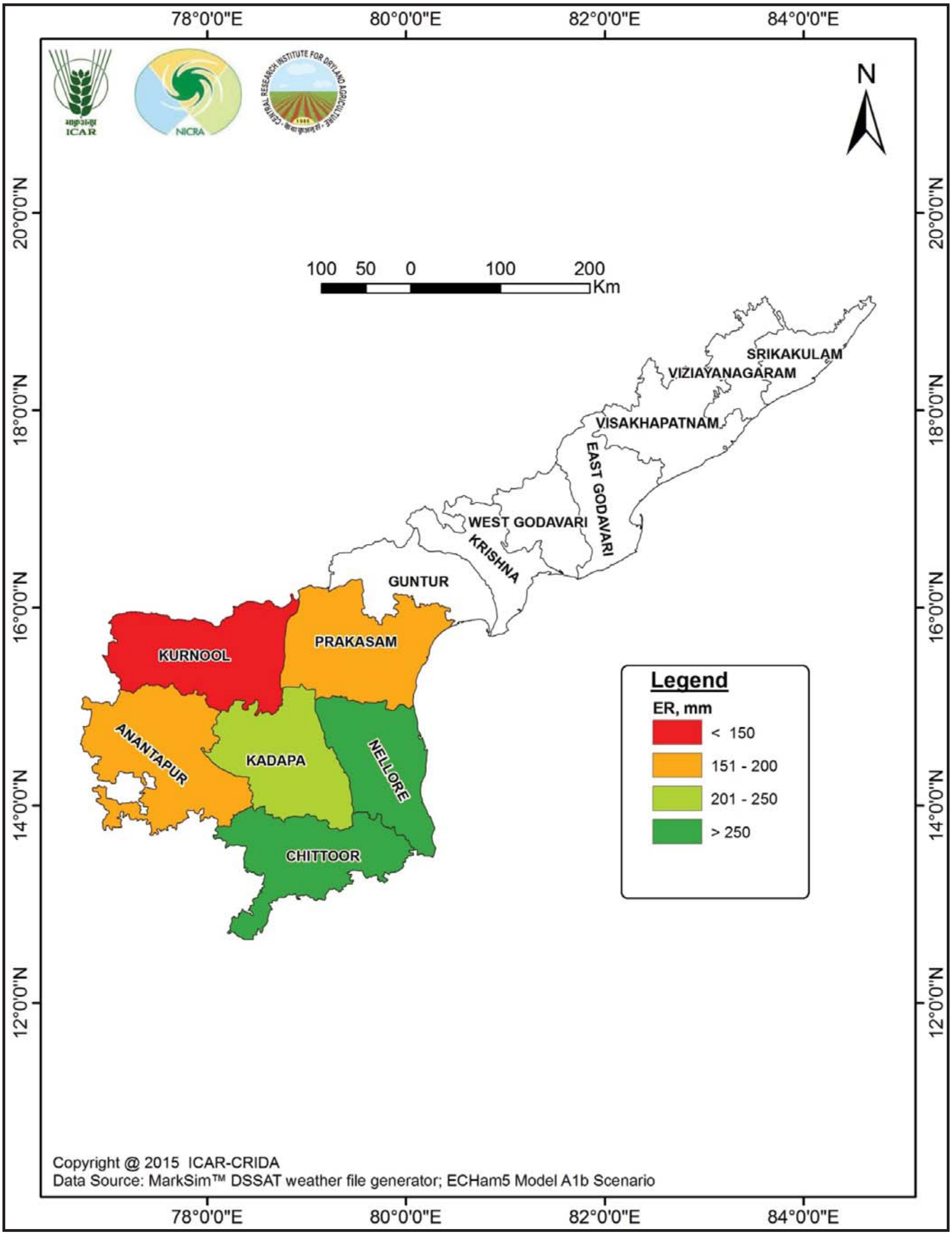

Fig.3.6 Effective rainfall (ER) during crop growth period of groundnut and pigeon pea under late sowing for the base period (1961-1990) in rainfed districts of Andhra Pradesh

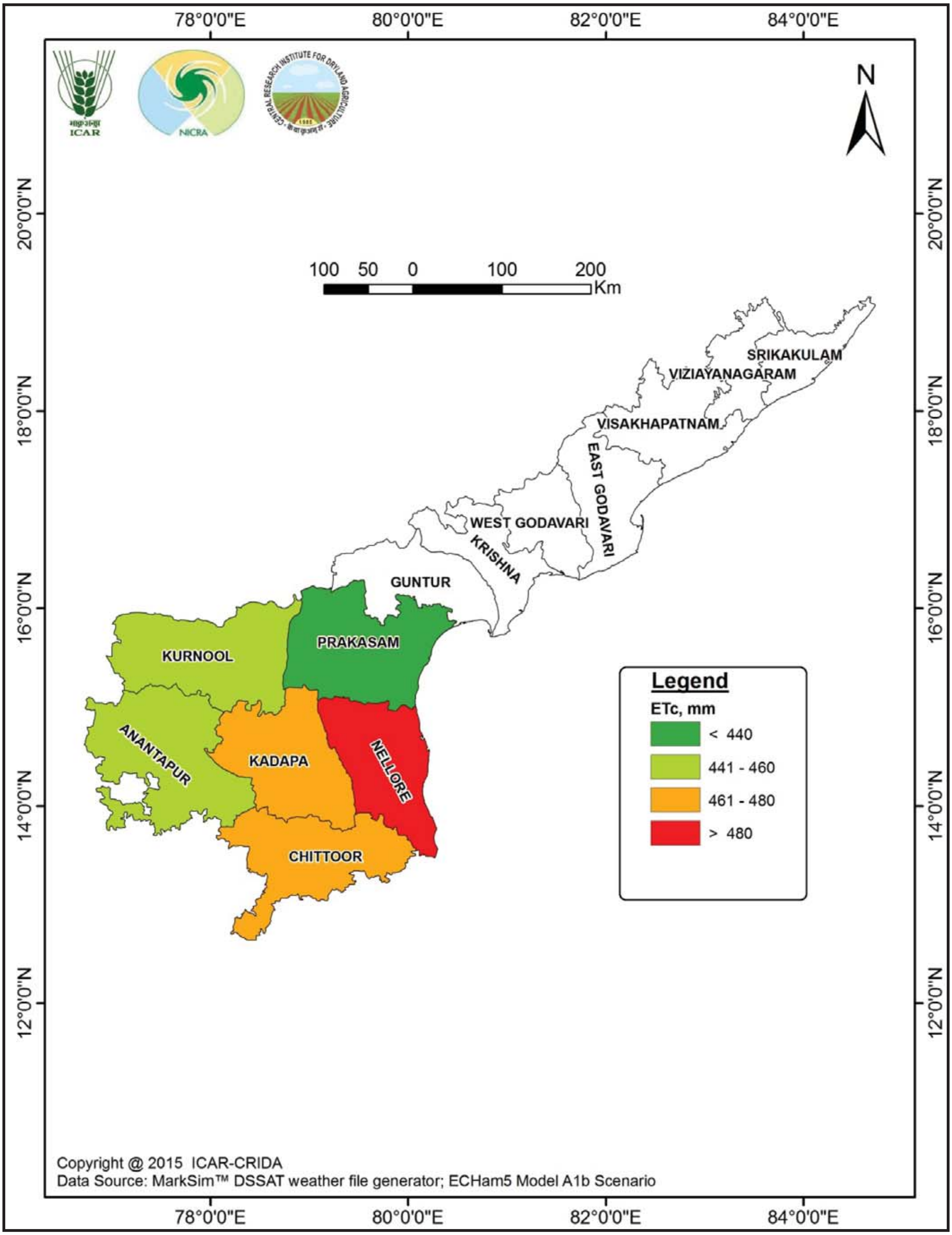

Fig.3.7 Crop evapotranspiration (ETc) during crop growth period of groundnut and pigeon pea under late sowing for the base period (1961-1990) in rainfed districts of Andhra Pradesh

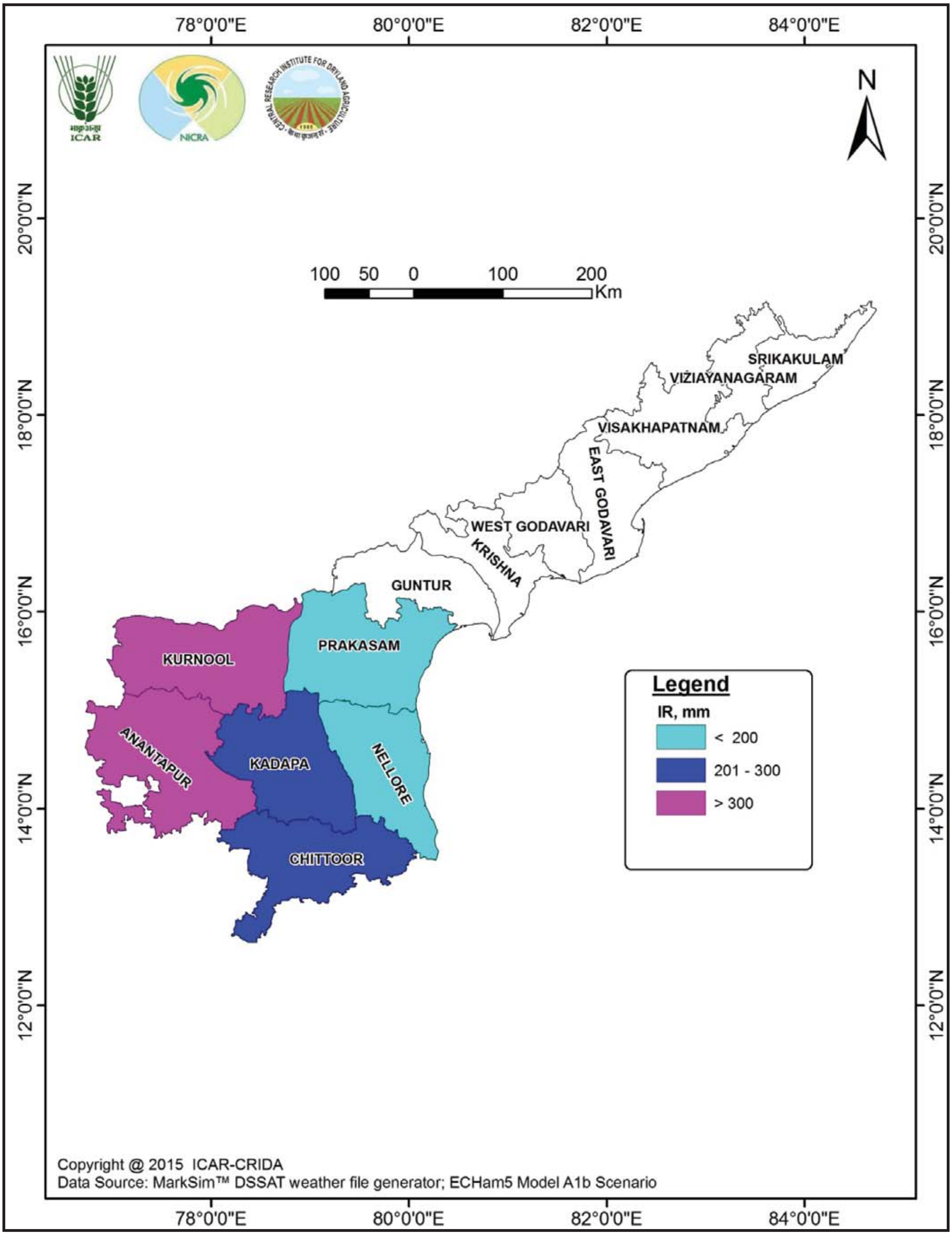

Fig.3.8 Irrigation requirement (IR) during crop growth period of groundnut and pigeon pea under late sowing for the base period (1961-1990) in rainfed districts of Andhra Pradesh

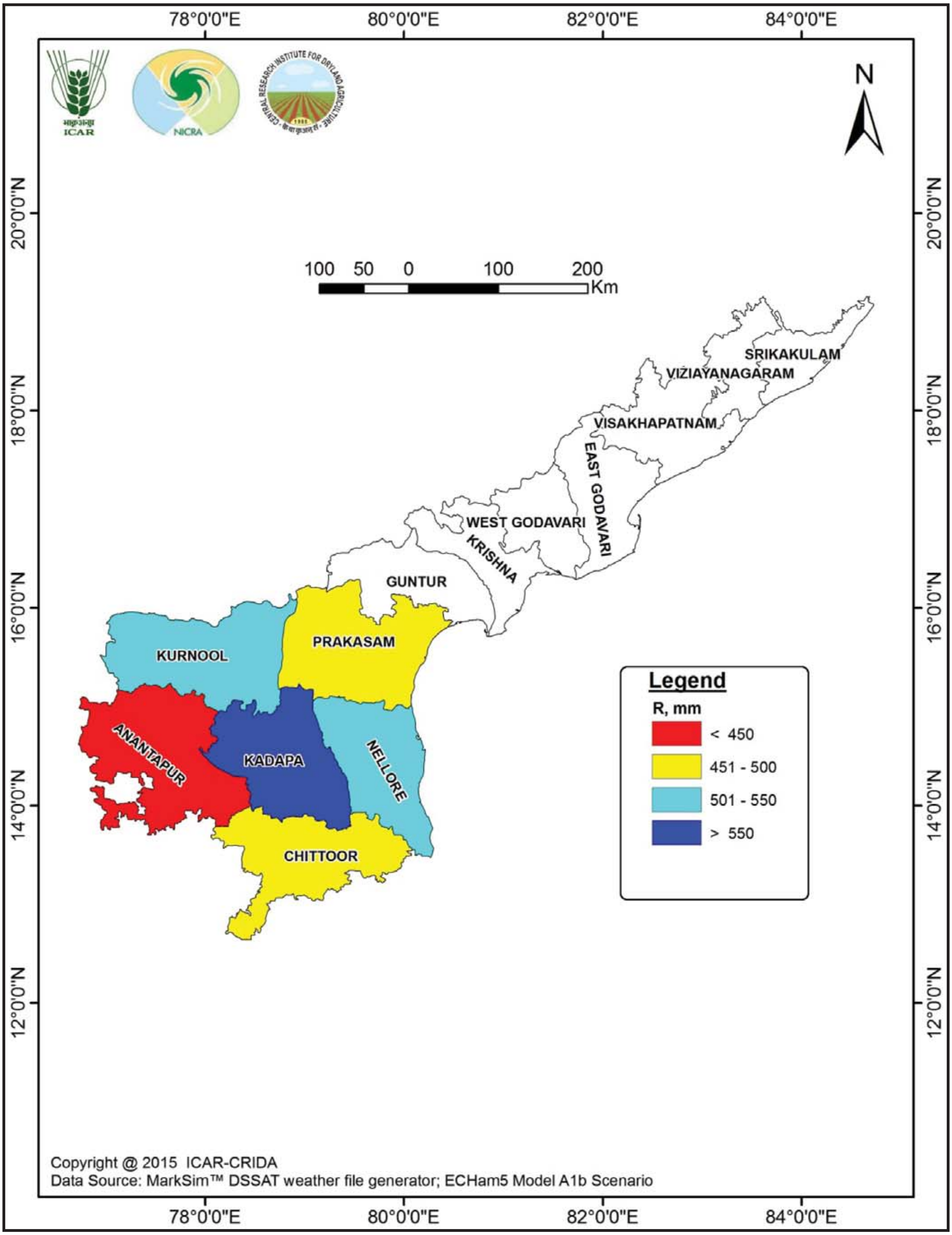

Fig.3.9 Rainfall (R) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2011-2020 in rainfed districts of Andhra Pradesh

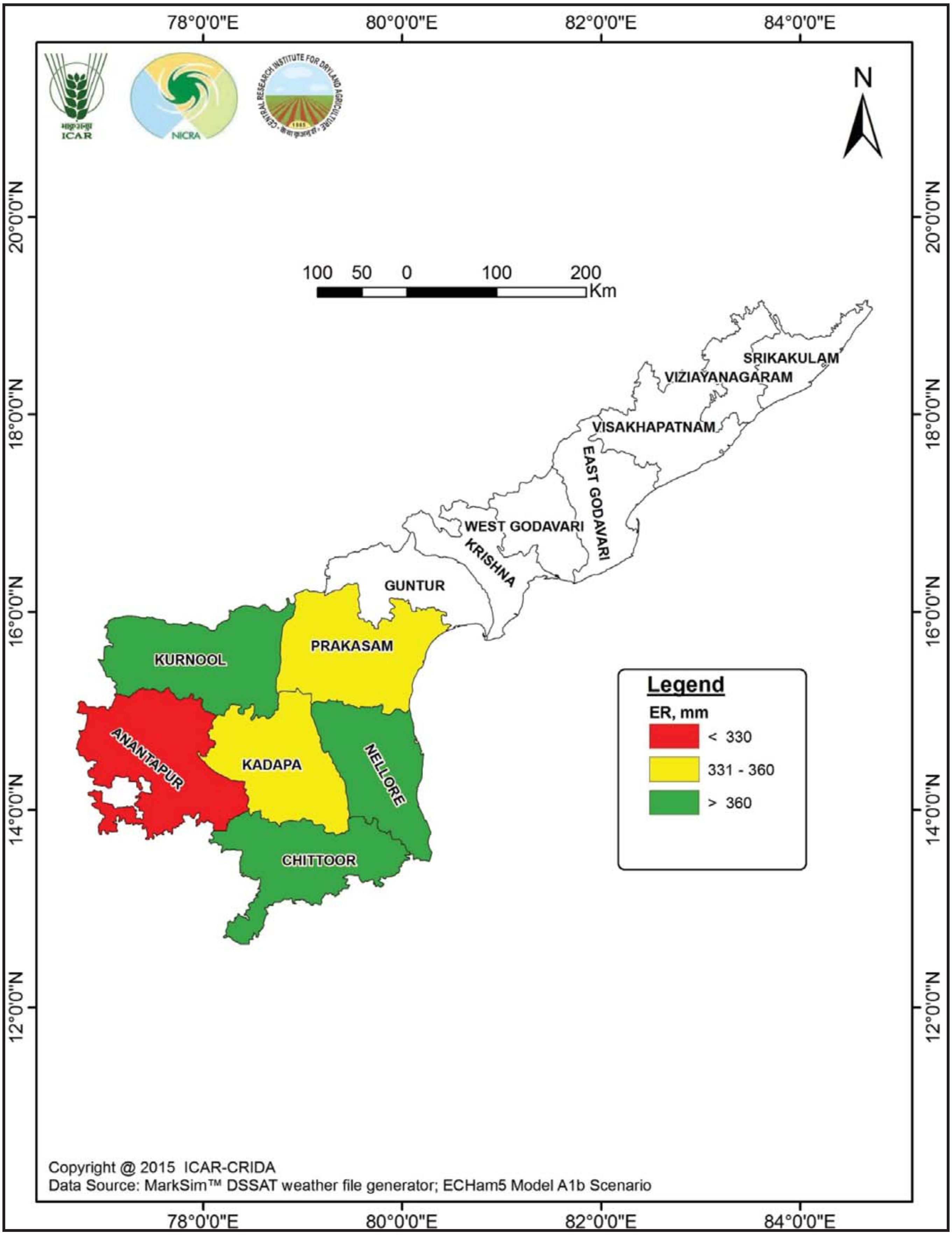

Fig.3.10 Effective rainfall (ER) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2011-2020 in rainfed districts of Andhra Pradesh

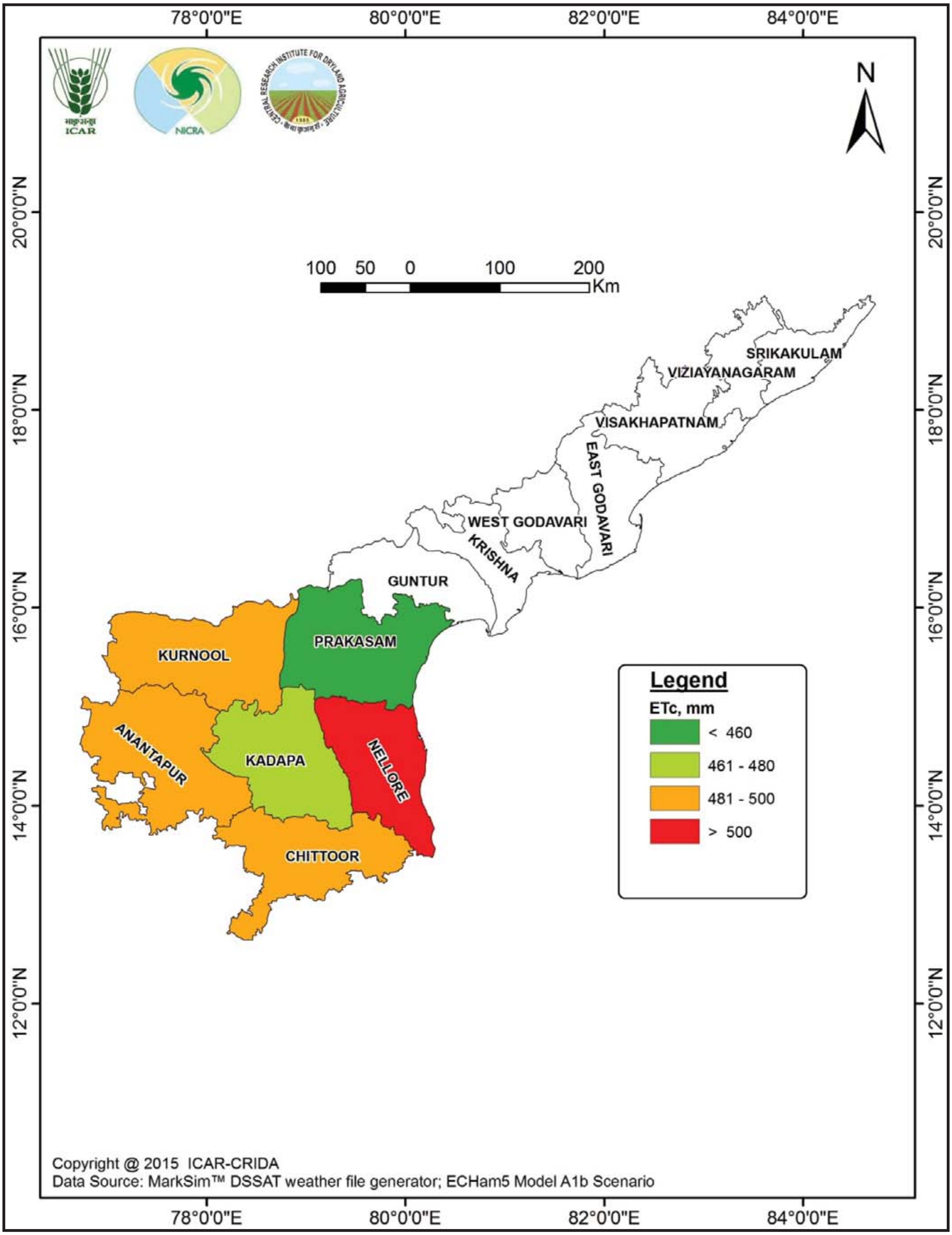

Fig.3.11 Crop evapotranspiration (ETc) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2011-2020 in rainfed districts of Andhra Pradesh

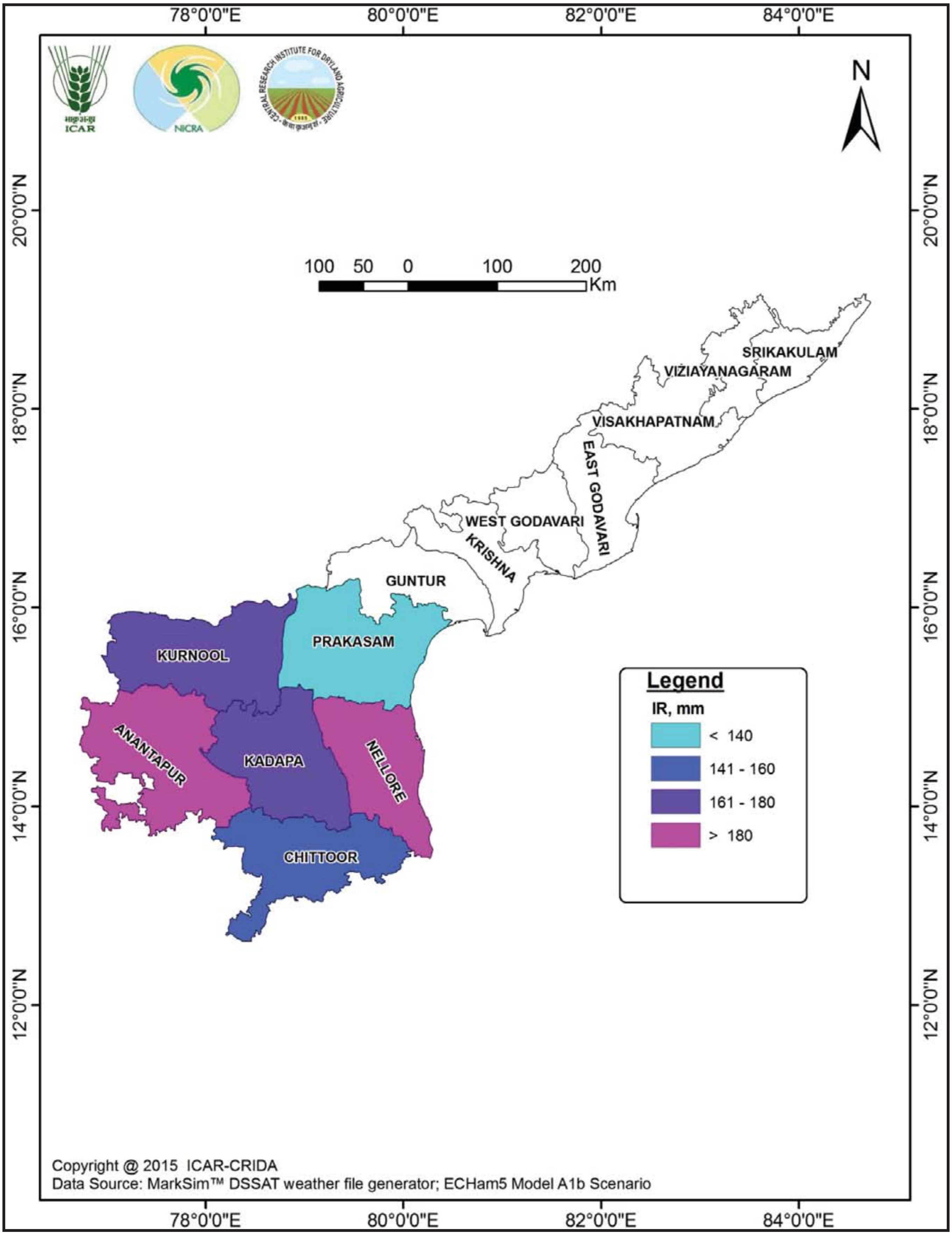

Fig.3.12 Irrigation requirement (IR) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2011-2020 in rainfed districts of Andhra Pradesh

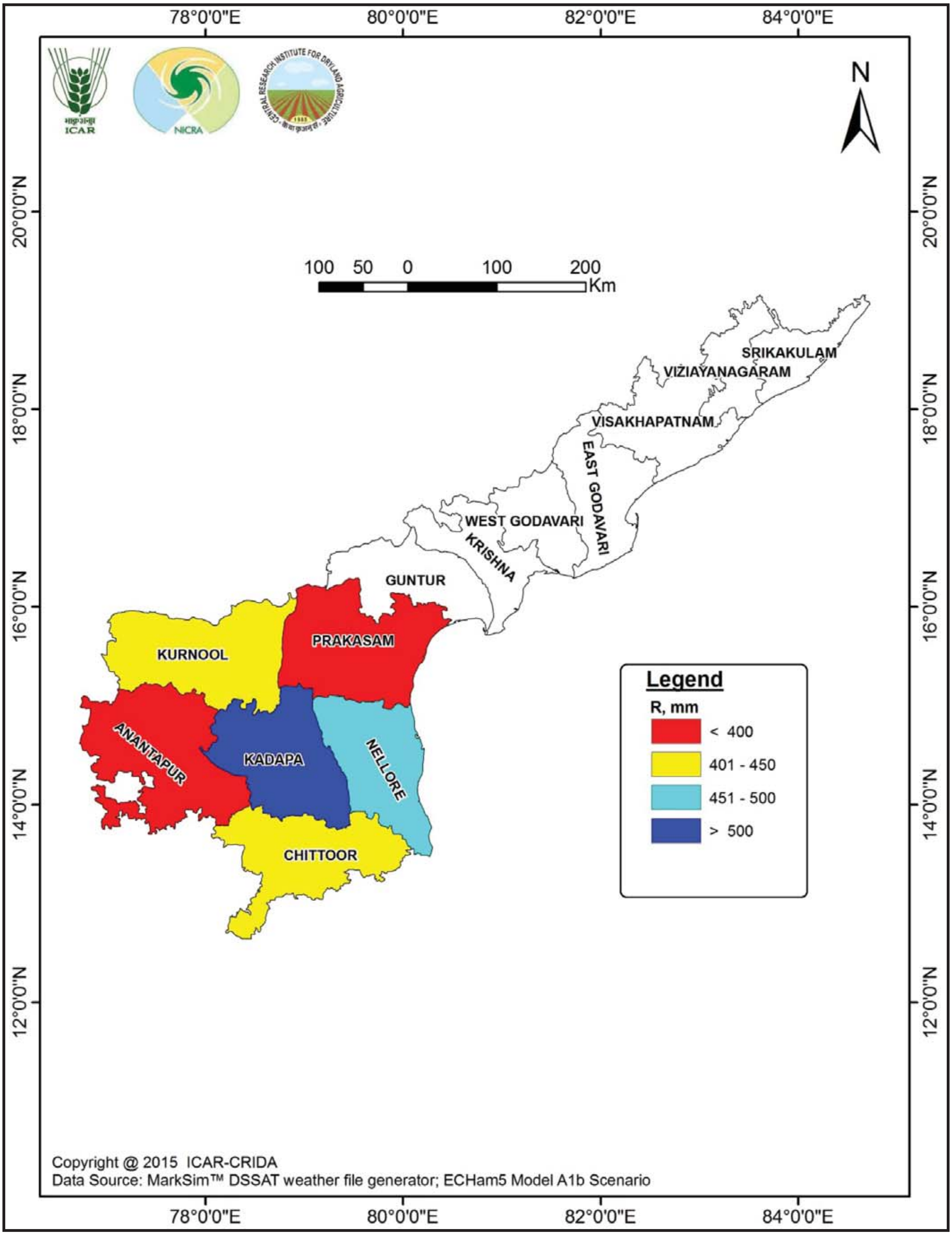

Fig.3.13 Rainfall (R) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2011-2020 in rainfed districts of Andhra Pradesh

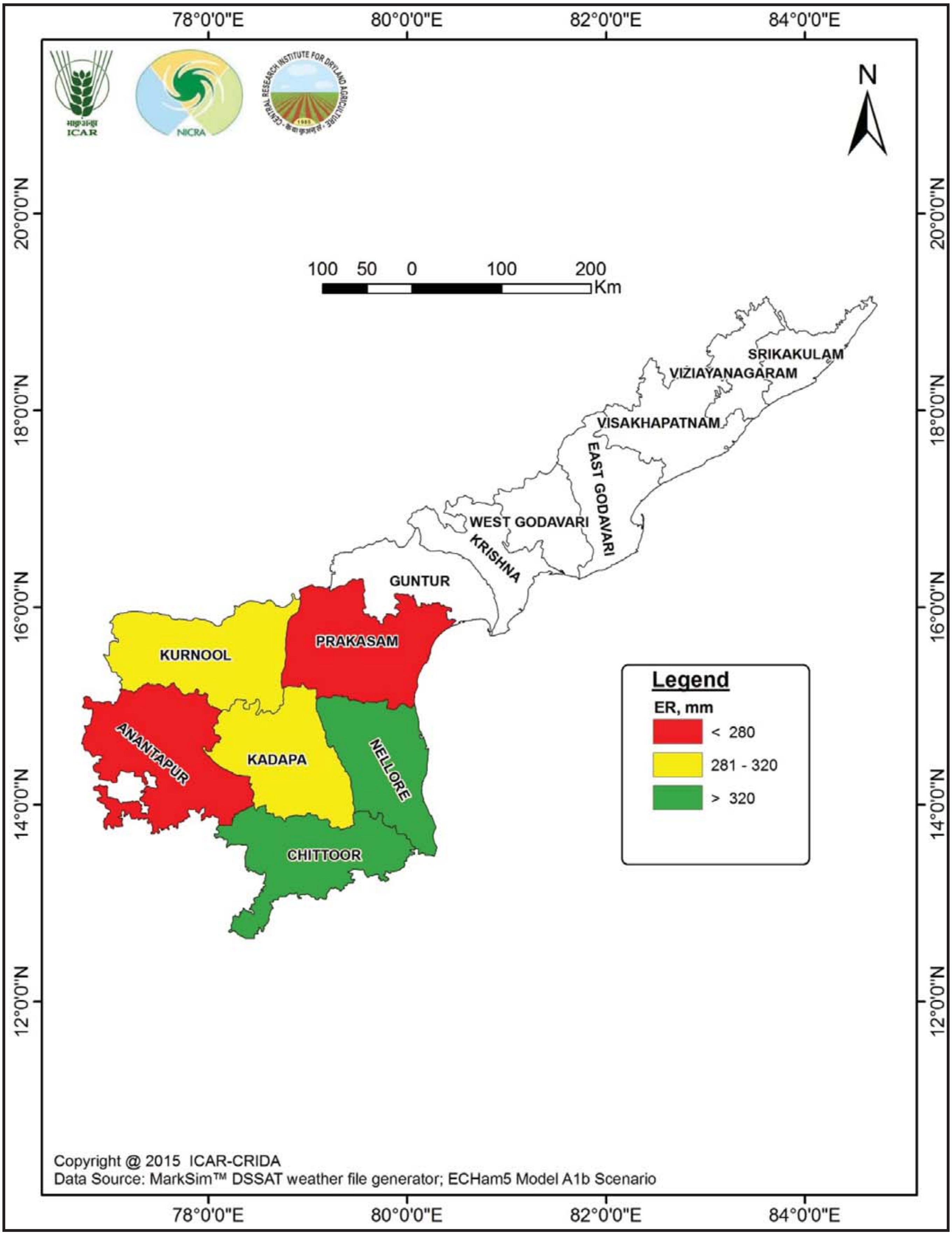

Fig.3.14 Effective rainfall (ER) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2011-2020 in rainfed districts of Andhra Pradesh

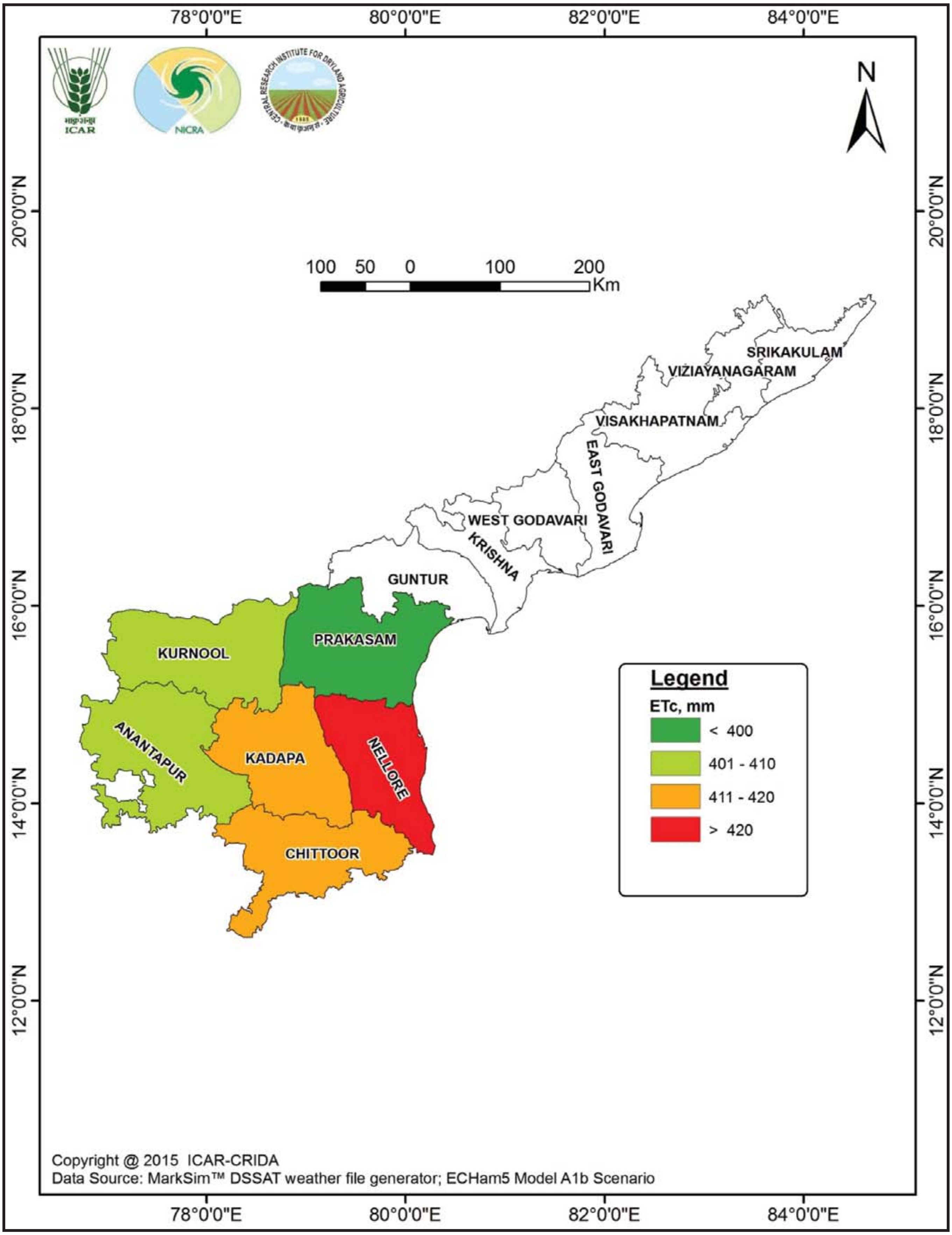

Fig.3.15 Crop evapotranspiration (ETc) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2011-2020 in rainfed districts of Andhra Pradesh

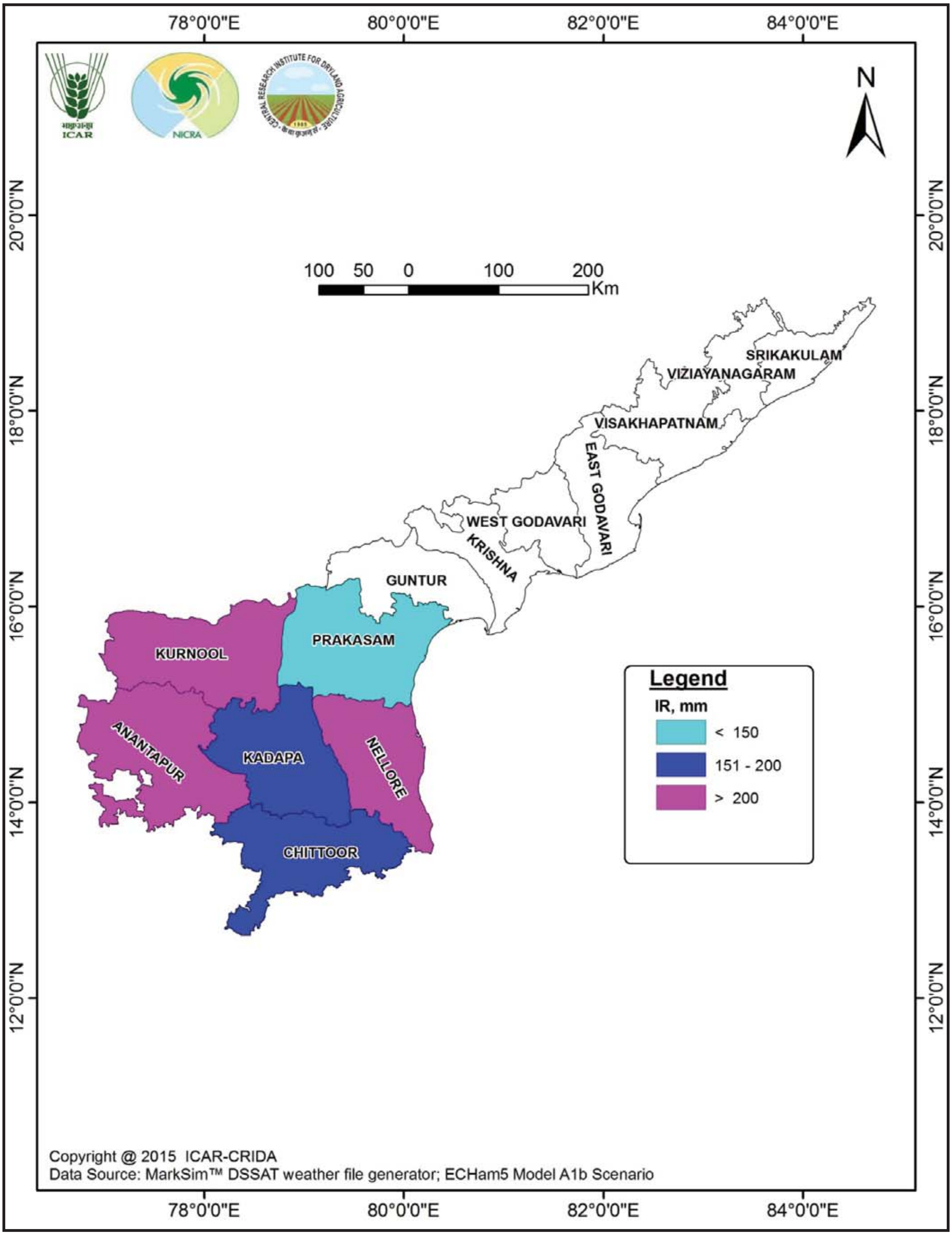

Fig.3.16 Irrigation requirement (IR) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2011-2020 in rainfed districts of Andhra Pradesh

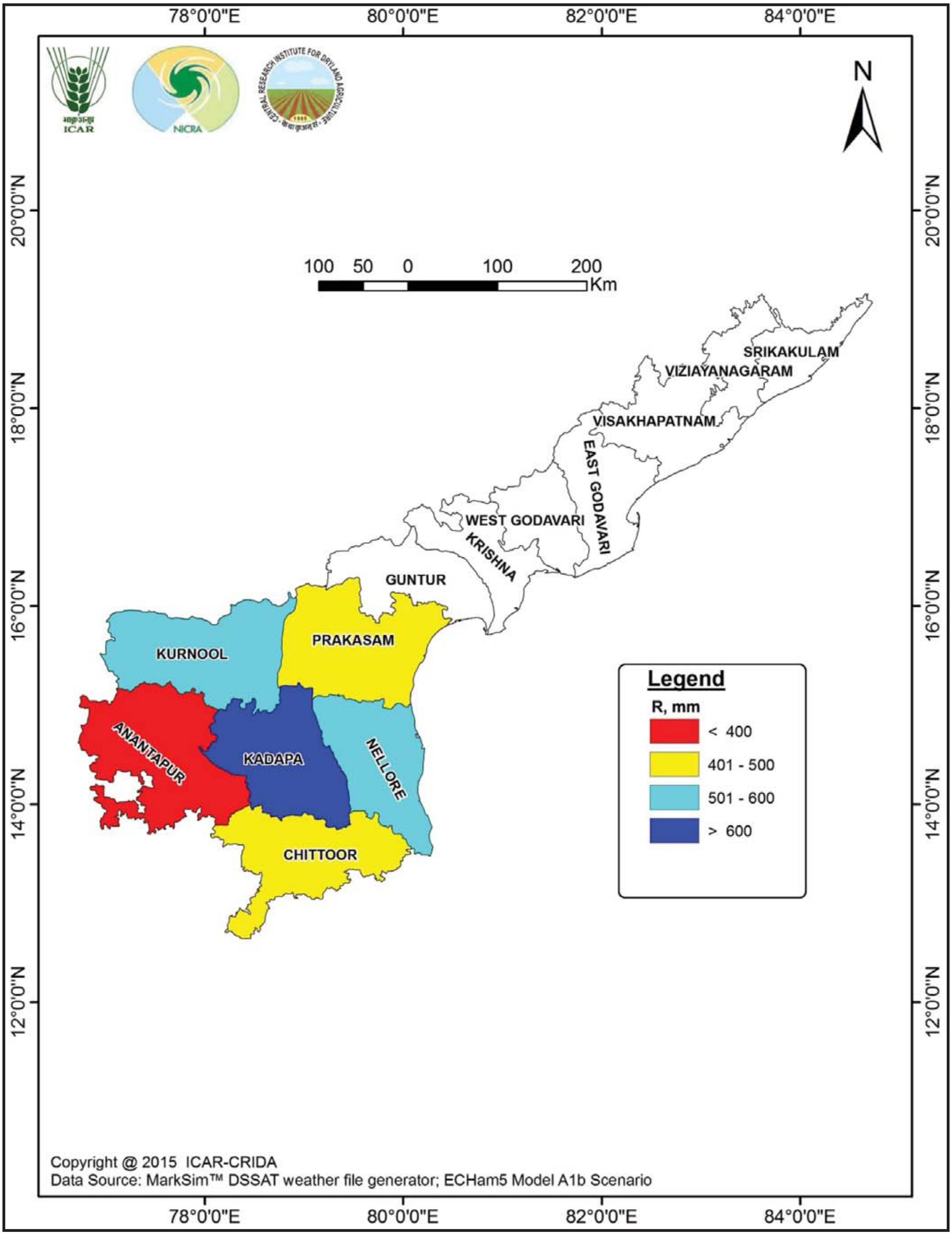

Fig.3.17 Rainfall (R) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2021-2030 in rainfed districts of Andhra Pradesh

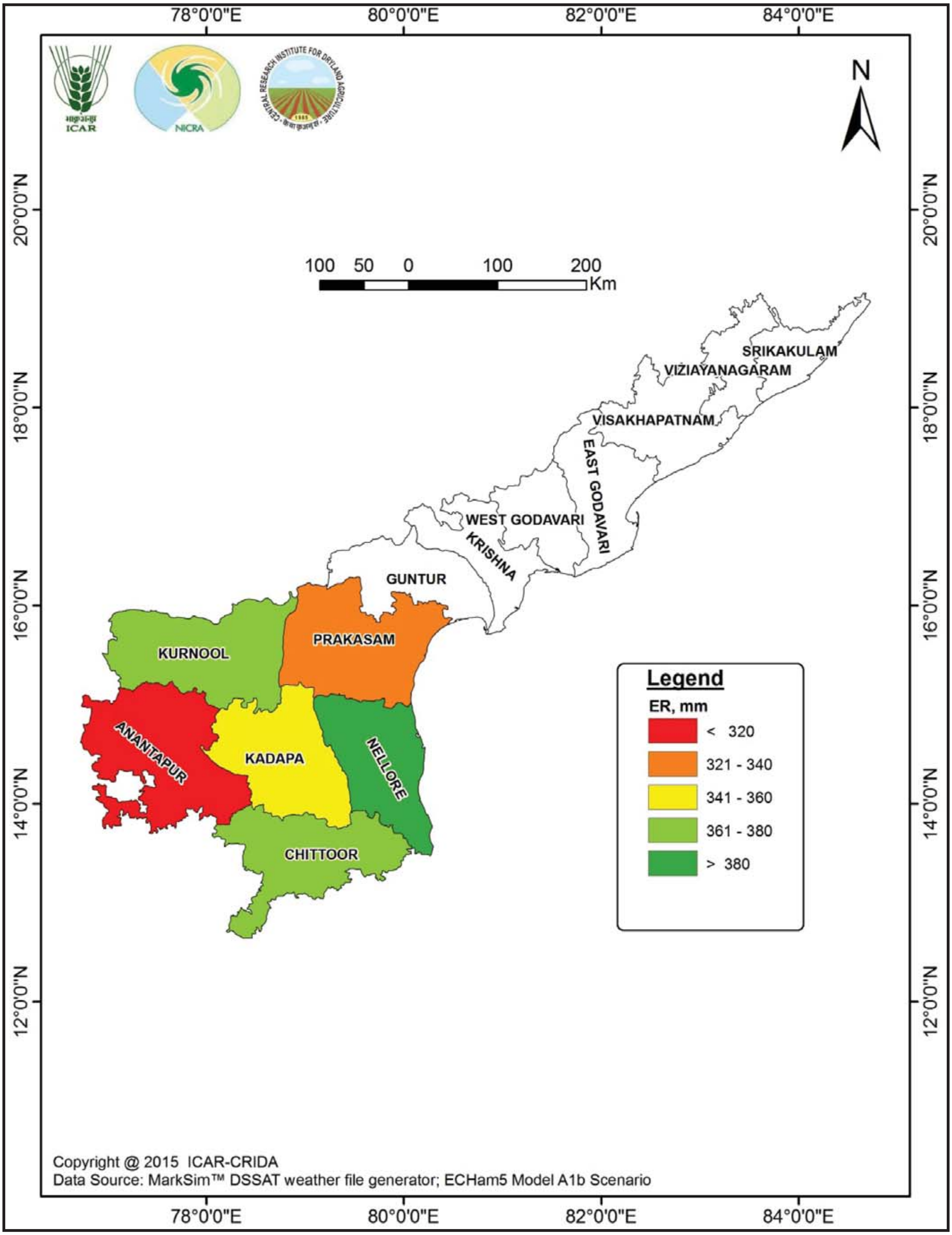

Fig.3.18 Effective rainfall (ER) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2021-2030 in rainfed districts of Andhra Pradesh

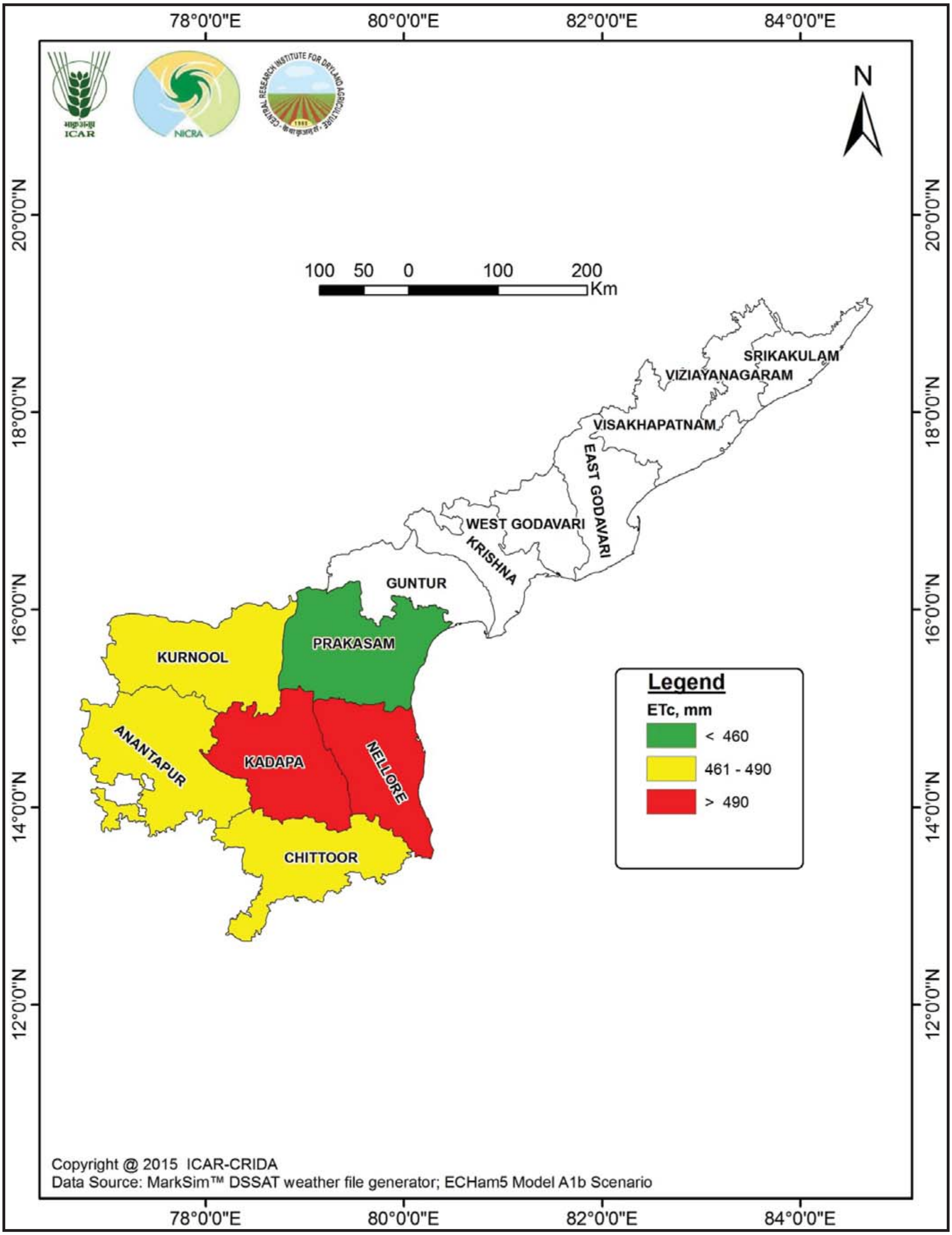

Fig.3.19 Crop evapotranspiration (ETc) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2021-2030 in rainfed districts of Andhra Pradesh

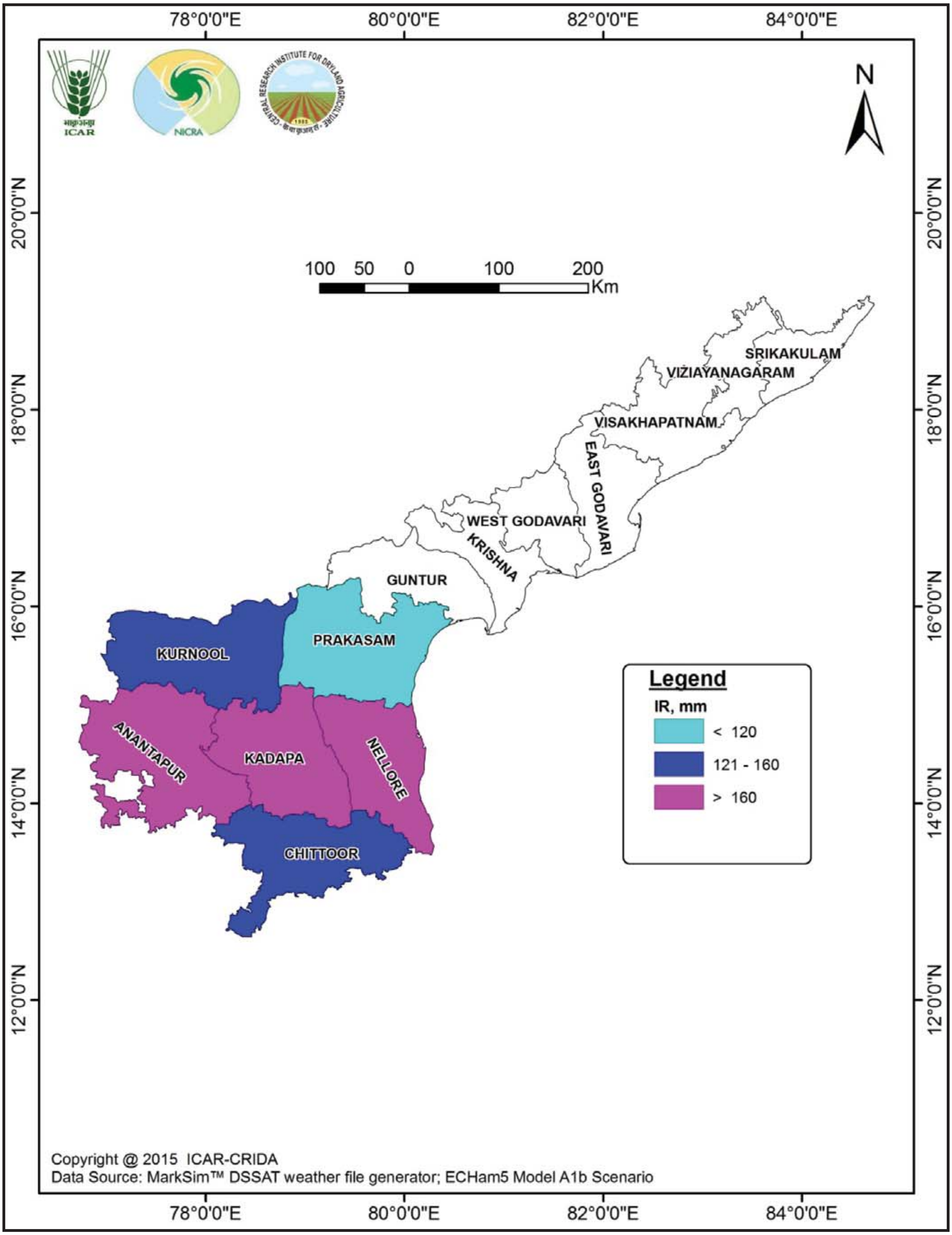

Fig.3.20 Irrigation requirement (IR) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2021-2030 in rainfed districts of Andhra Pradesh

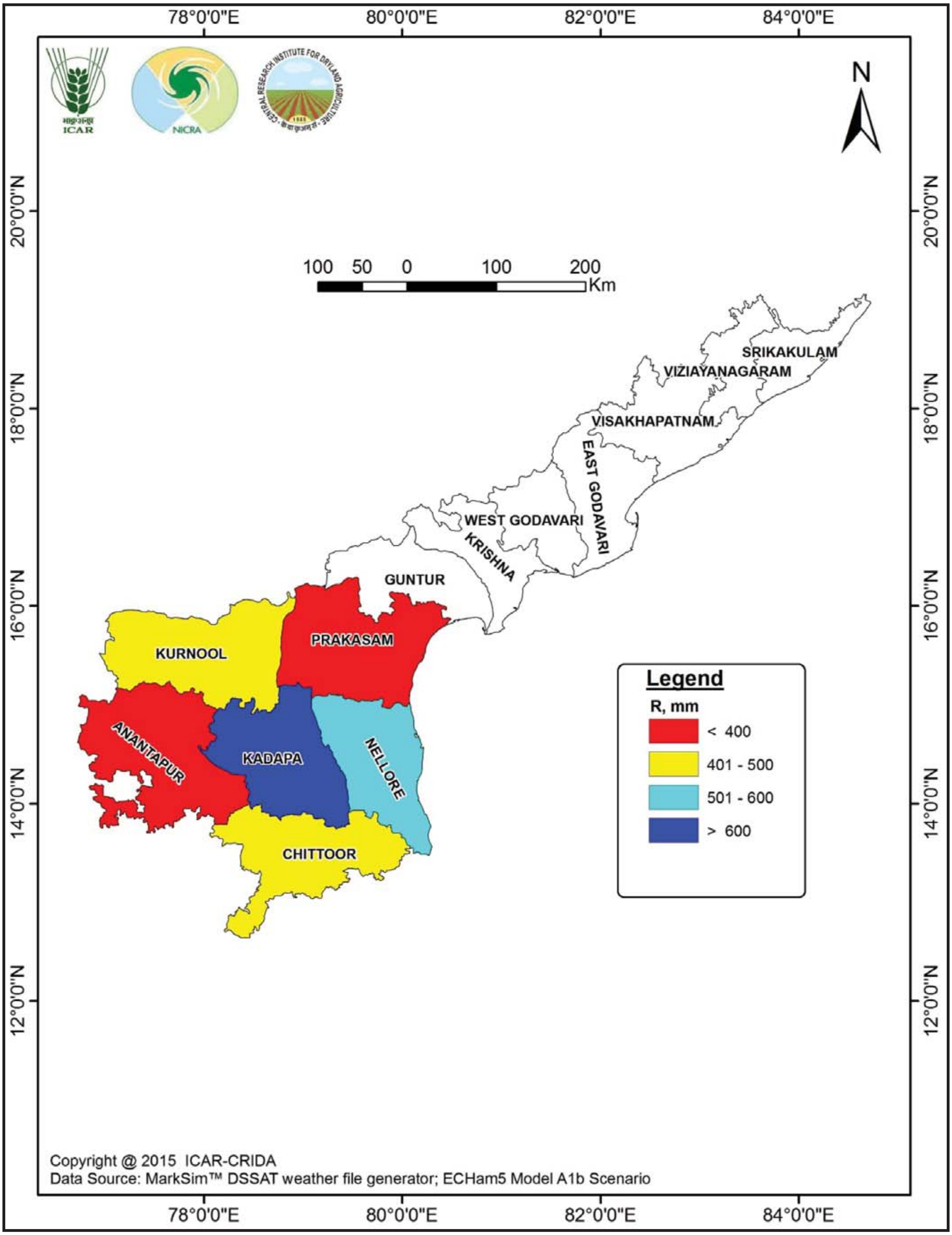

Fig.3.21 Rainfall (R) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2021-2030 in rainfed districts of Andhra Pradesh

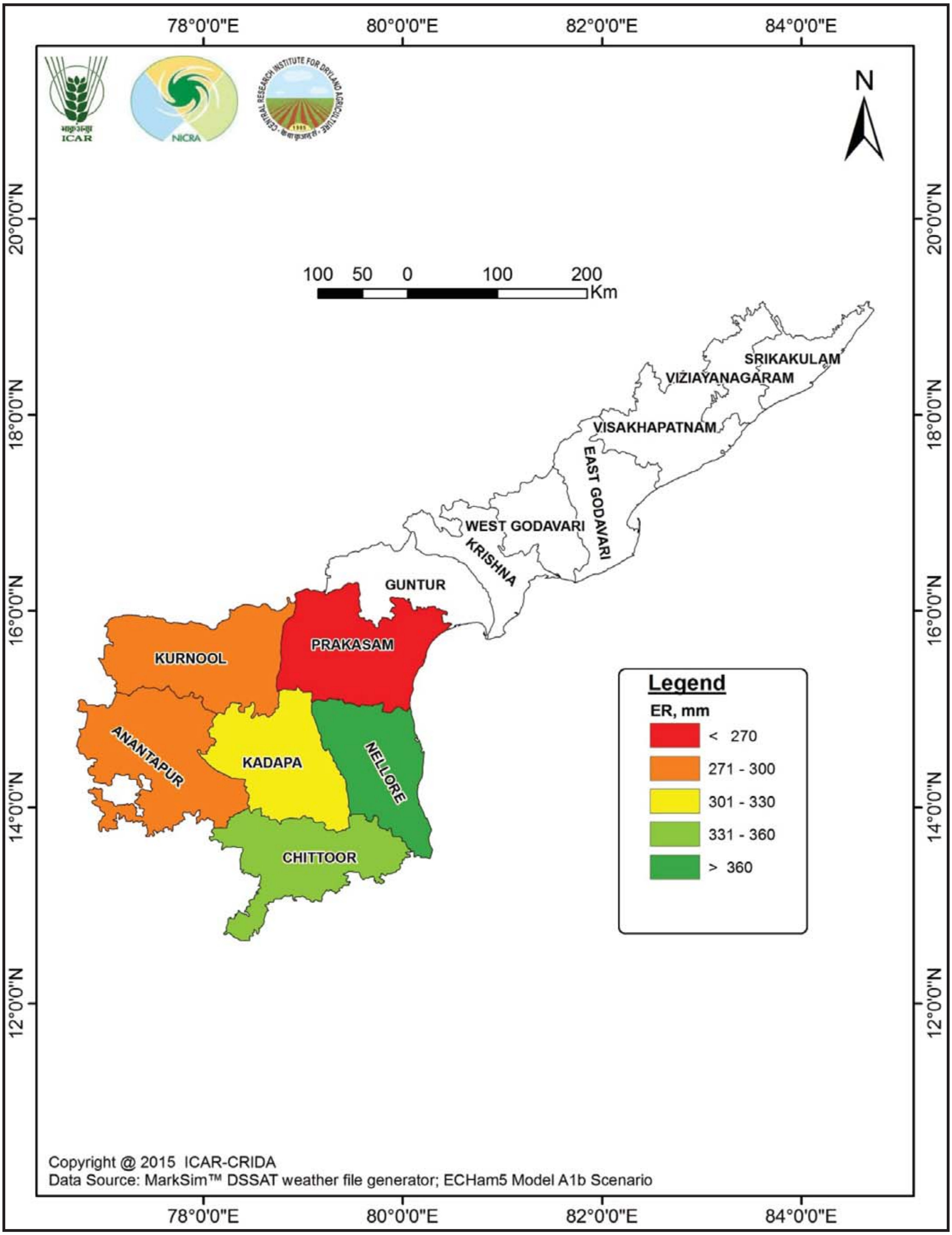

Fig.3.22 Effective rainfall (ER) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2021-2030 in rainfed districts of Andhra Pradesh

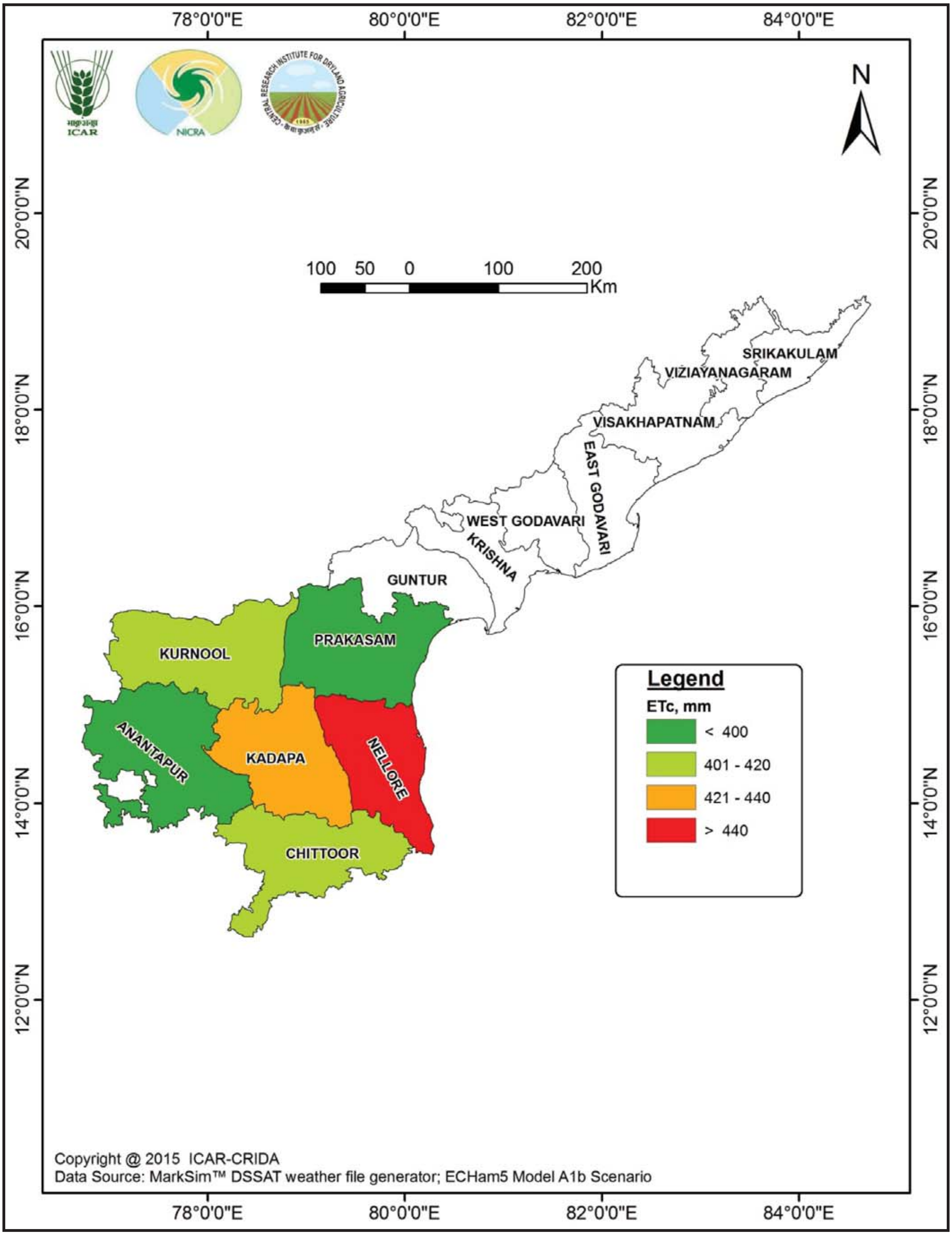

Fig.3.23 Crop evapotranspiration (ETc) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2021-2030 in rainfed districts of Andhra Pradesh

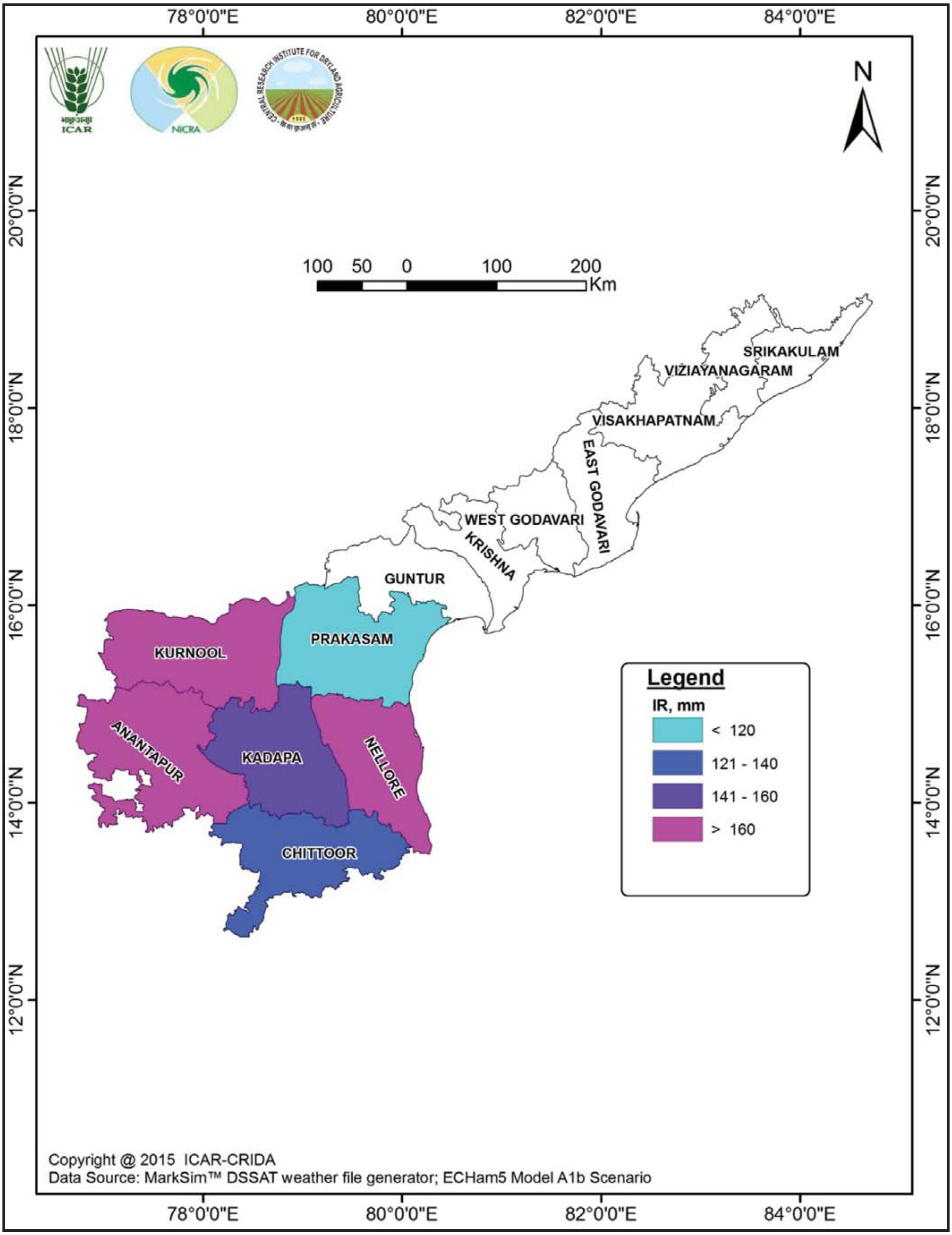

Fig.3.24 Irrigation requirement (IR) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2021-2030 in rainfed districts of Andhra Pradesh

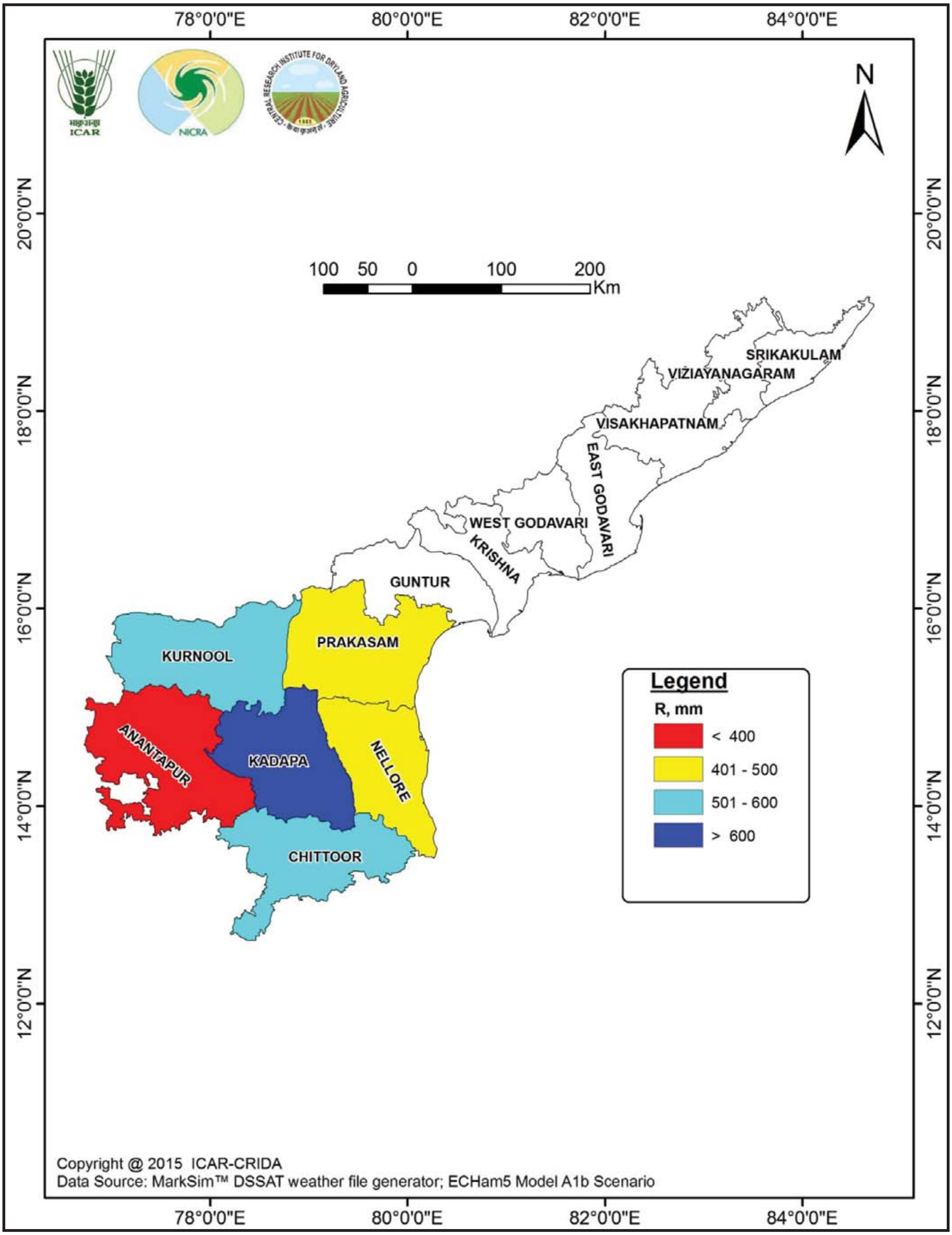

Fig.3.25 Rainfall (R) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2031-2040 in rainfed districts of Andhra Pradesh

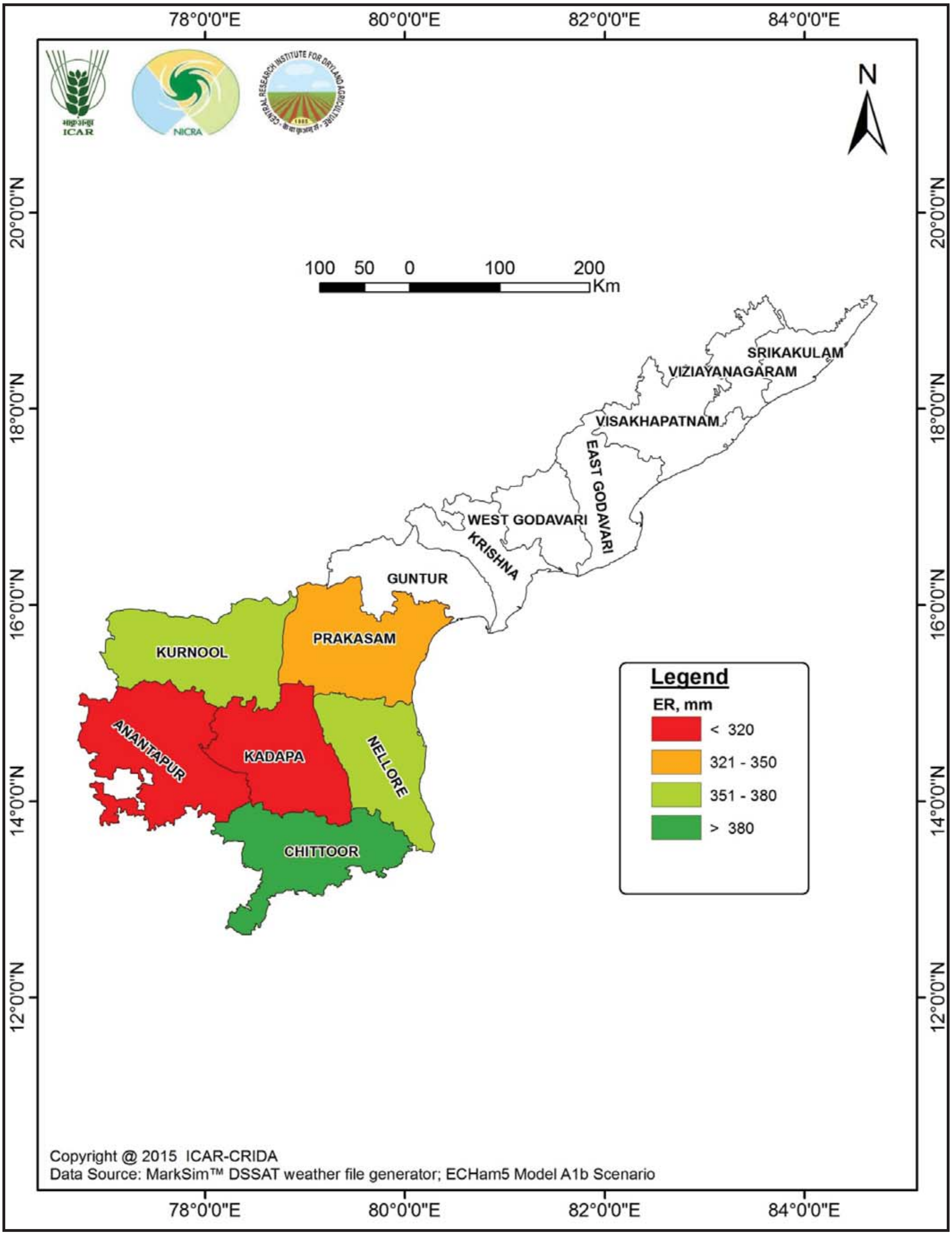

Fig.3.26 Effective rainfall (ER) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2031-2040 in rainfed districts of Andhra Pradesh

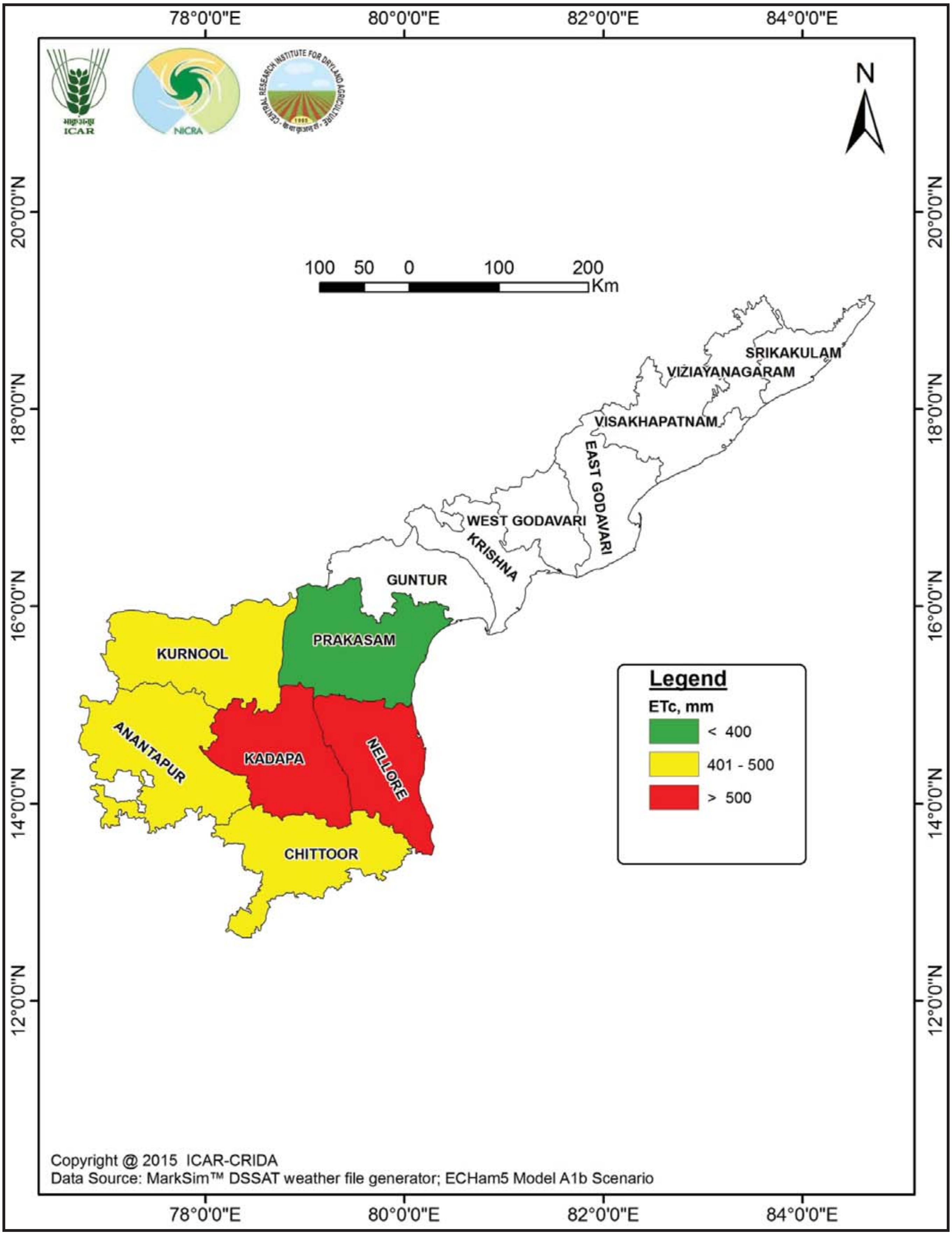

Fig.3.27 Crop evapotranspiration (ETc) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2031-2040 in rainfed districts of Andhra Pradesh

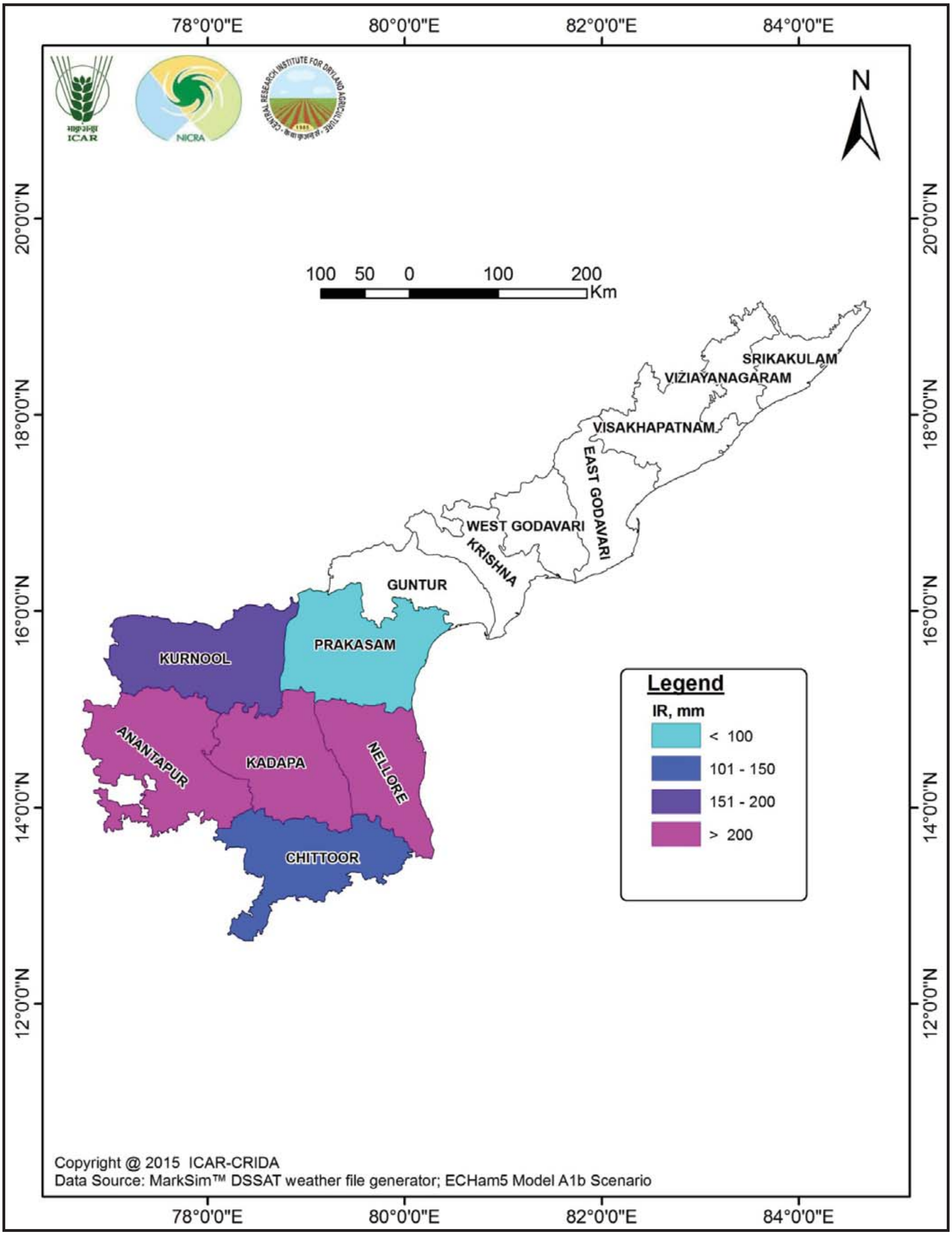

Fig.3.28 Irrigation requirement (IR) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2031-2040 in rainfed districts of Andhra Pradesh

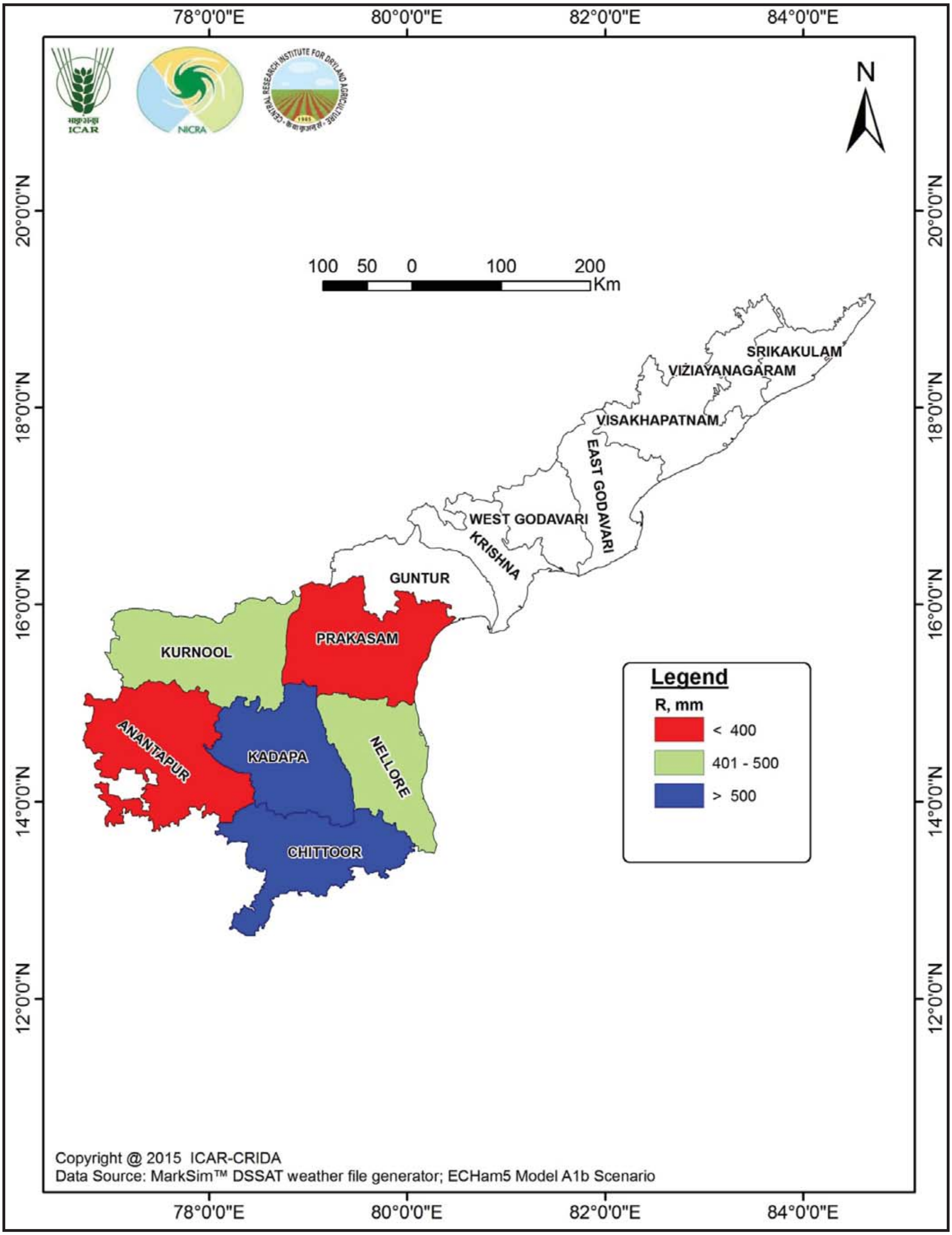

Fig.3.29 Rainfall (R) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2031-2040 in rainfed districts of Andhra Pradesh

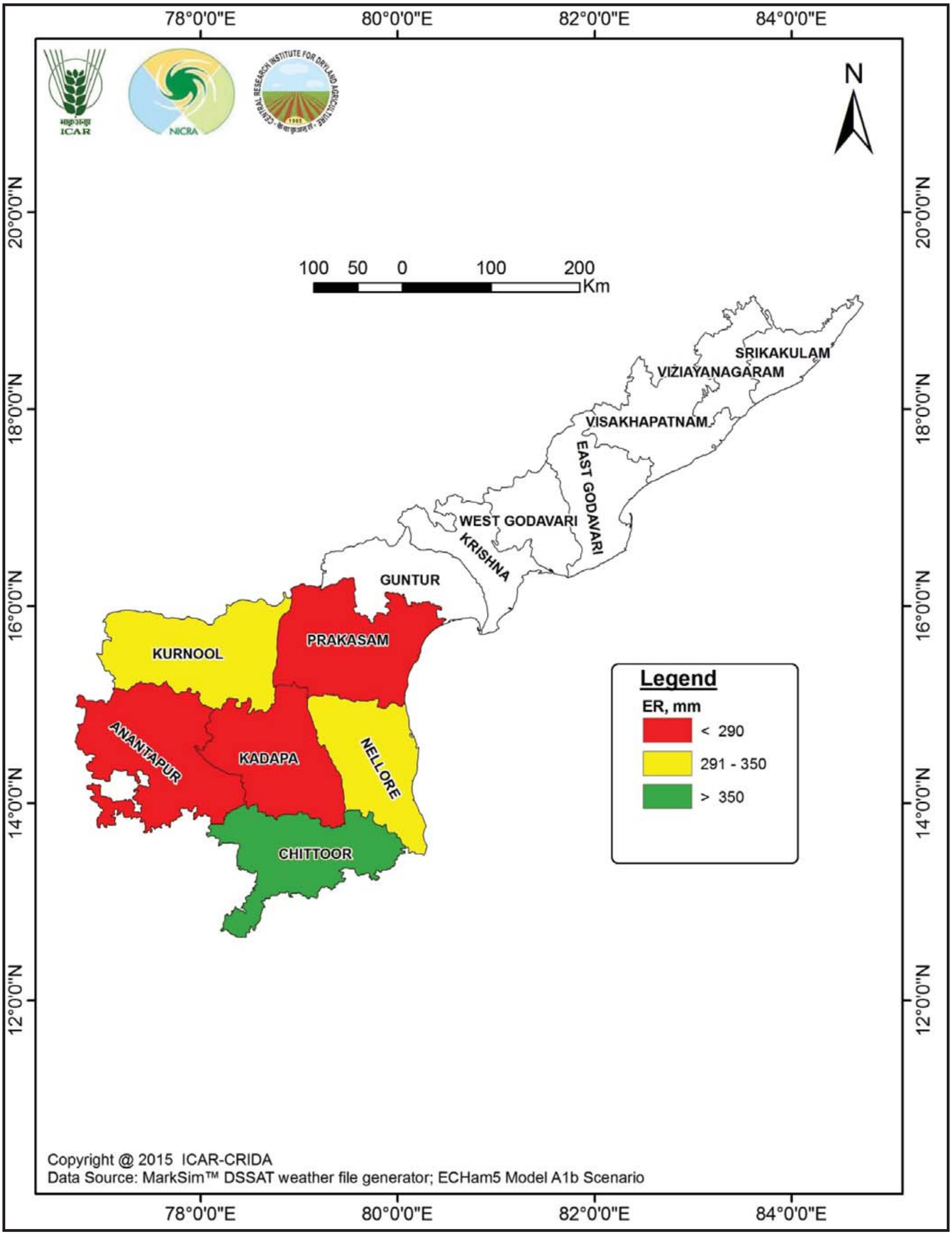

Fig.3.30 Effective rainfall (ER) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2031-2040 in rainfed districts of Andhra Pradesh

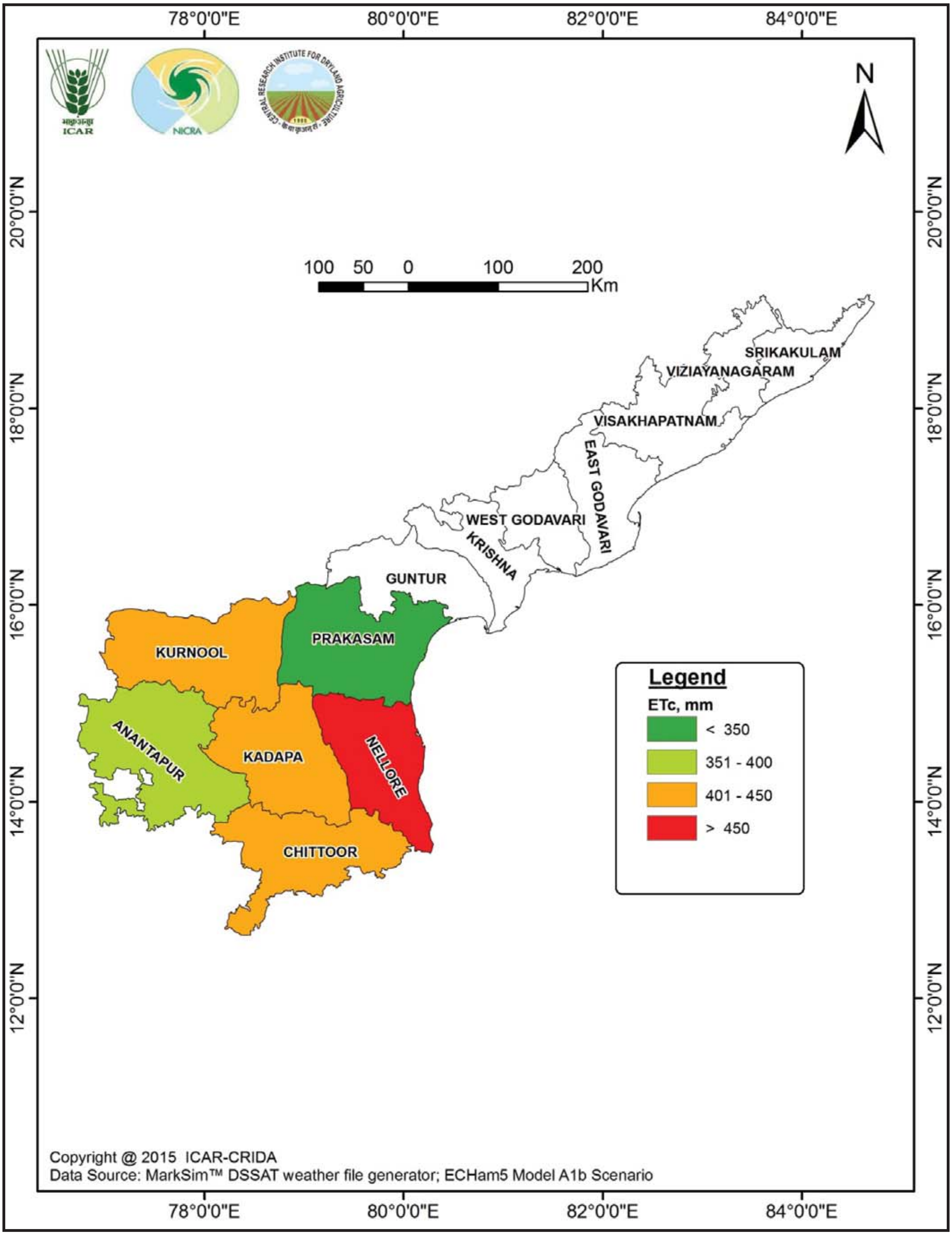

Fig.3.31 Crop evapotranspiration (ETc) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2031-2040 in rainfed districts of Andhra Pradesh

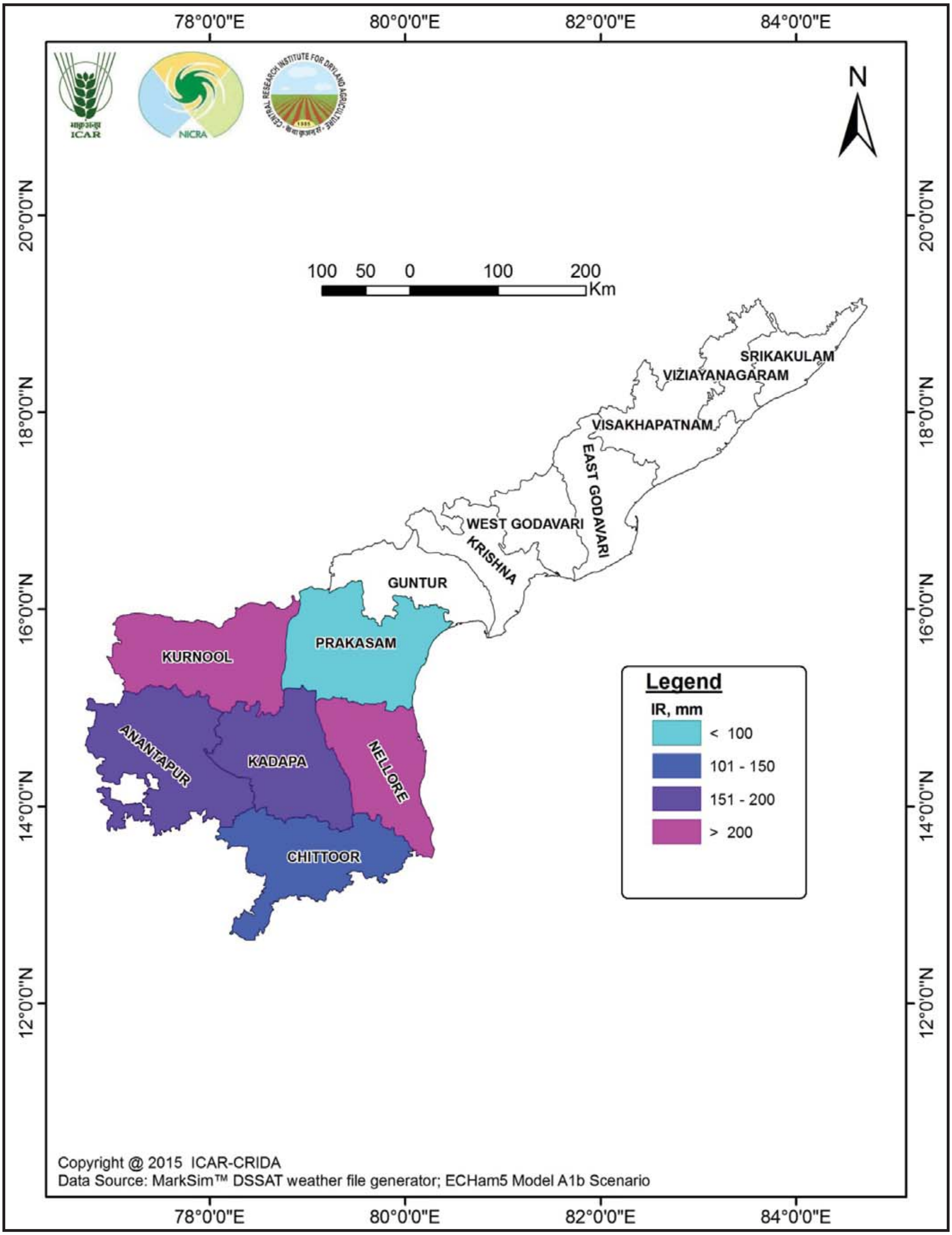

Fig.3.32 Irrigation requirement (IR) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2031-2040 in rainfed districts of Andhra Pradesh

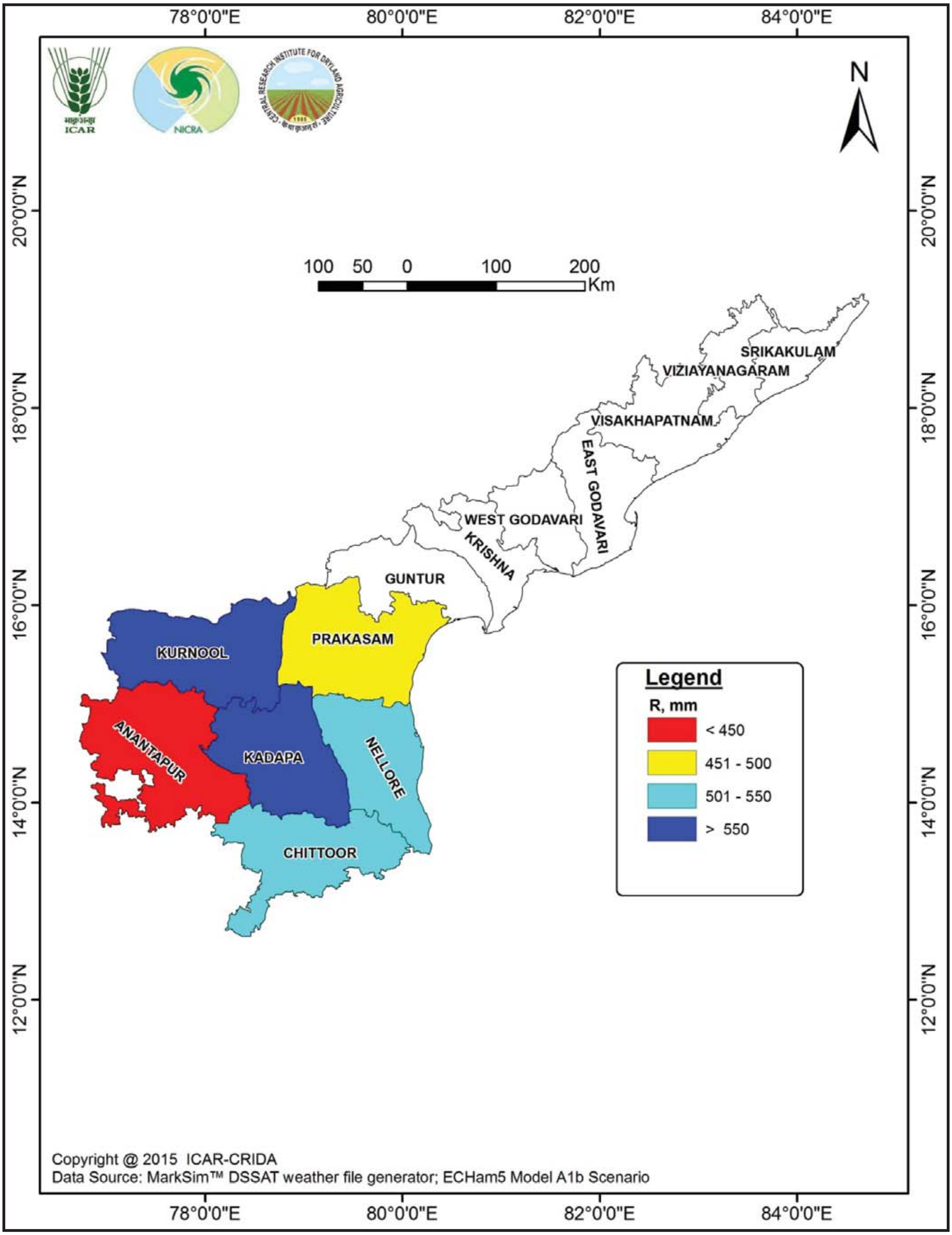

Fig.3.33 Rainfall (R) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2041-2050 in rainfed districts of Andhra Pradesh

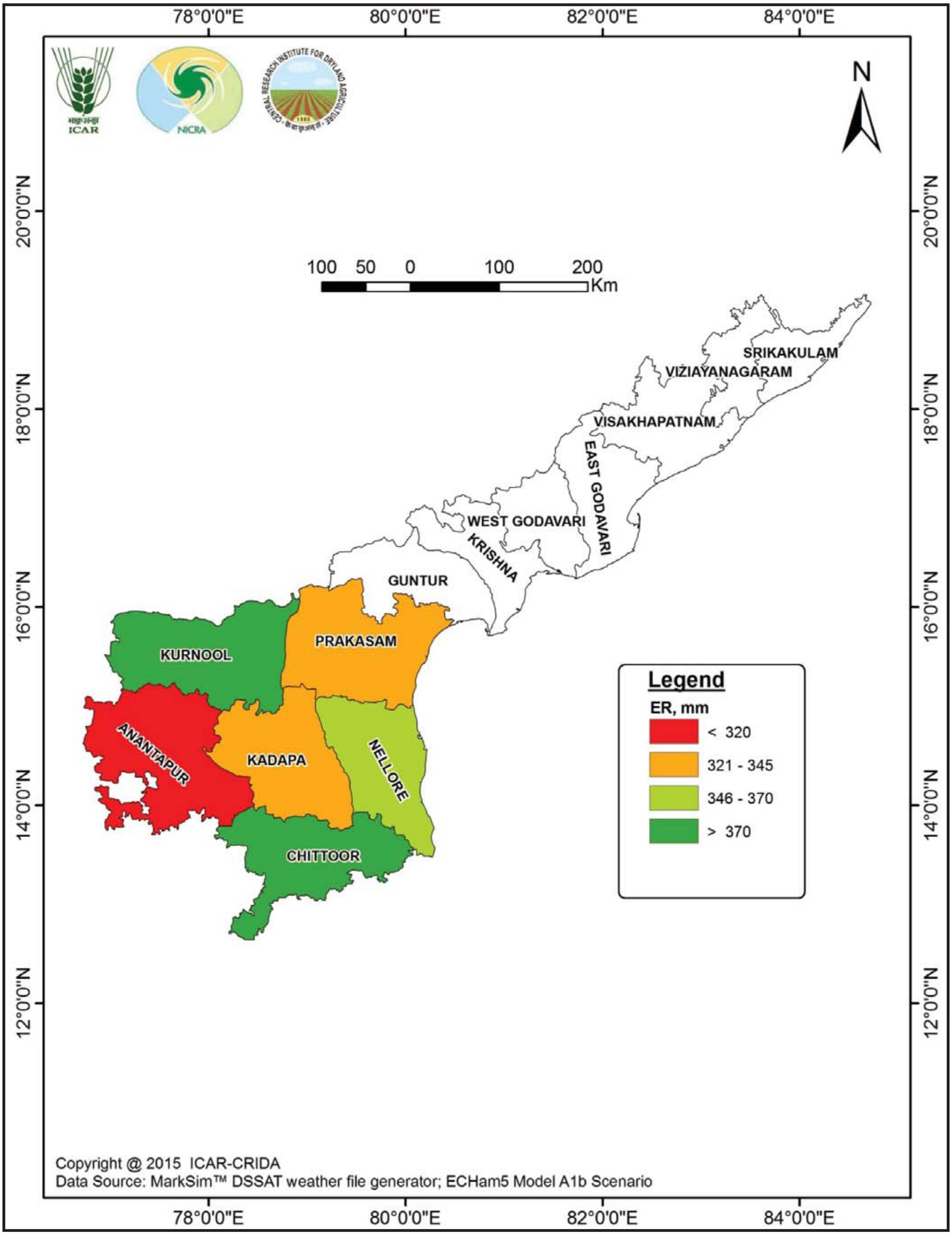

Fig.3.34 Effective rainfall (ER) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2041-2050 in rainfed districts of Andhra Pradesh

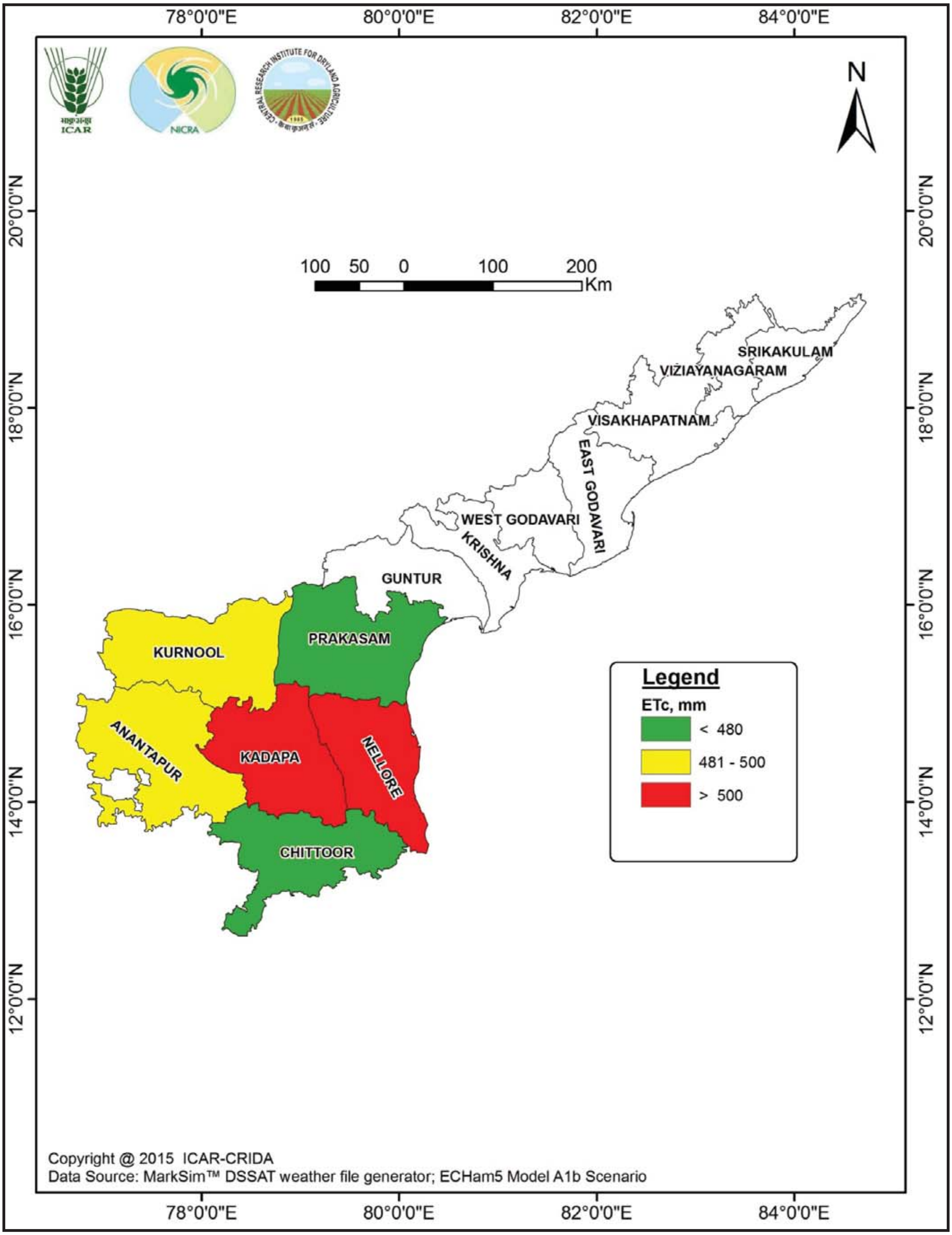

Fig.3.35 Crop evapotranspiration (ETc) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2041-2050 in rainfed districts of Andhra Pradesh

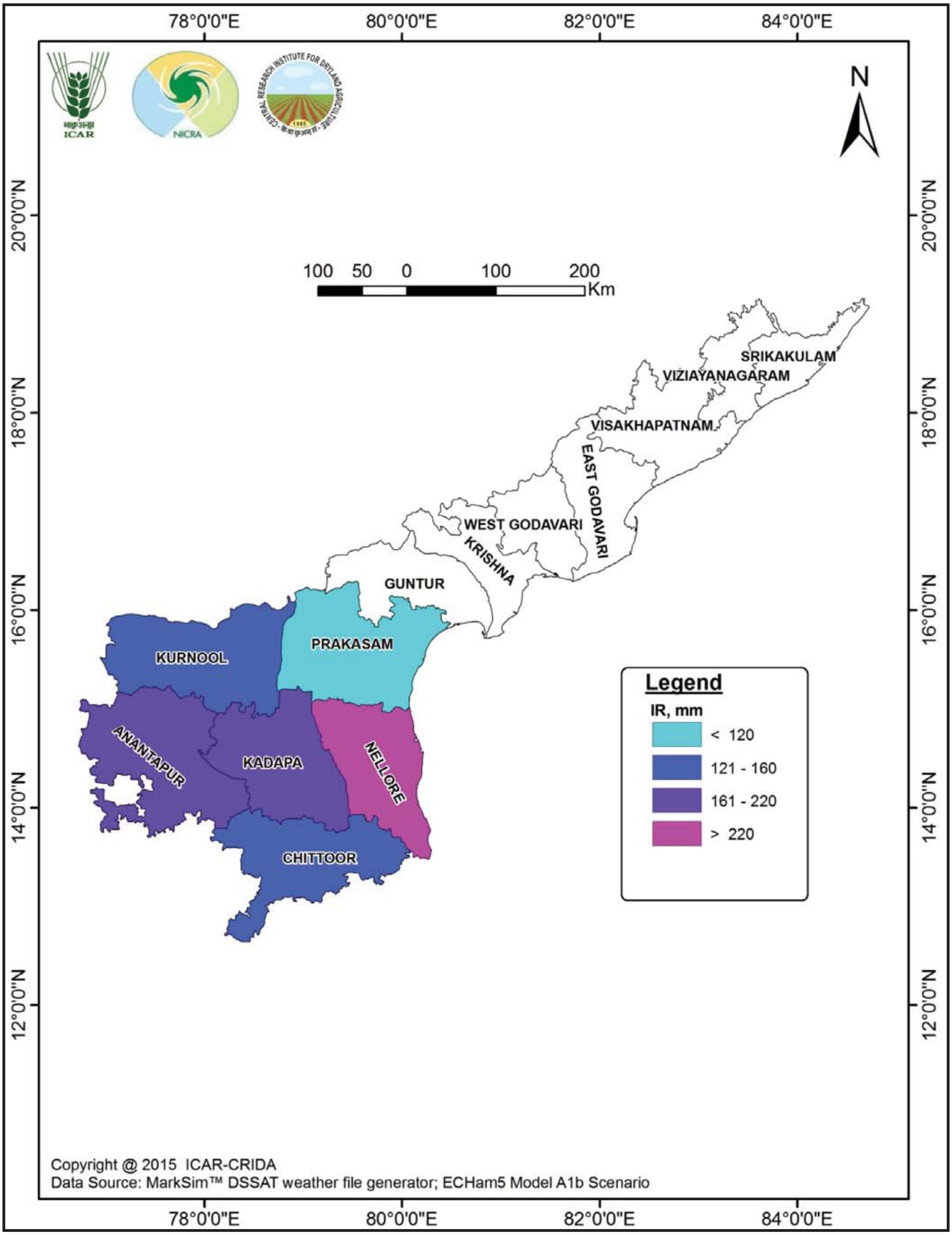

Fig.3.36 Irrigation requirement (IR) during crop growth period of groundnut and pigeon pea under normal sowing for the decade 2041-2050 in rainfed districts of Andhra Pradesh

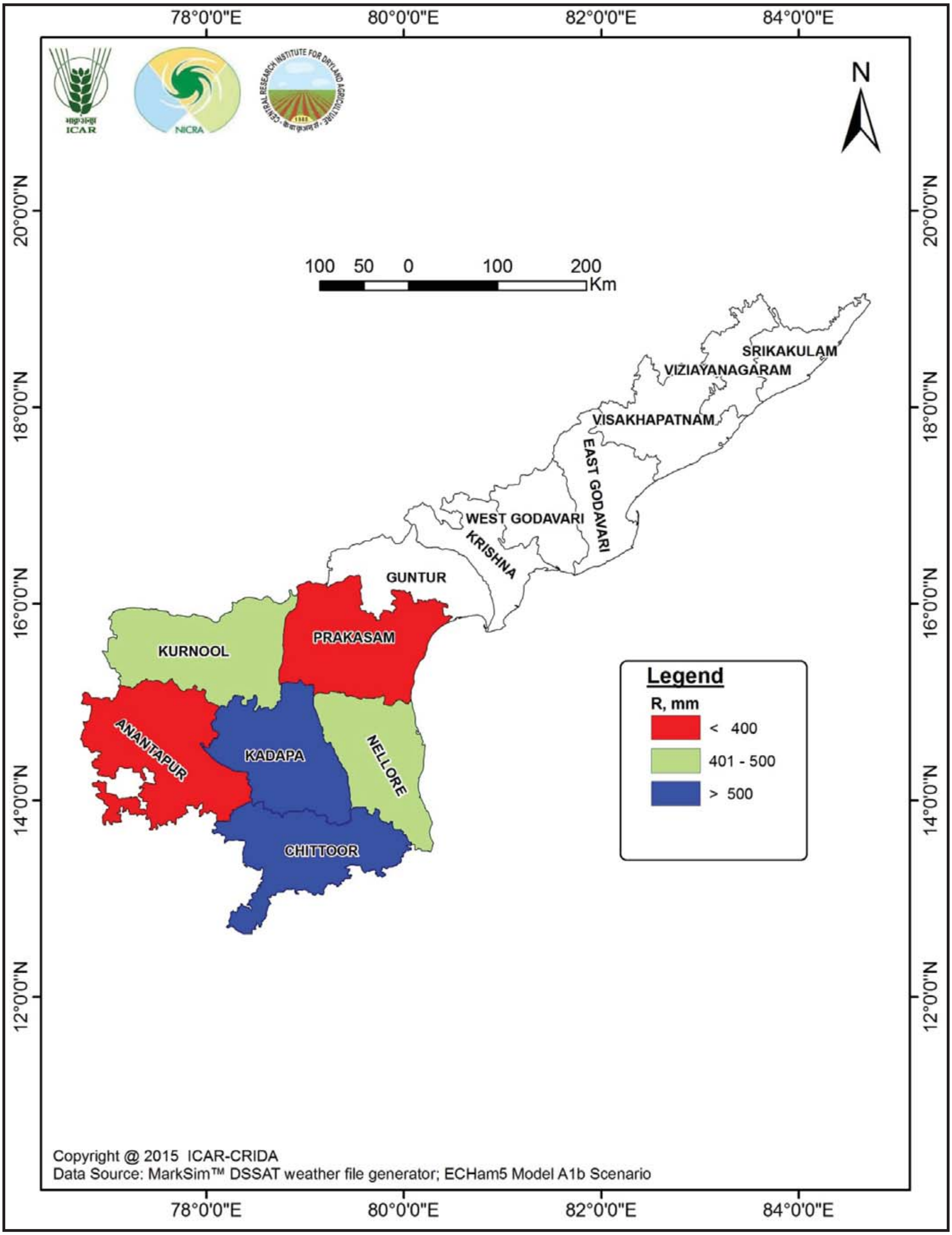

Fig.3.37 Rainfall (R) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2041-2050 in rainfed districts of Andhra Pradesh

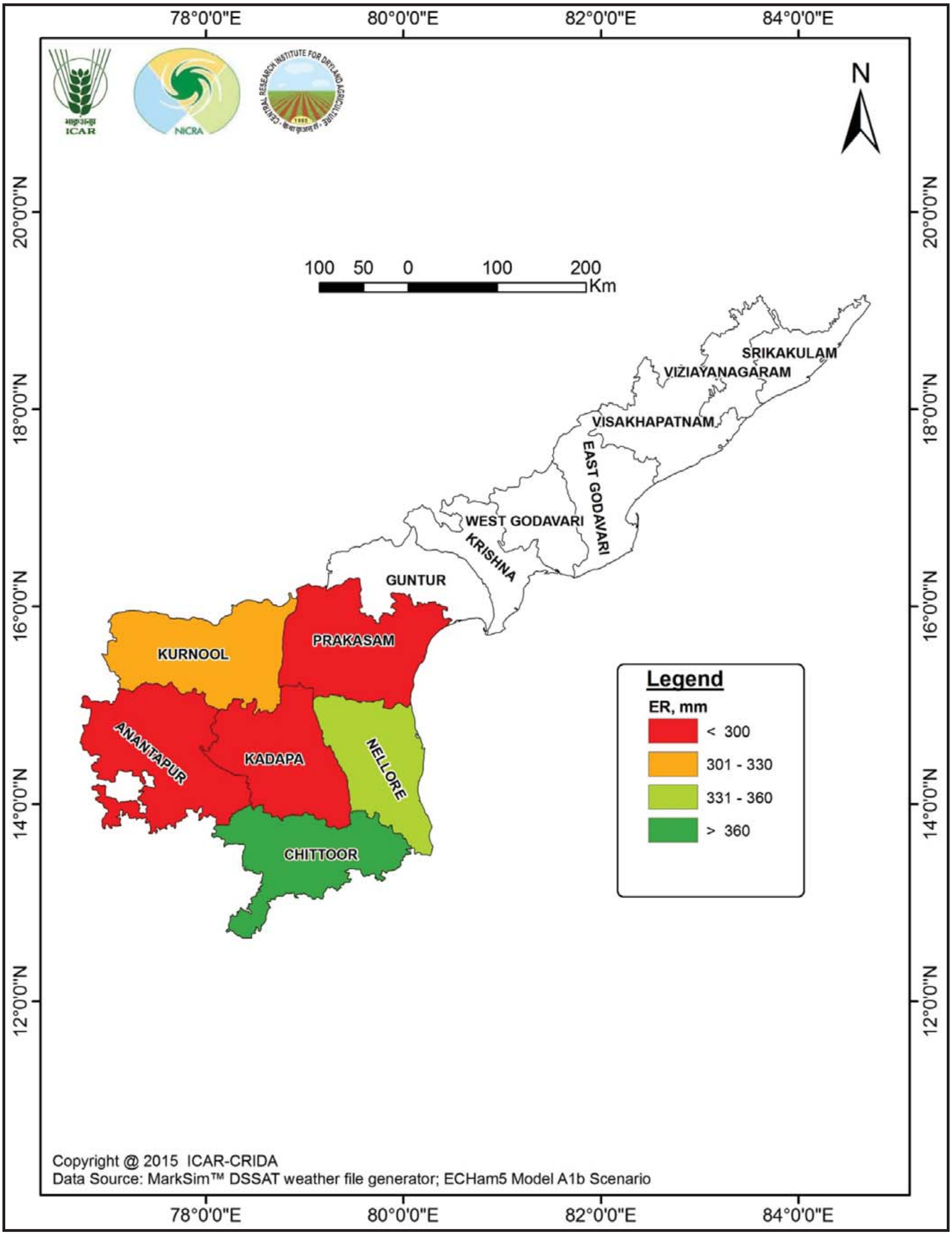

Fig.3.38 Effective rainfall (ER) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2041-2050 in rainfed districts of Andhra Pradesh

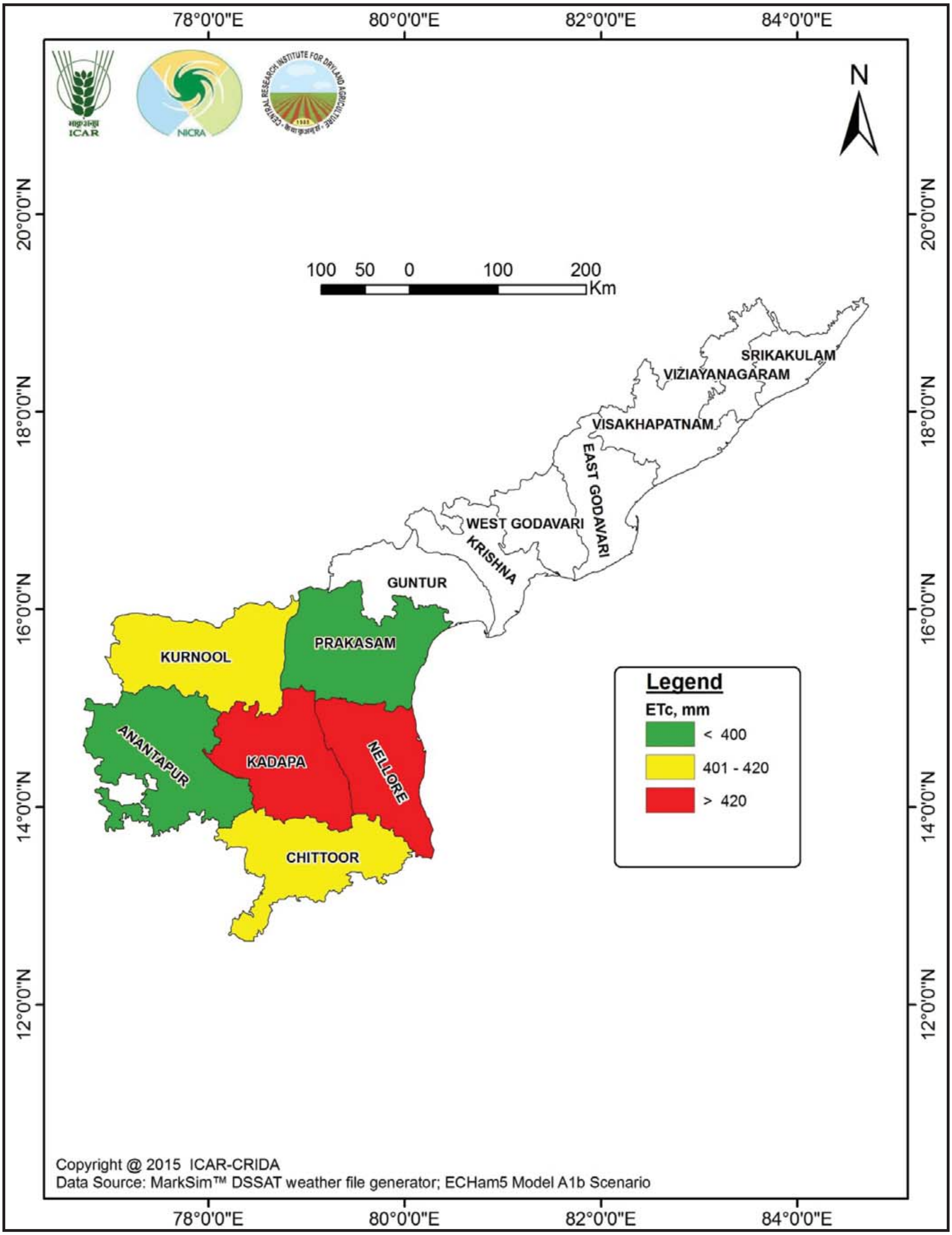

Fig.3.39 Crop evapotranspiration (ETc) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2041-2050 in rainfed districts of Andhra Pradesh

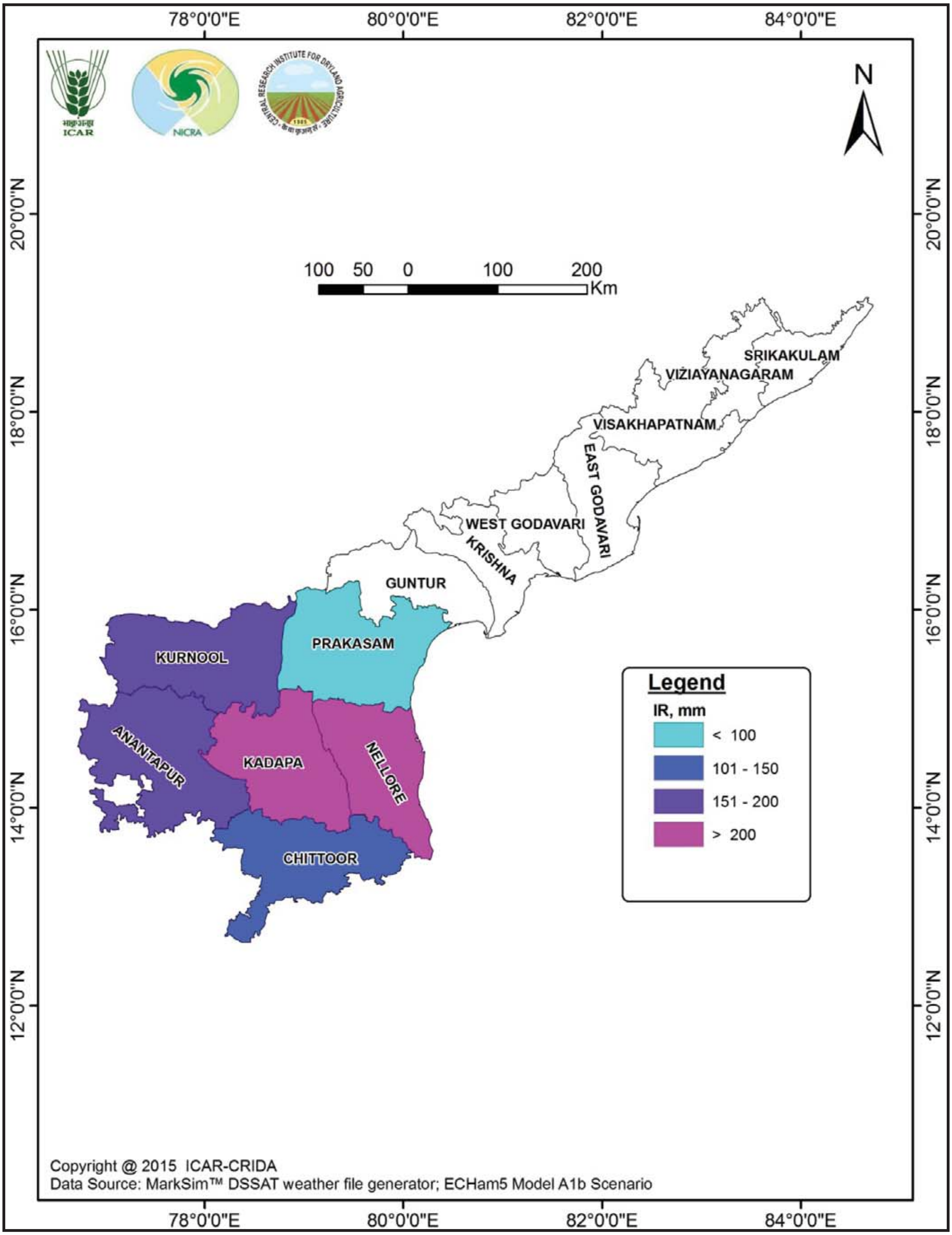

Fig.3.40 Irrigation requirement (IR) during crop growth period of groundnut and pigeon pea under late sowing for the decade 2041-2050 in rainfed districts of Andhra Pradesh

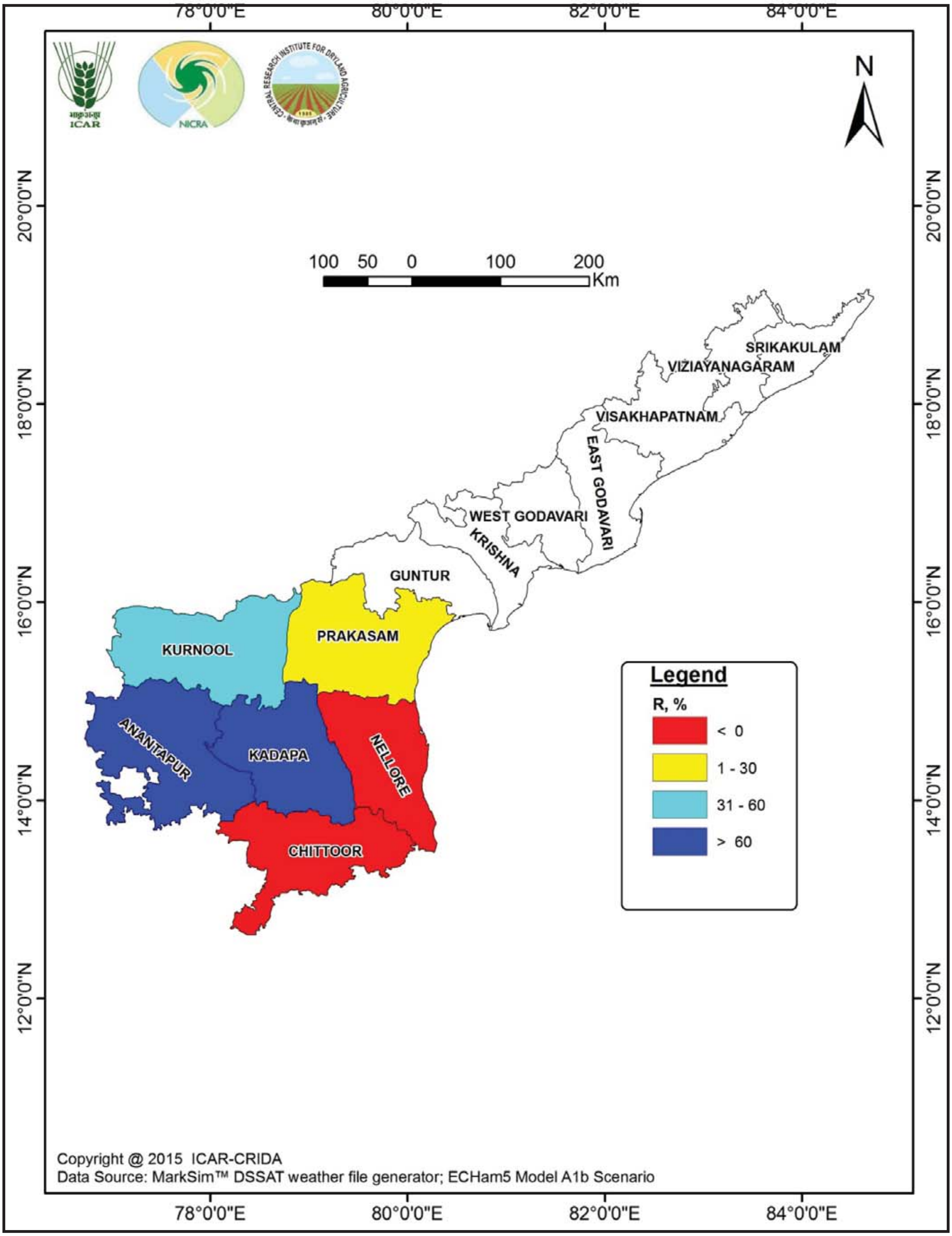

Fig.3.41 Percent decadal (2011-2020) deviation of rainfall (R) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

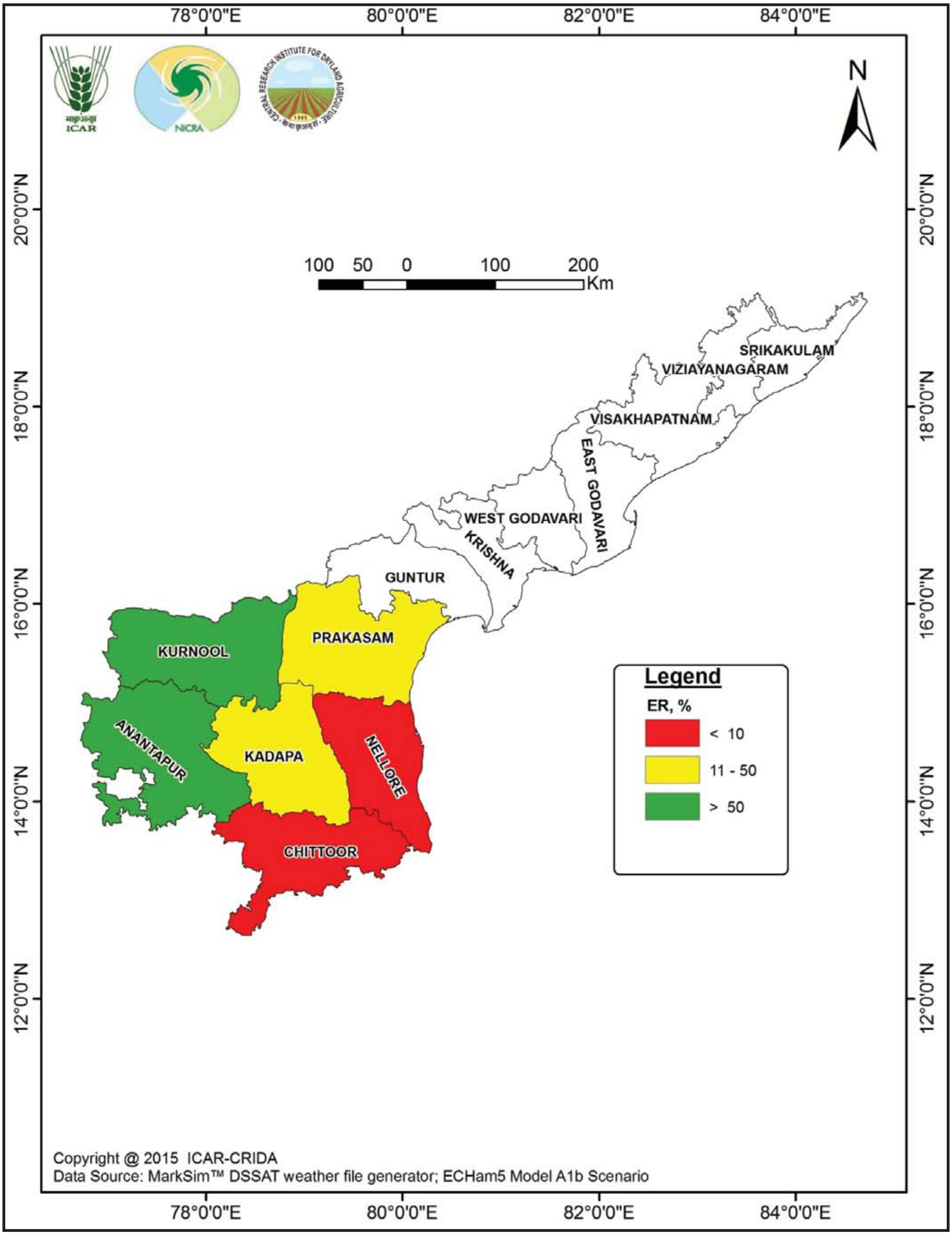

Fig.3.42 Percent decadal (2011-2020) deviation of effective rainfall (ER) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

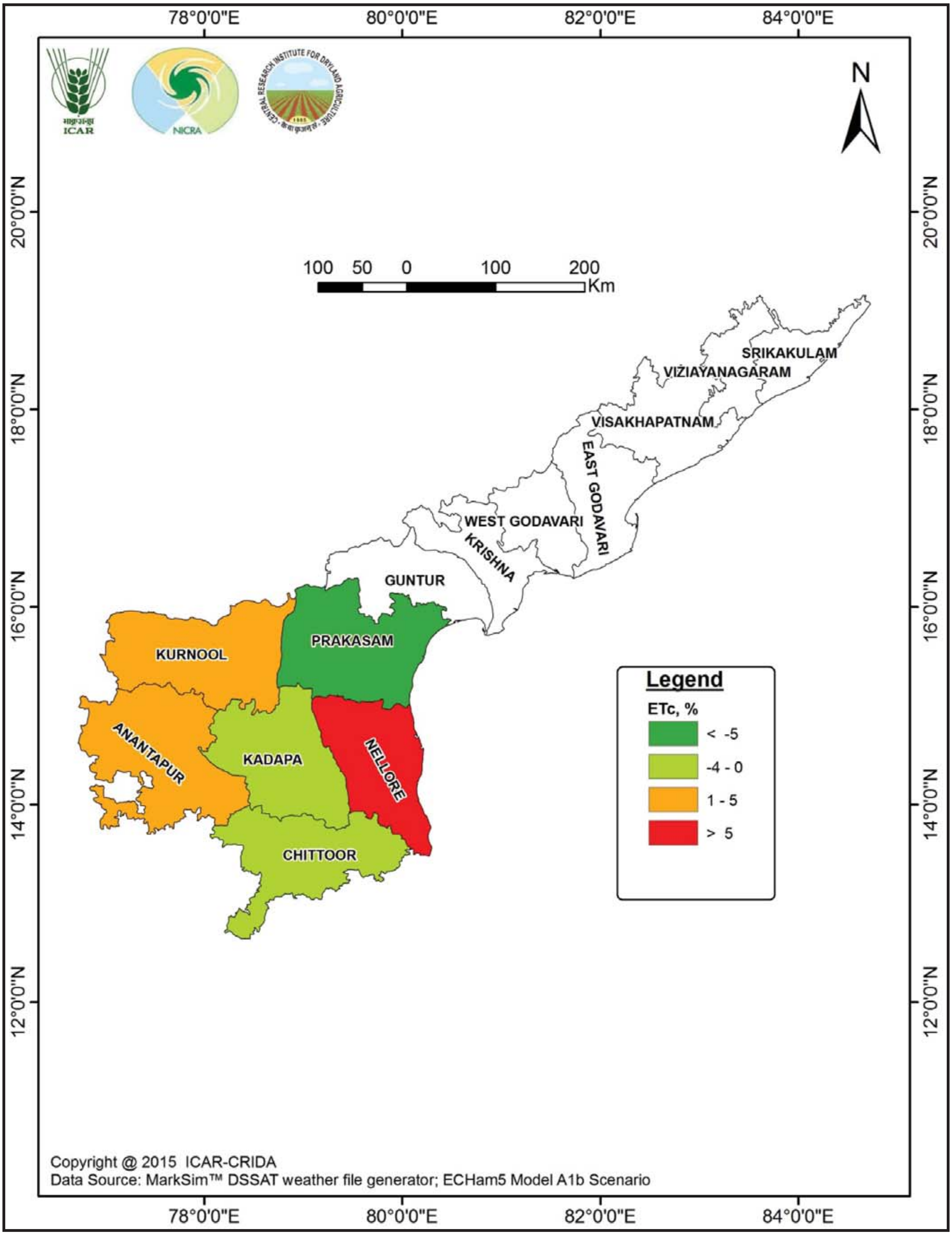

Fig.3.43 Percent decadal (2011-2020) deviation of crop evapotranspiration (ETc) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

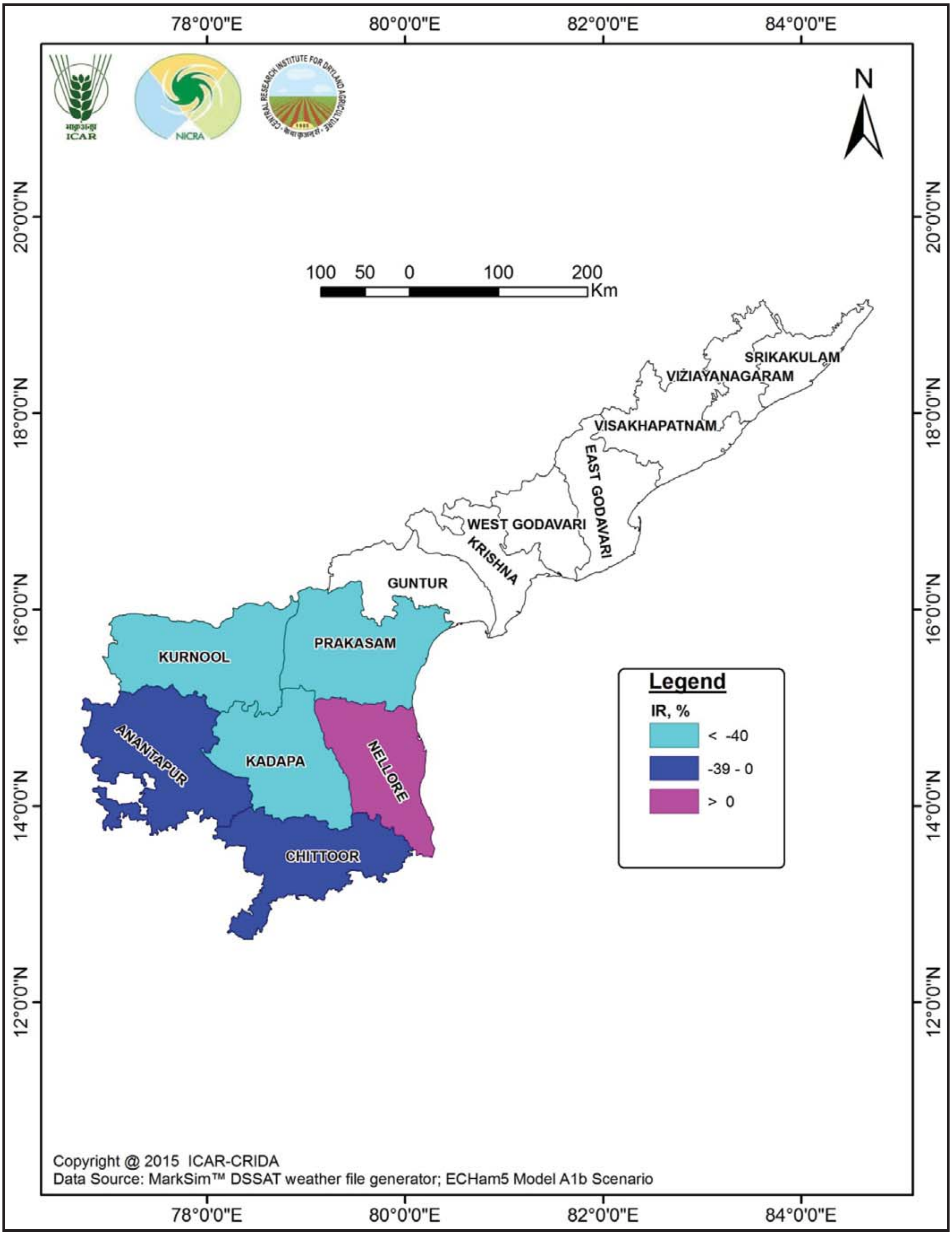

Fig.3.44 Percent decadal (2011-2020) deviation of irrigation requirement (IR) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

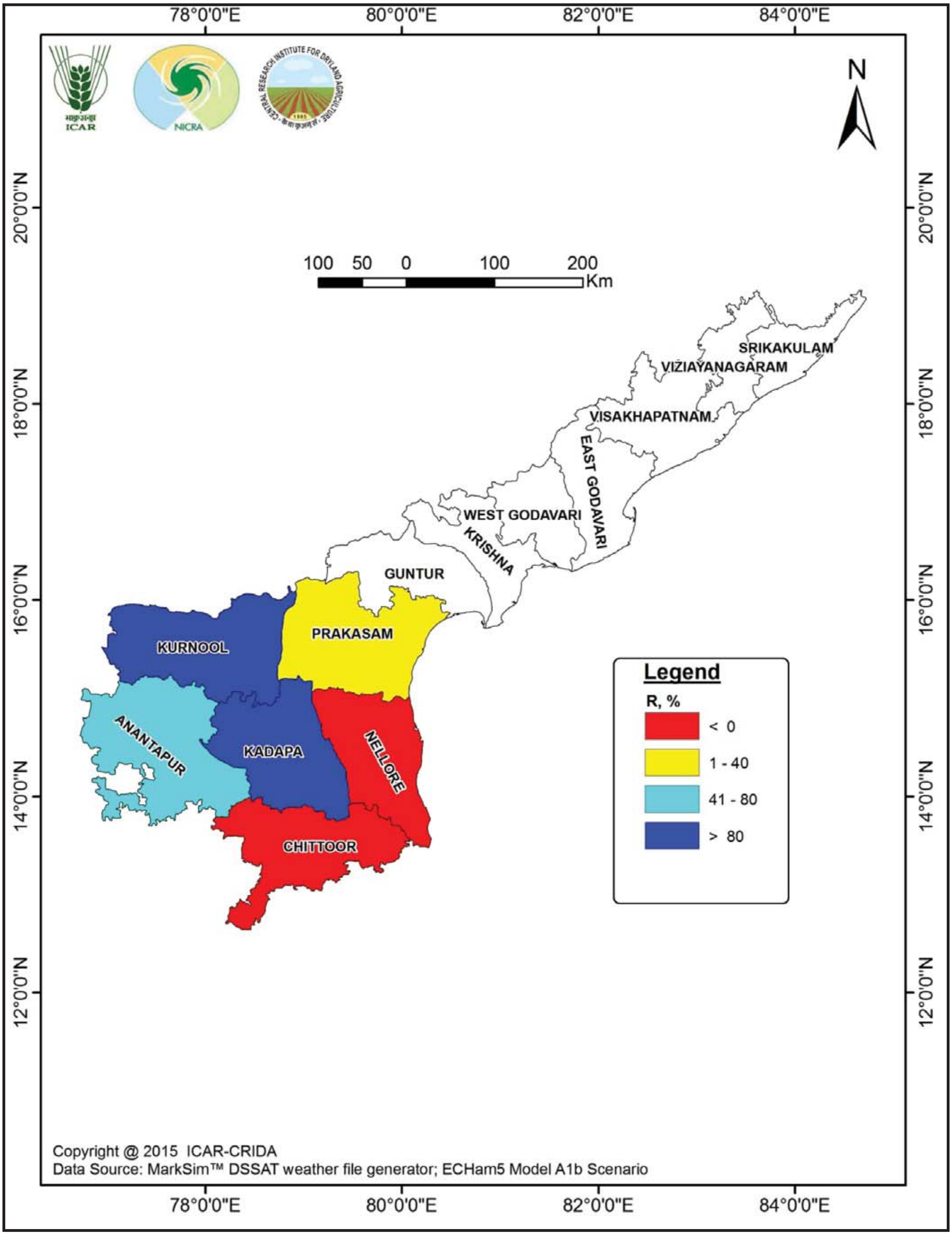

Fig.3.45 Percent decadal (2011-2020) deviation of rainfall (R) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

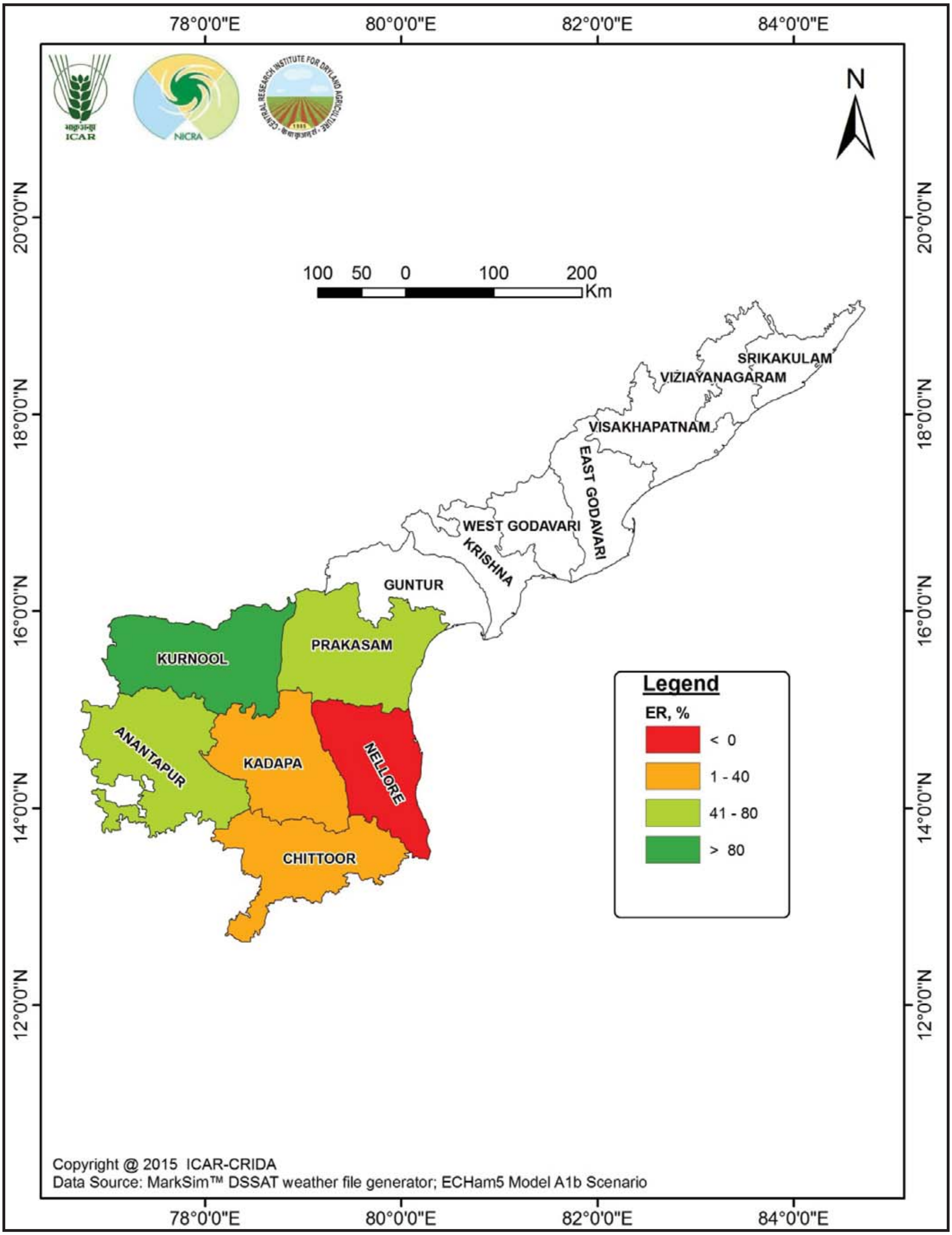

Fig.3.46 Percent decadal (2011-2020) deviation of effective rainfall (ER) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

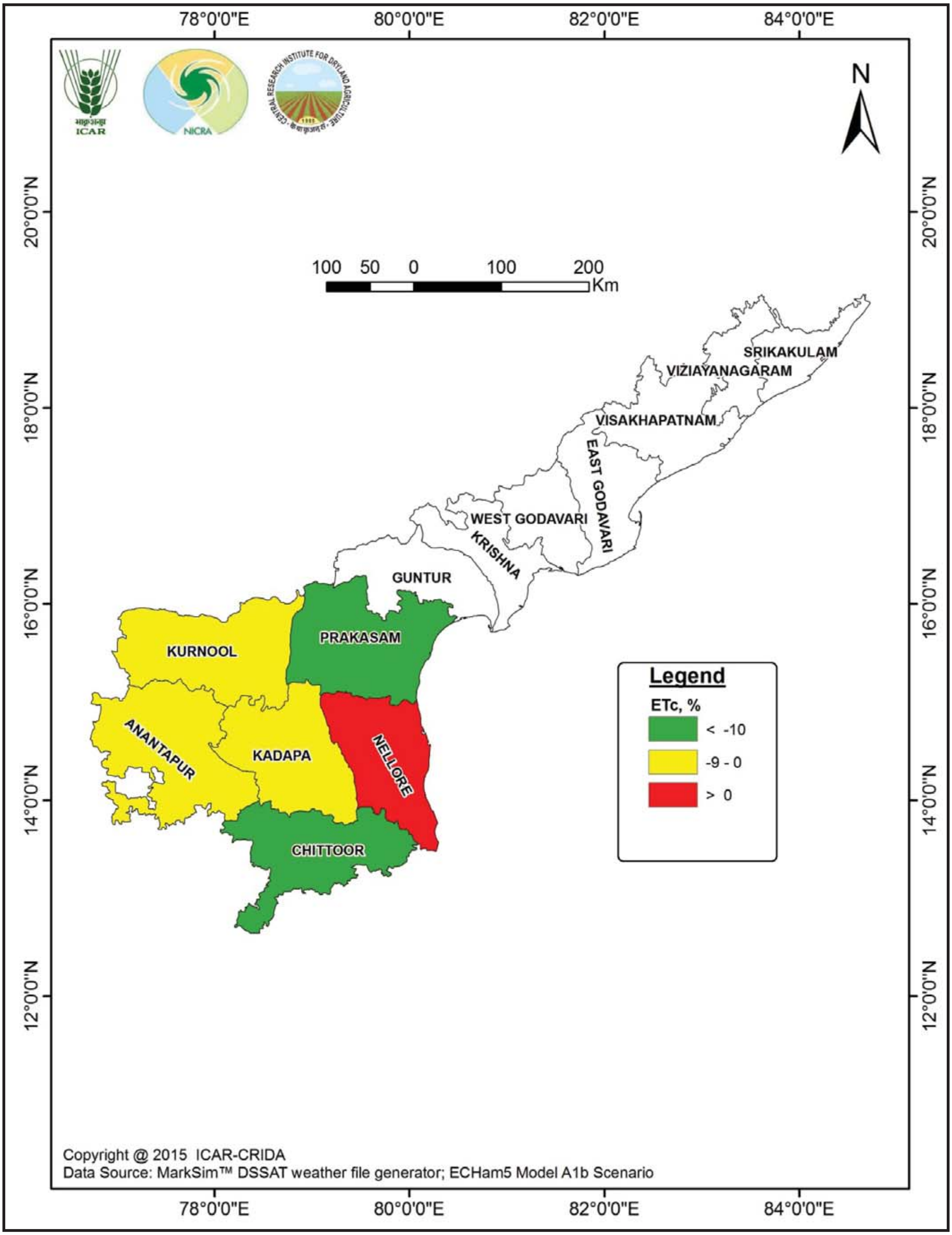

Fig.3.47 Percent decadal (2011-2020) deviation of crop evapotranspiration (ETc) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

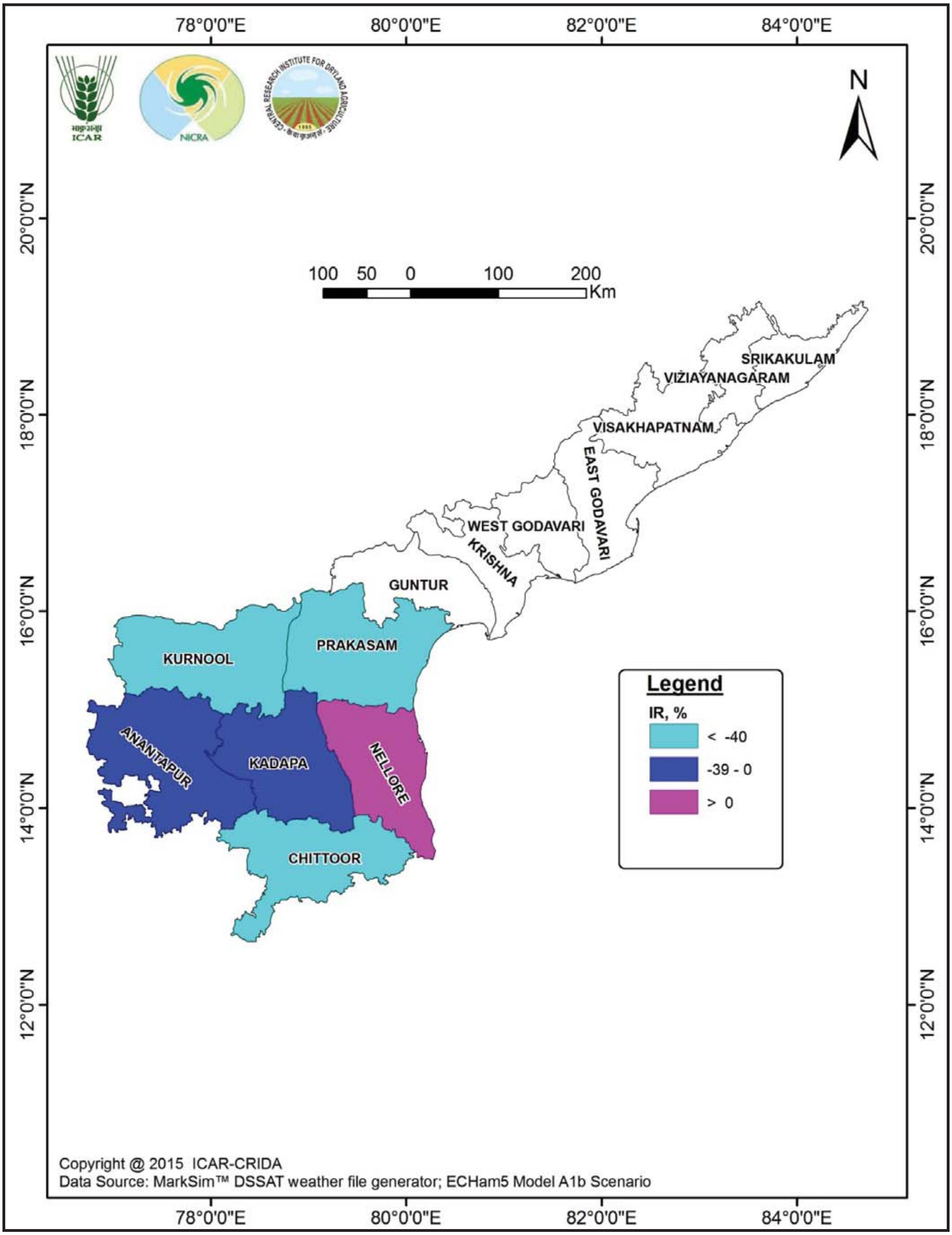

Fig.3.48 Percent decadal (2011-2020) deviation of irrigation requirement (IR) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

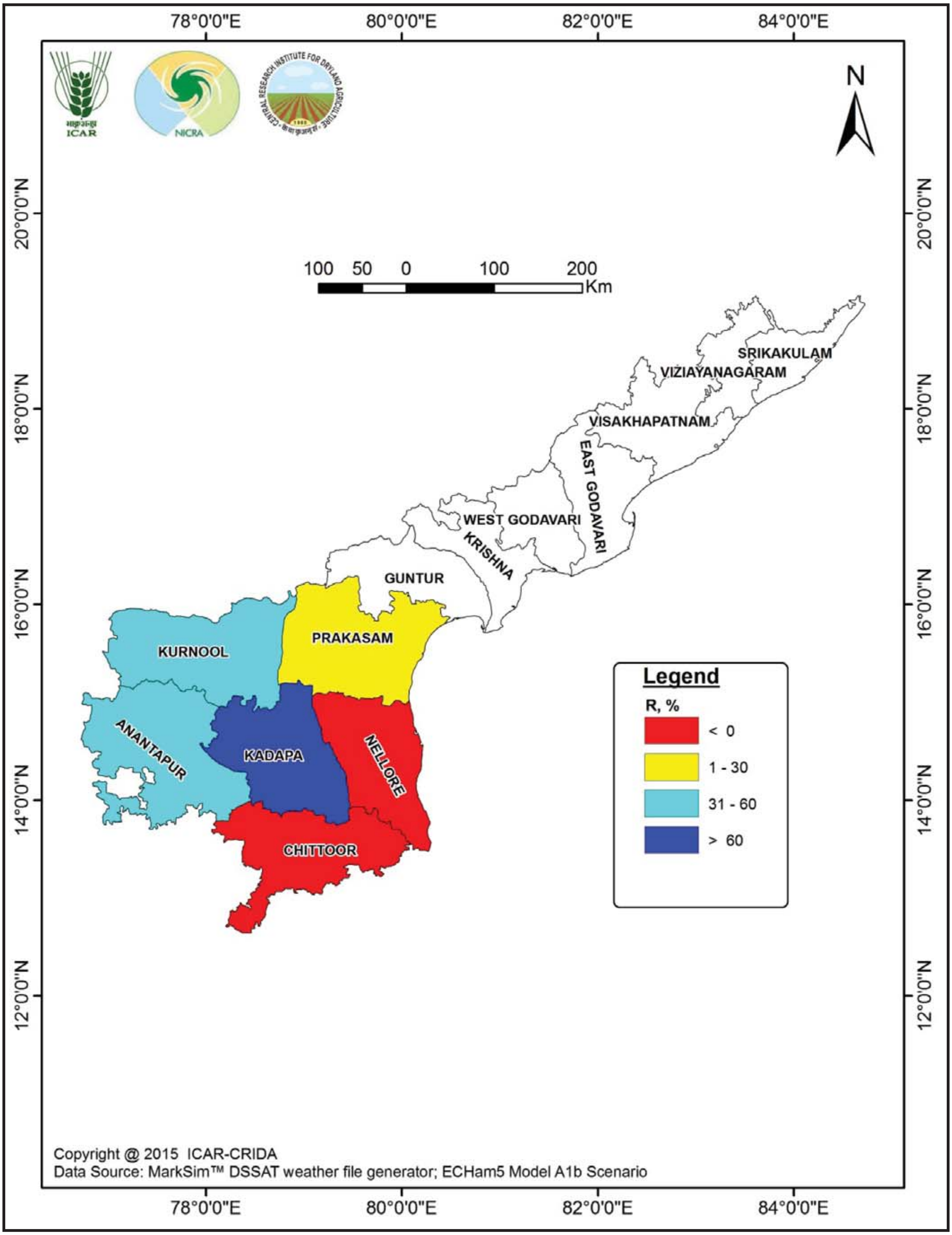

Fig.3.49 Percent decadal (2021-2030) deviation of rainfall (R) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

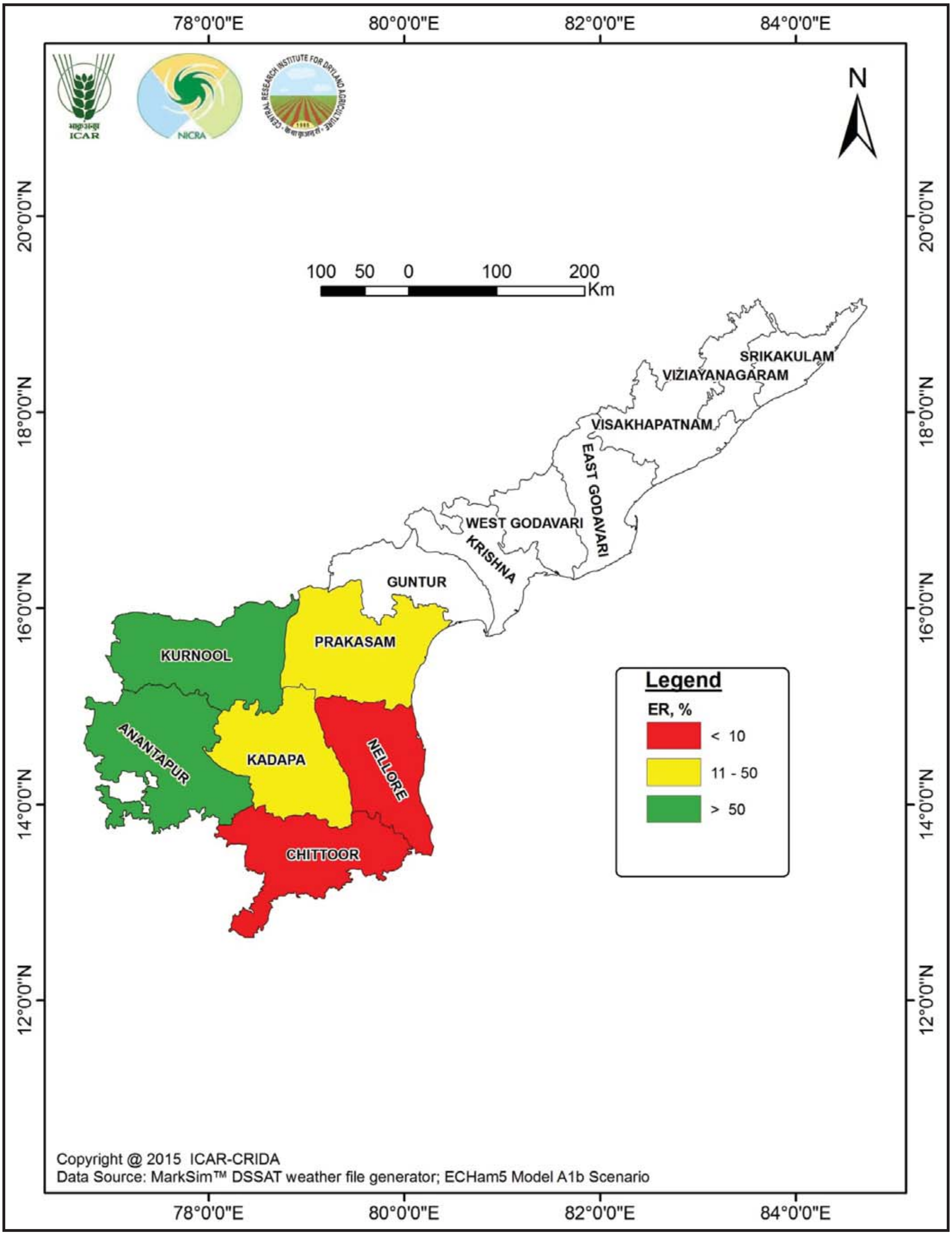

Fig.3.50 Percent decadal (2021-2030) deviation of effective rainfall (ER) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

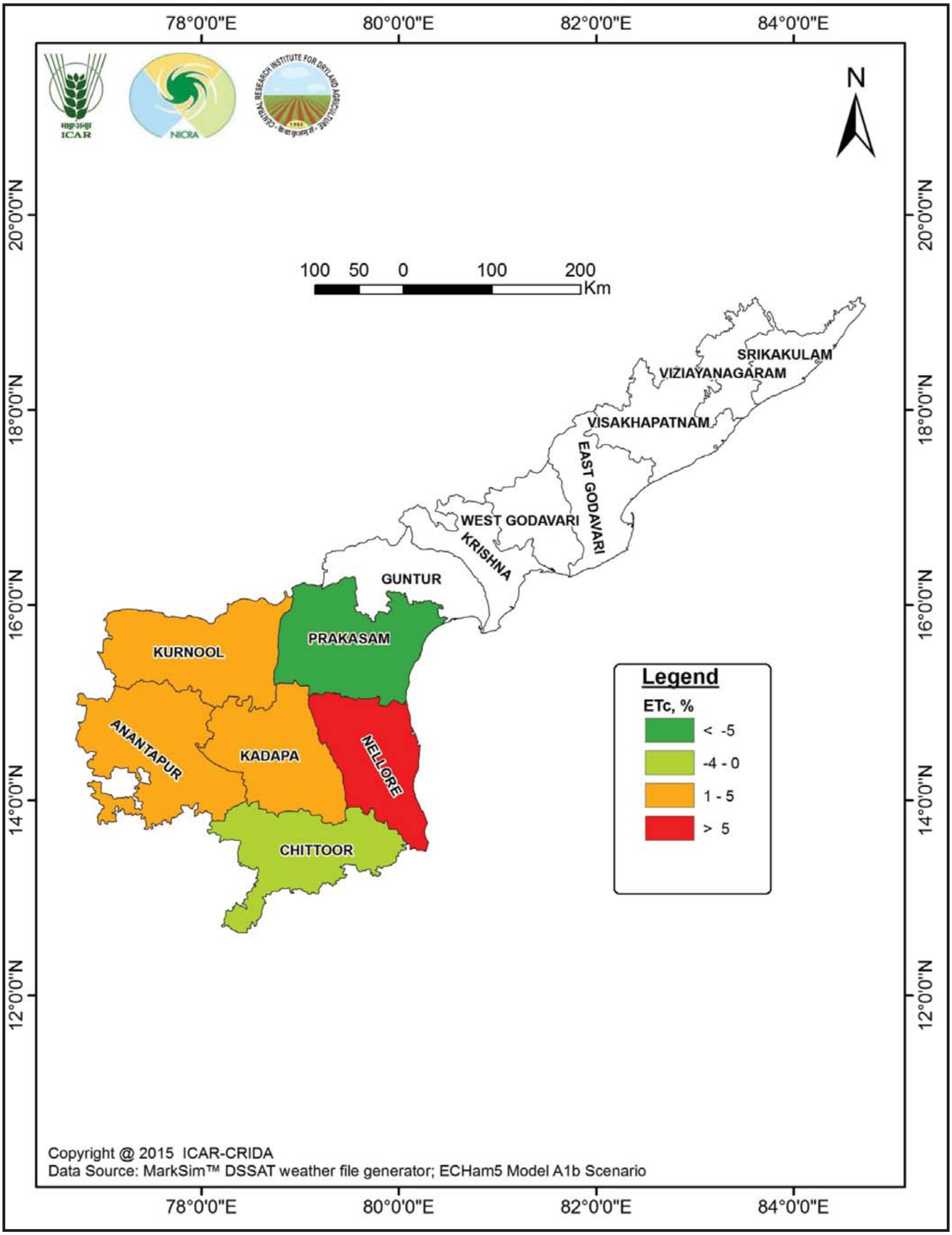

Fig.3.51 Percent decadal (2021-2030) deviation of crop evapotranspiration (ETc) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

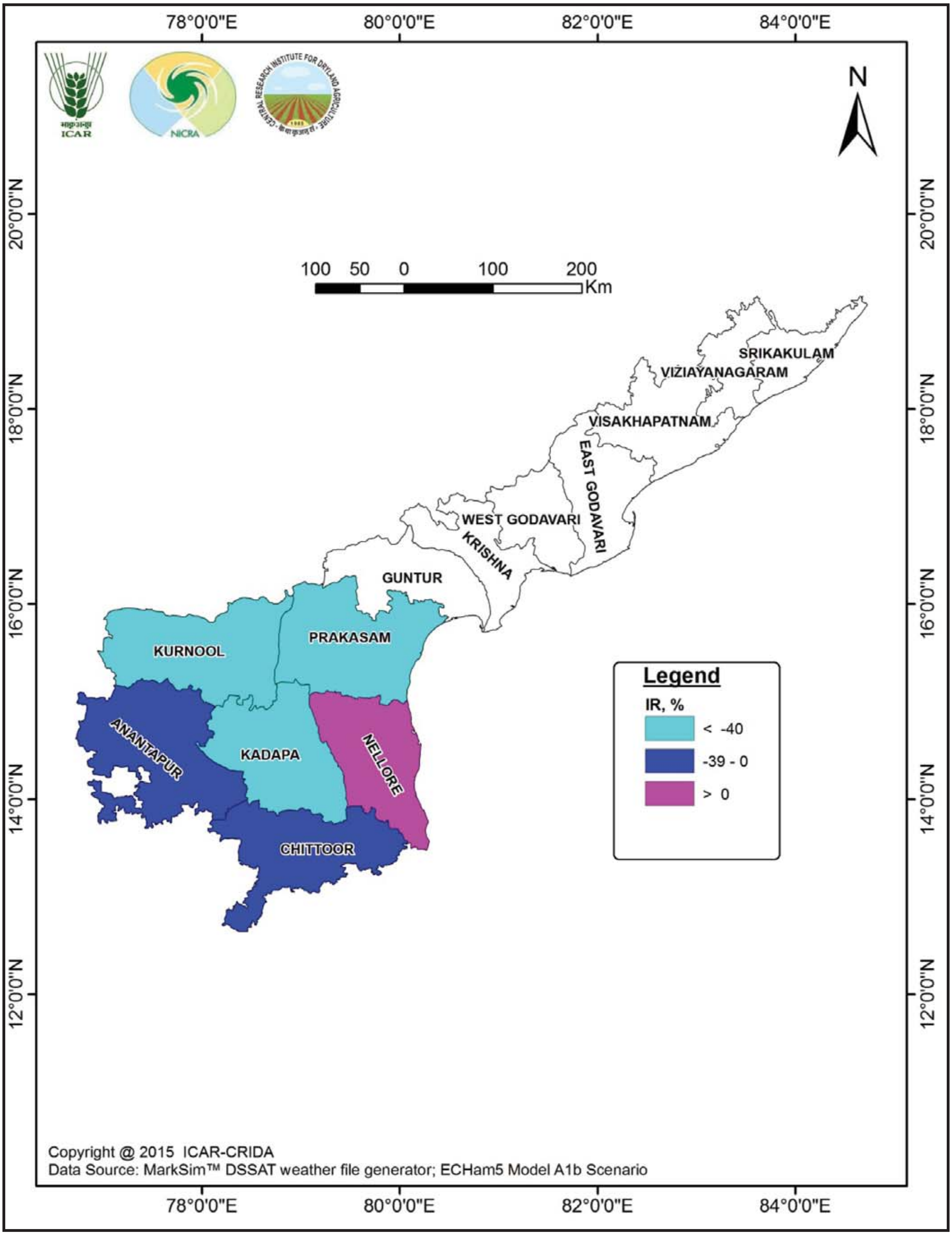

Fig.3.52 Percent decadal (2021-2030) deviation of irrigation requirement (IR) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

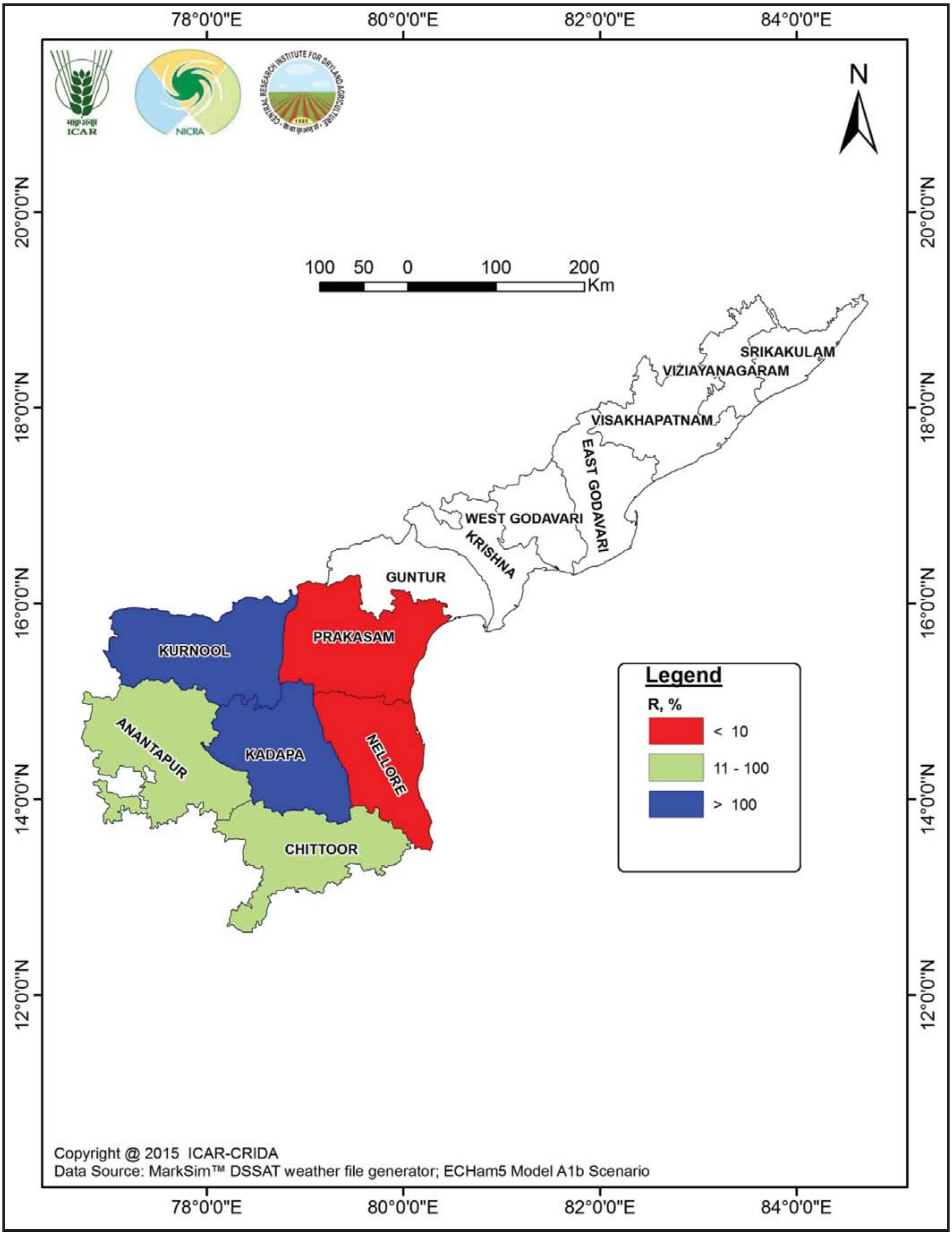

Fig.3.53 Percent decadal (2021-2030) deviation of rainfall (R) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

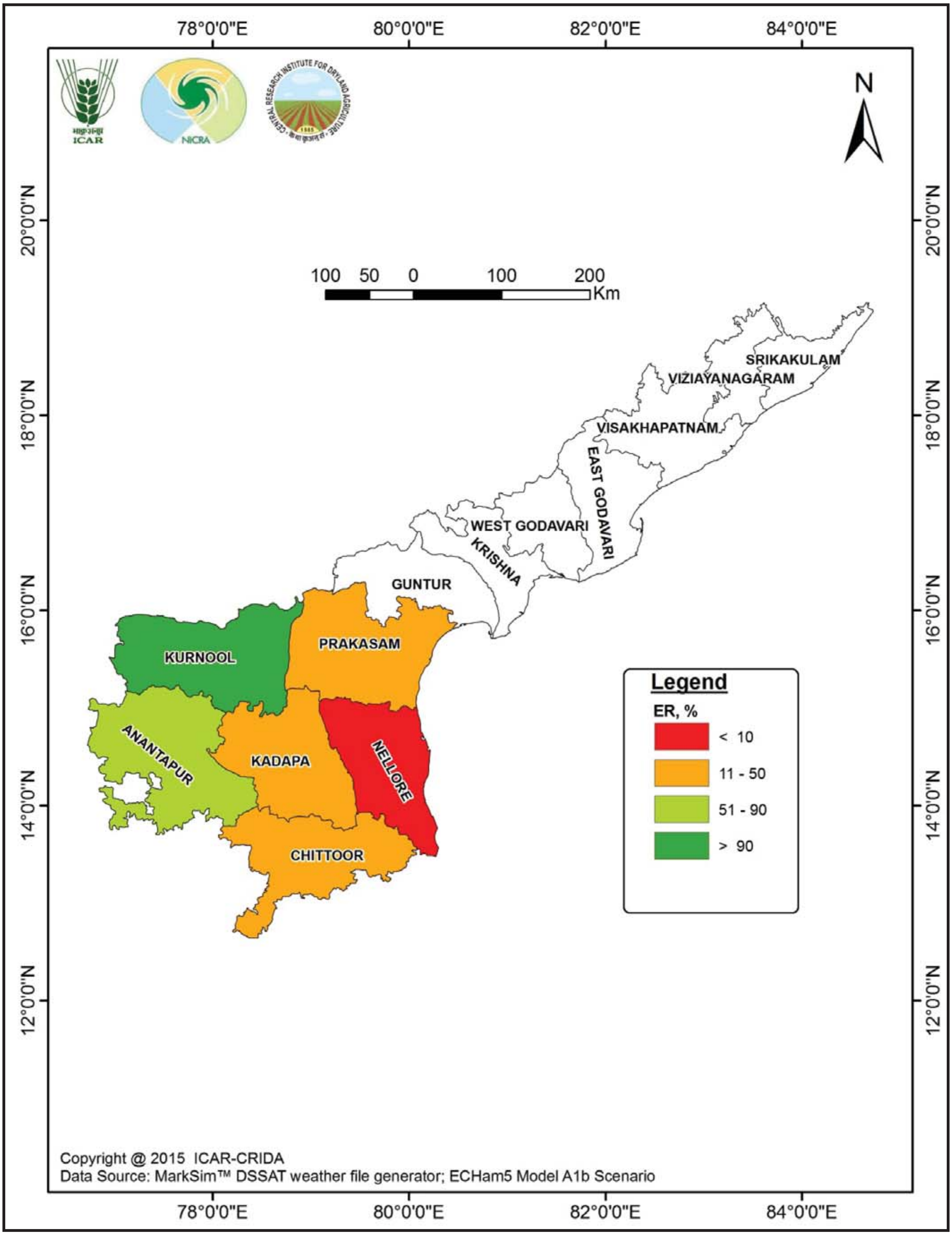

Fig.3.54 Percent decadal (2021-2030) deviation of effective rainfall (ER) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

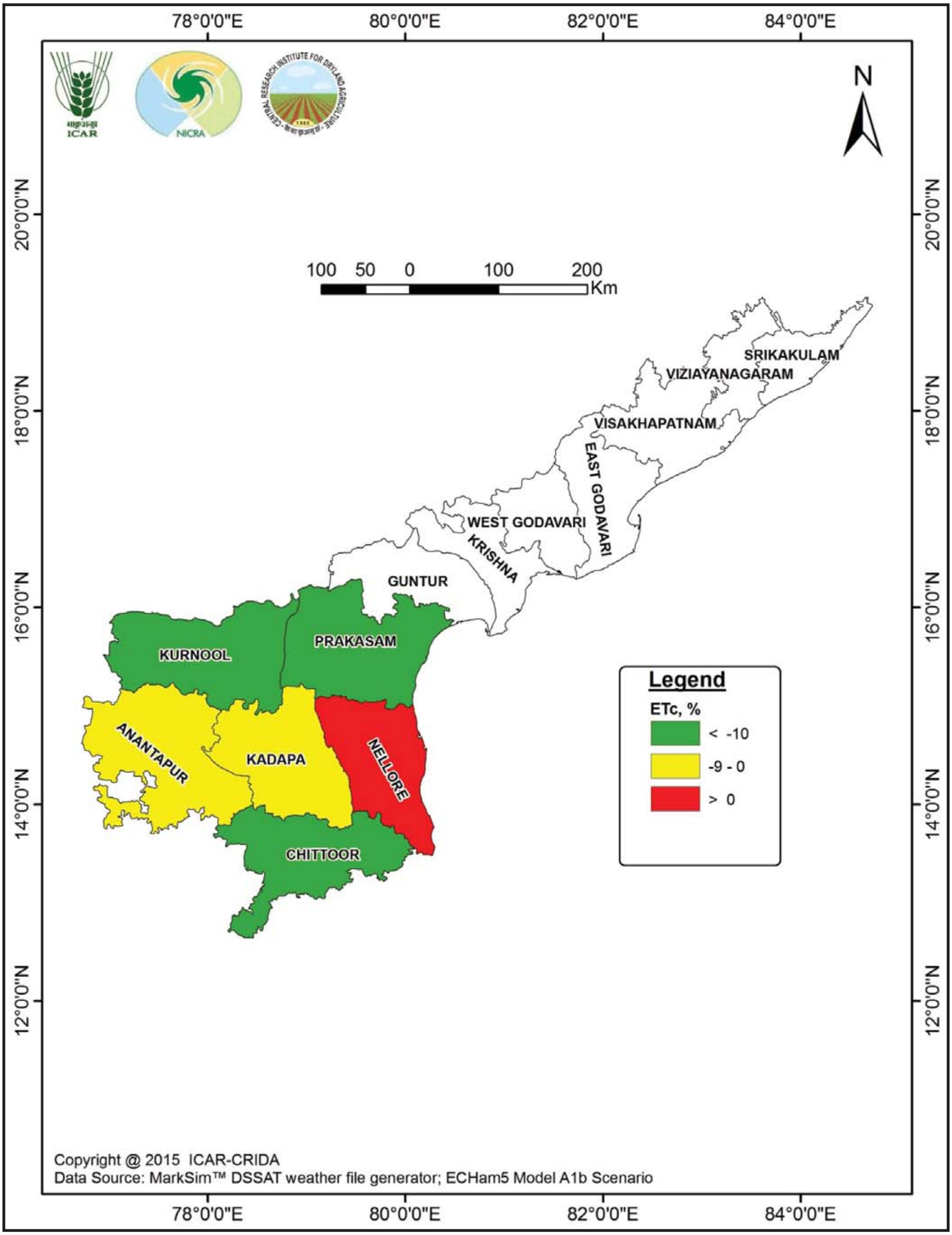

Fig.3.55 Percent decadal (2021-2030) deviation of crop evapotranspiration (ETc) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

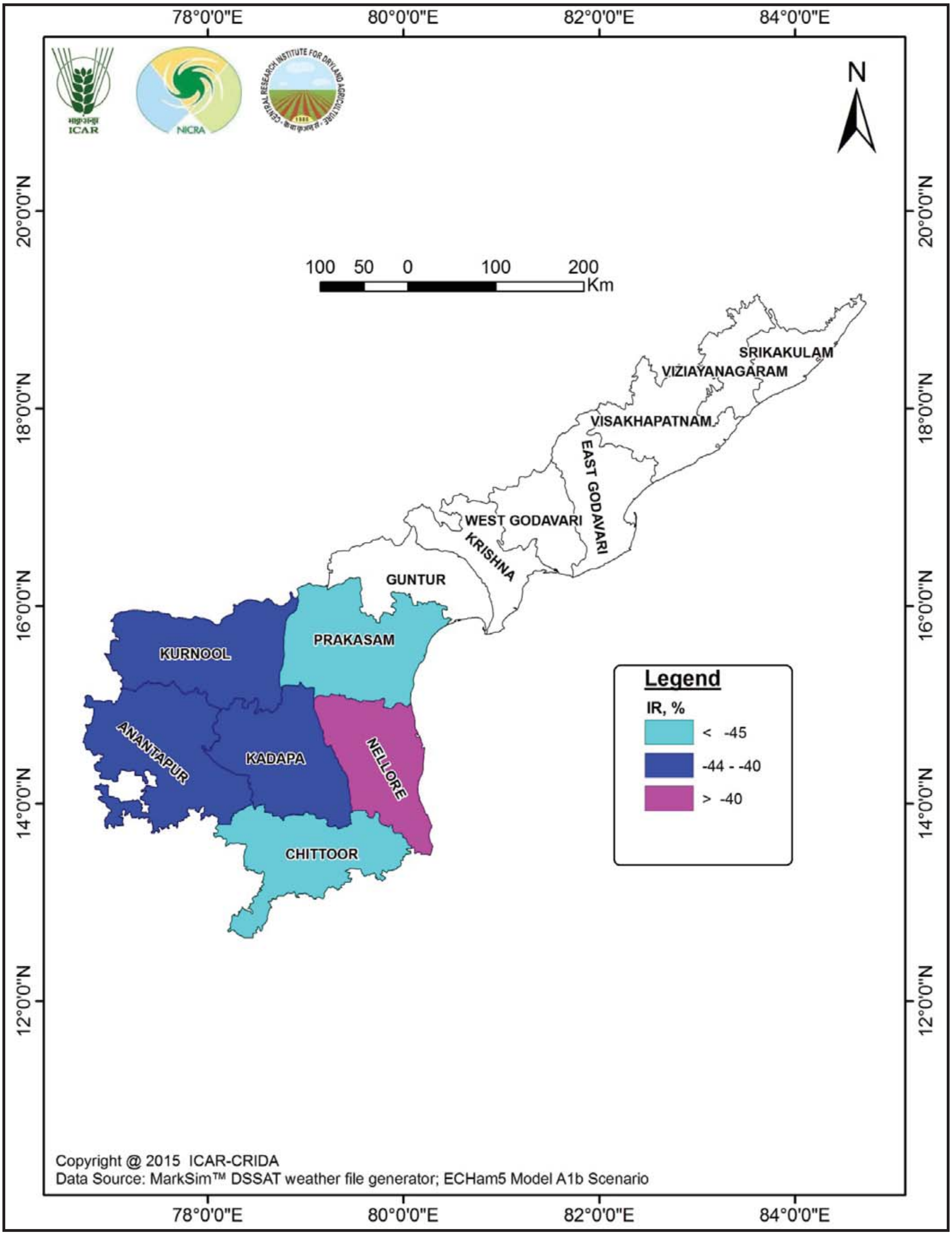

Fig.3.56 Percent decadal (2021-2030) deviation of irrigation requirement (IR) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

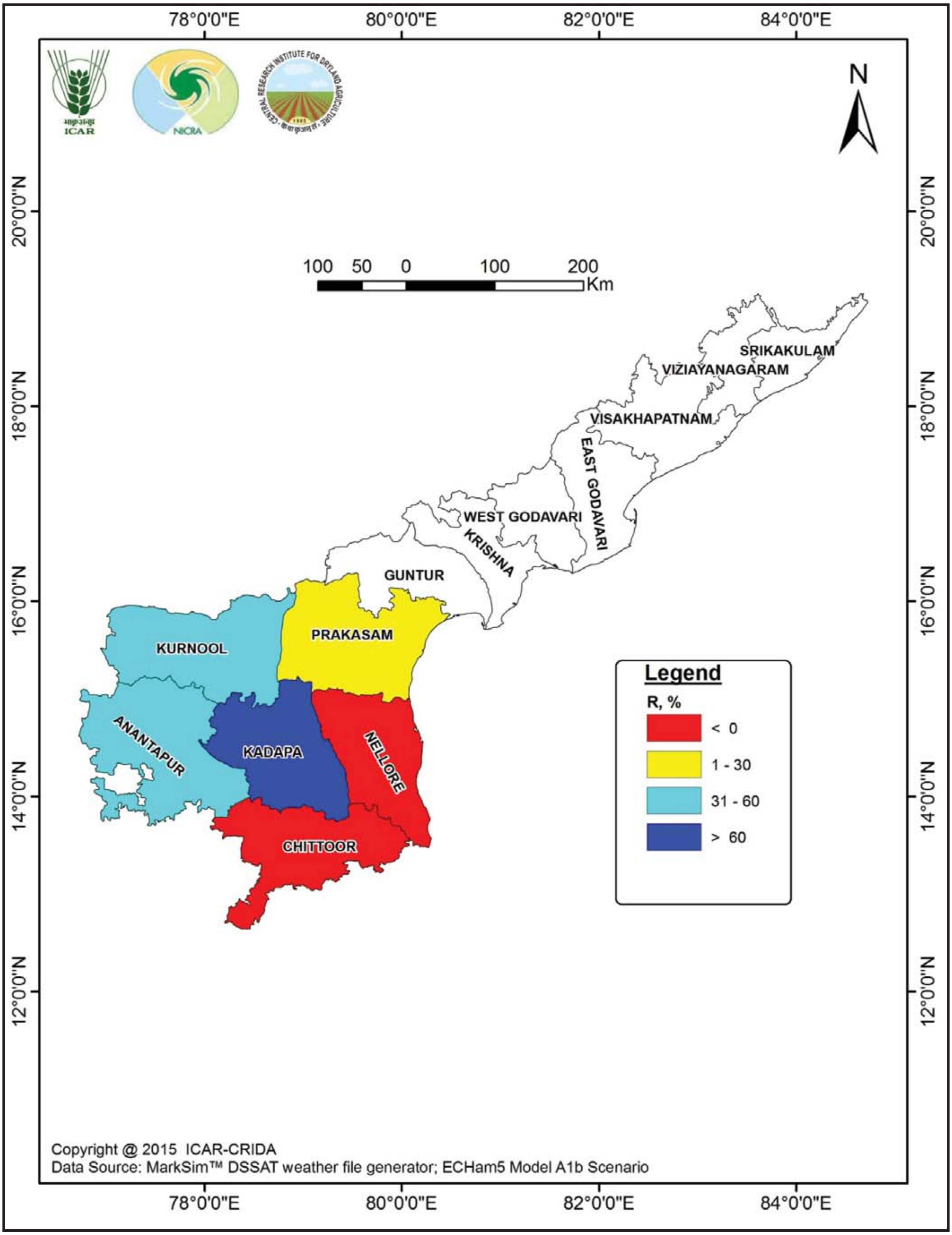

Fig.3.57 Percent decadal (2031-2040) deviation of rainfall (R) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

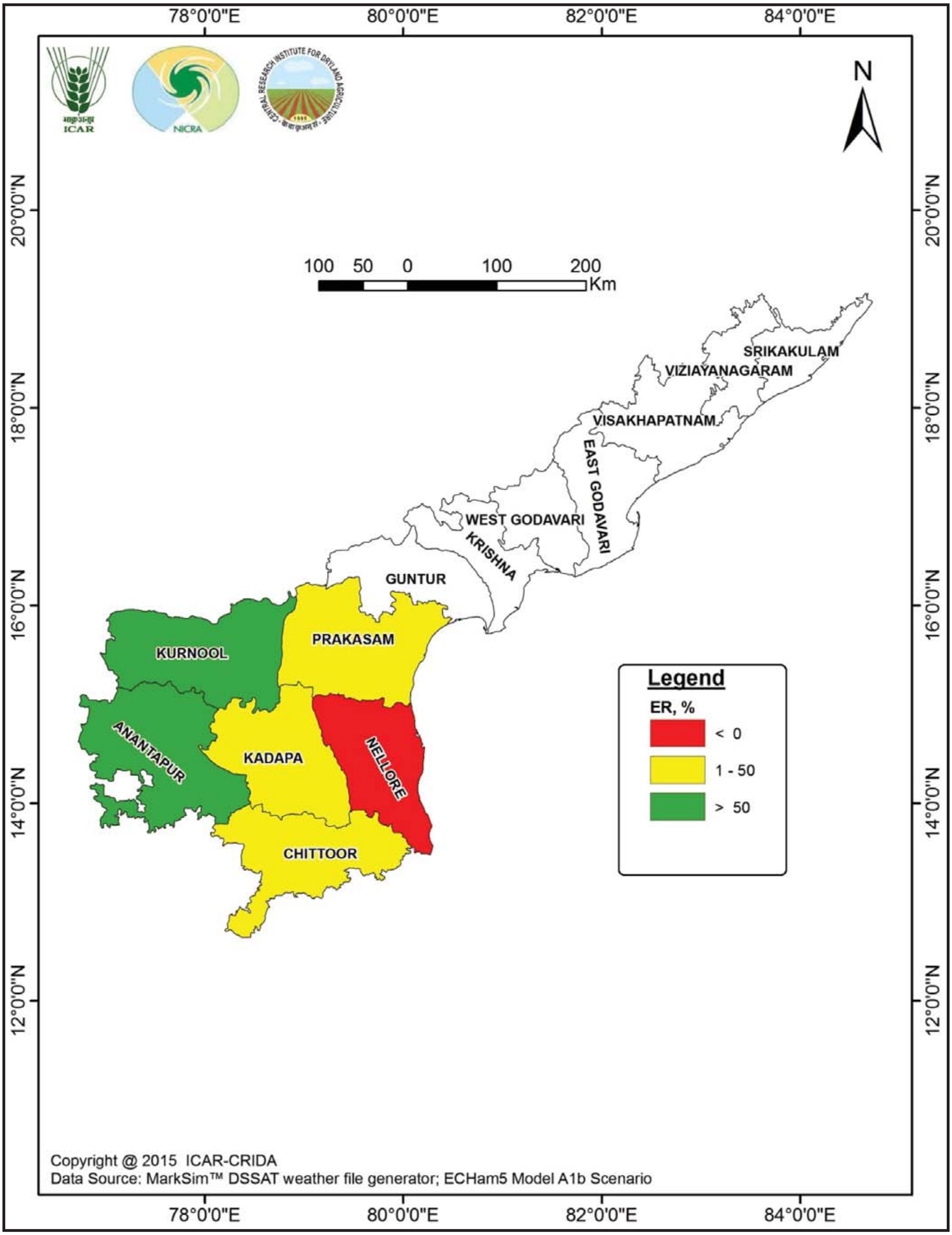

Fig.3.58 Percent decadal (2031-2040) deviation of effective rainfall (ER) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

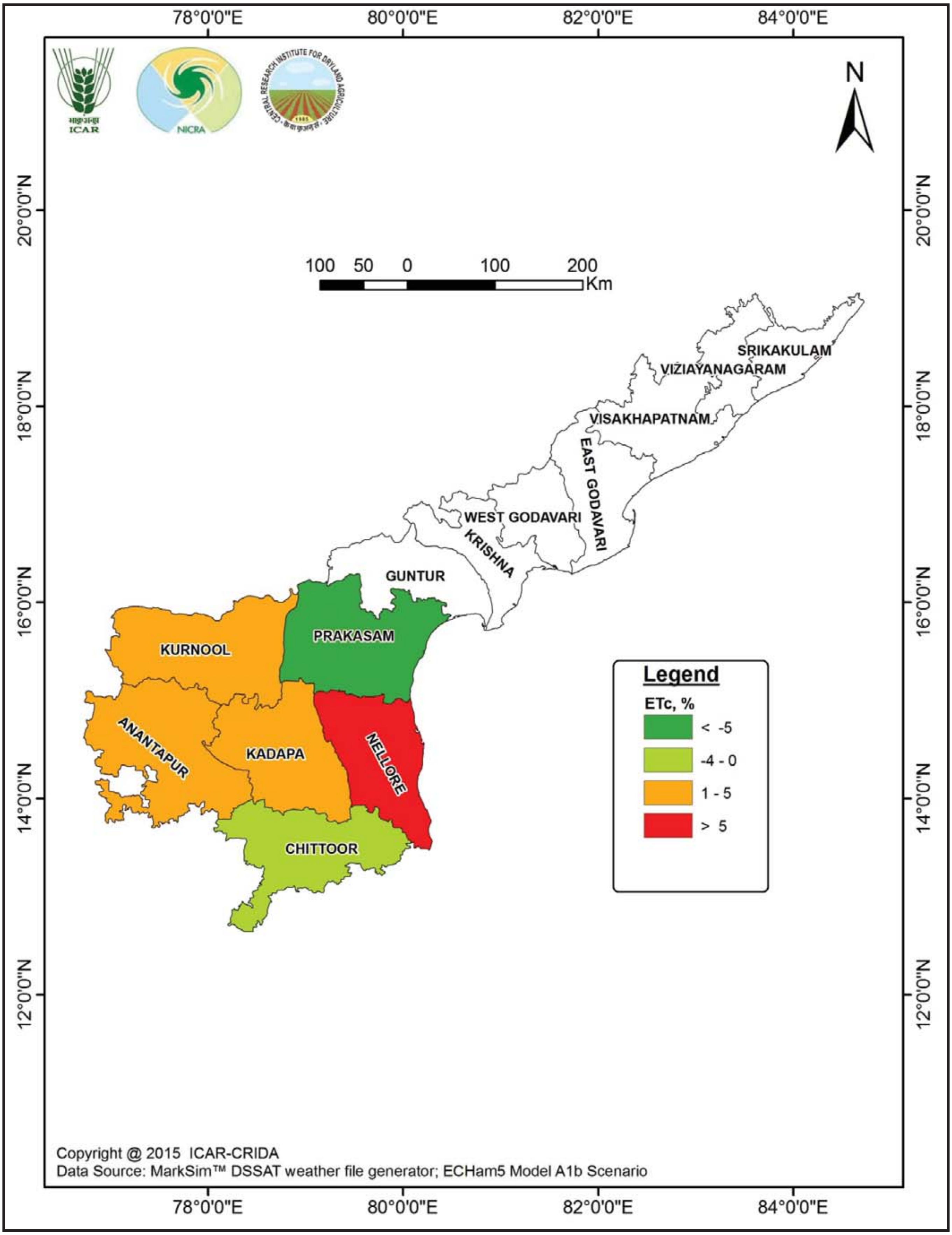

Fig.3.59 Percent decadal (2031-2040) deviation of crop evapotranspiration (ETc) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

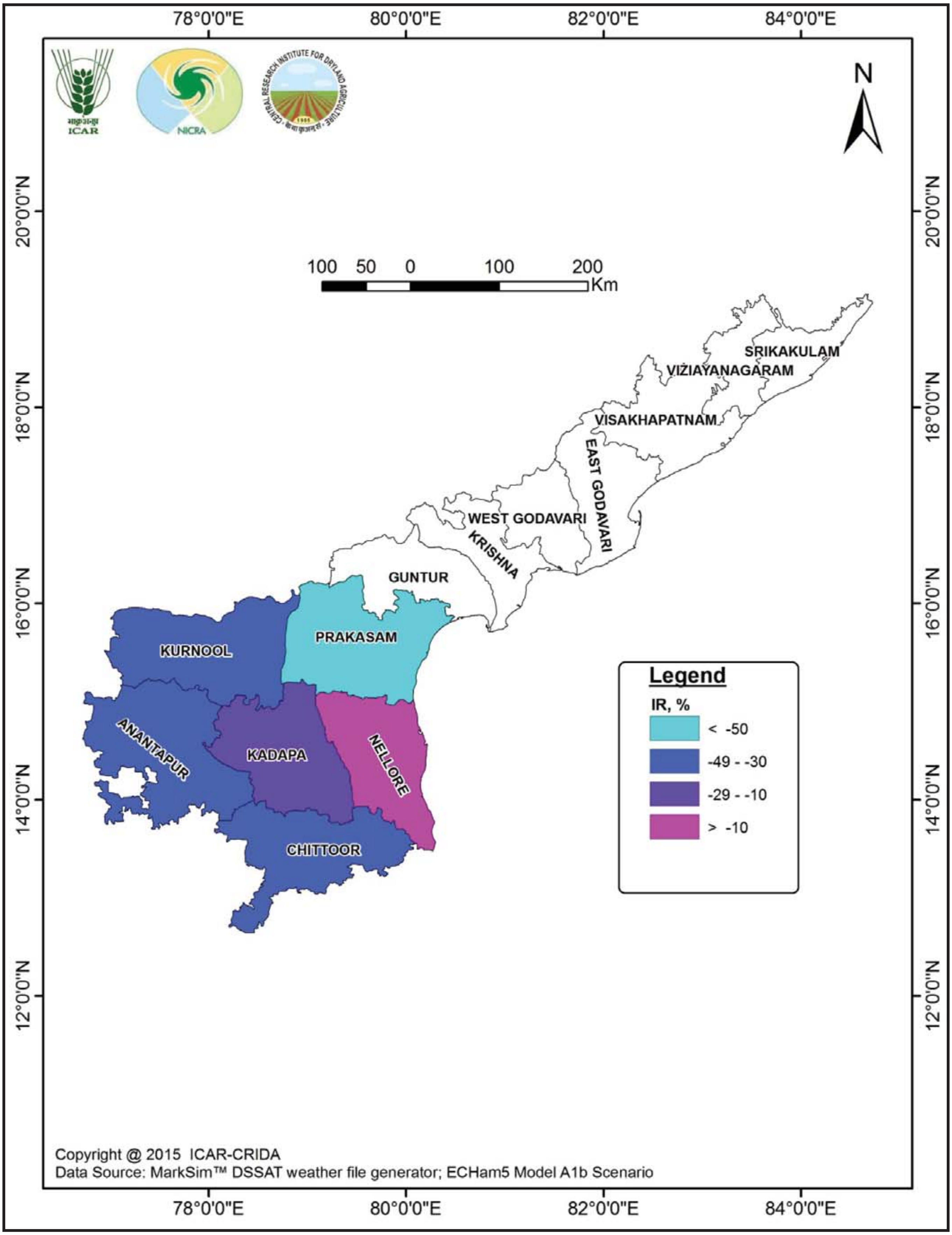

Fig.3.60 Percent decadal (2031-2040) deviation of irrigation requirement (IR) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

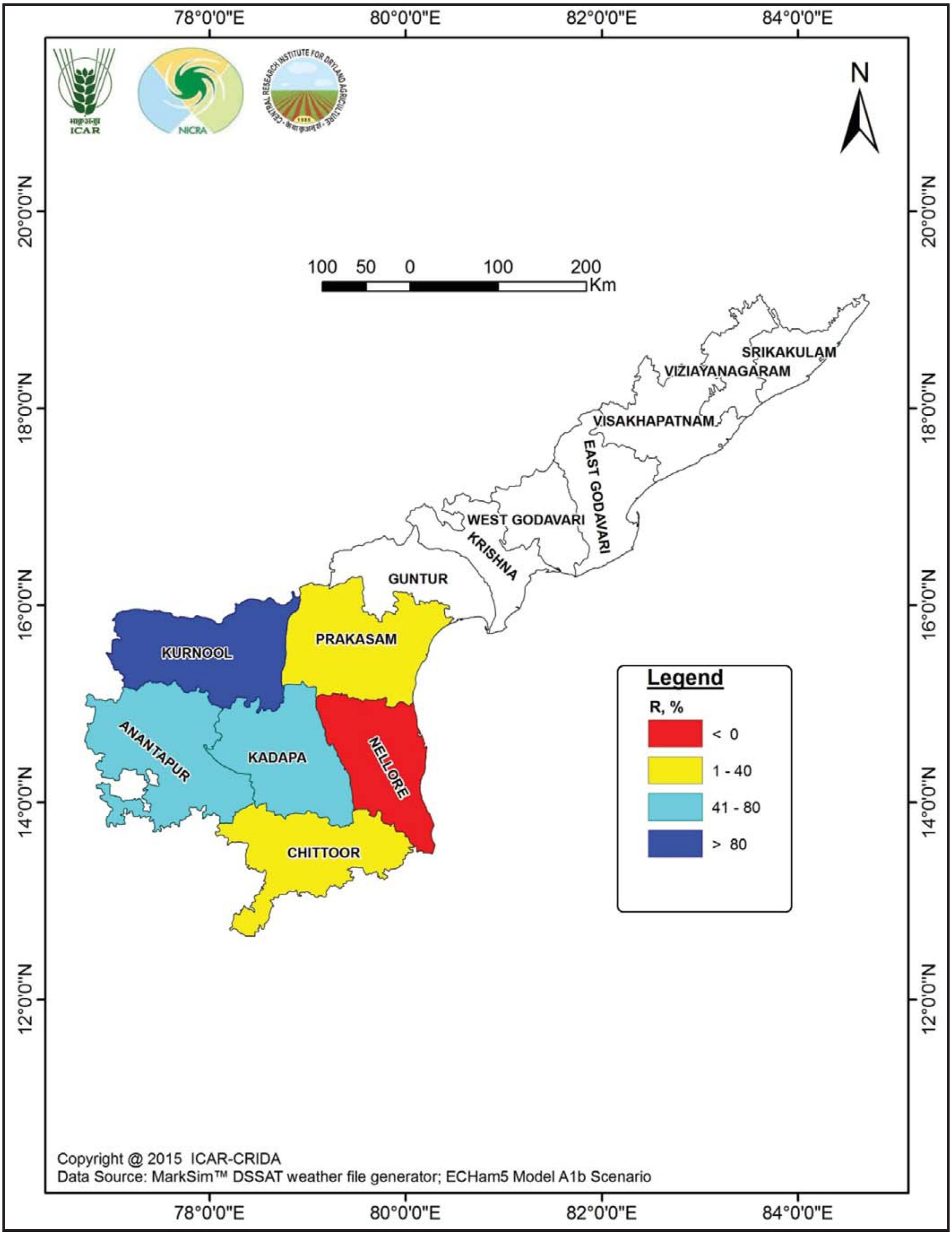

Fig.3.61 Percent decadal (2031-2040) deviation of rainfall (R) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

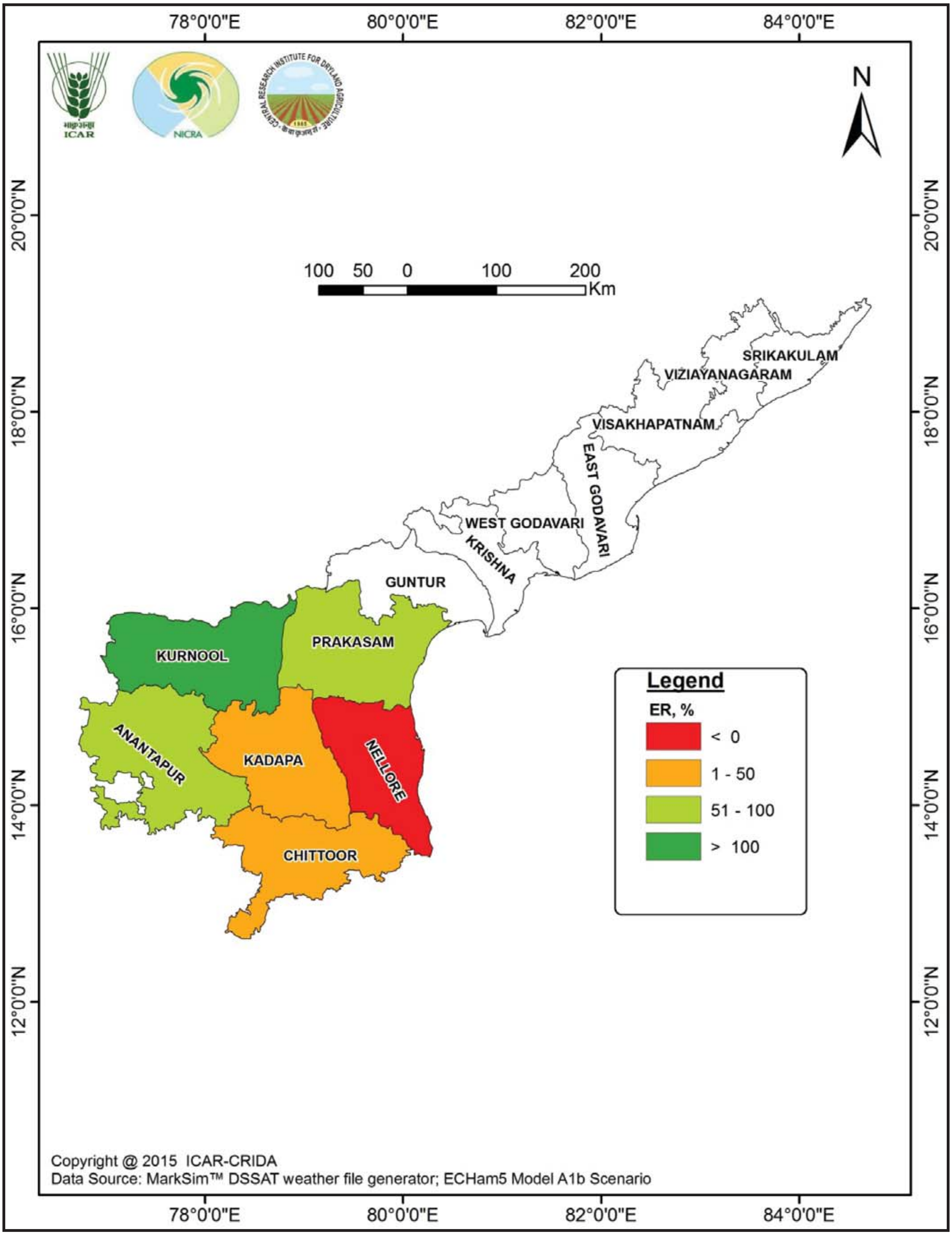

Fig.3.62 Percent decadal (2031-2040) deviation of effective rainfall (ER) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

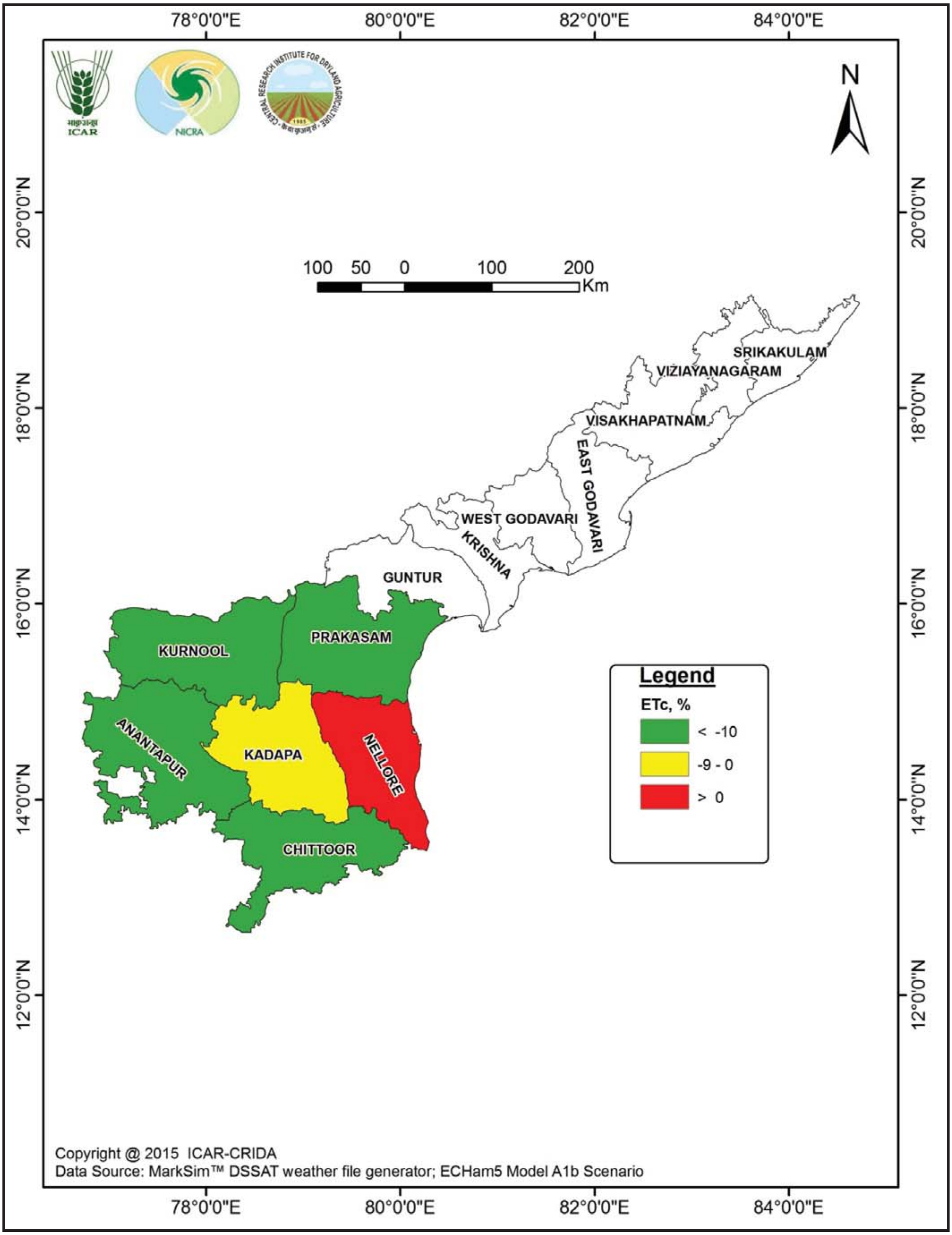

Fig.3.63 Percent decadal (2031-2040) deviation of crop evapotranspiration (ETc) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

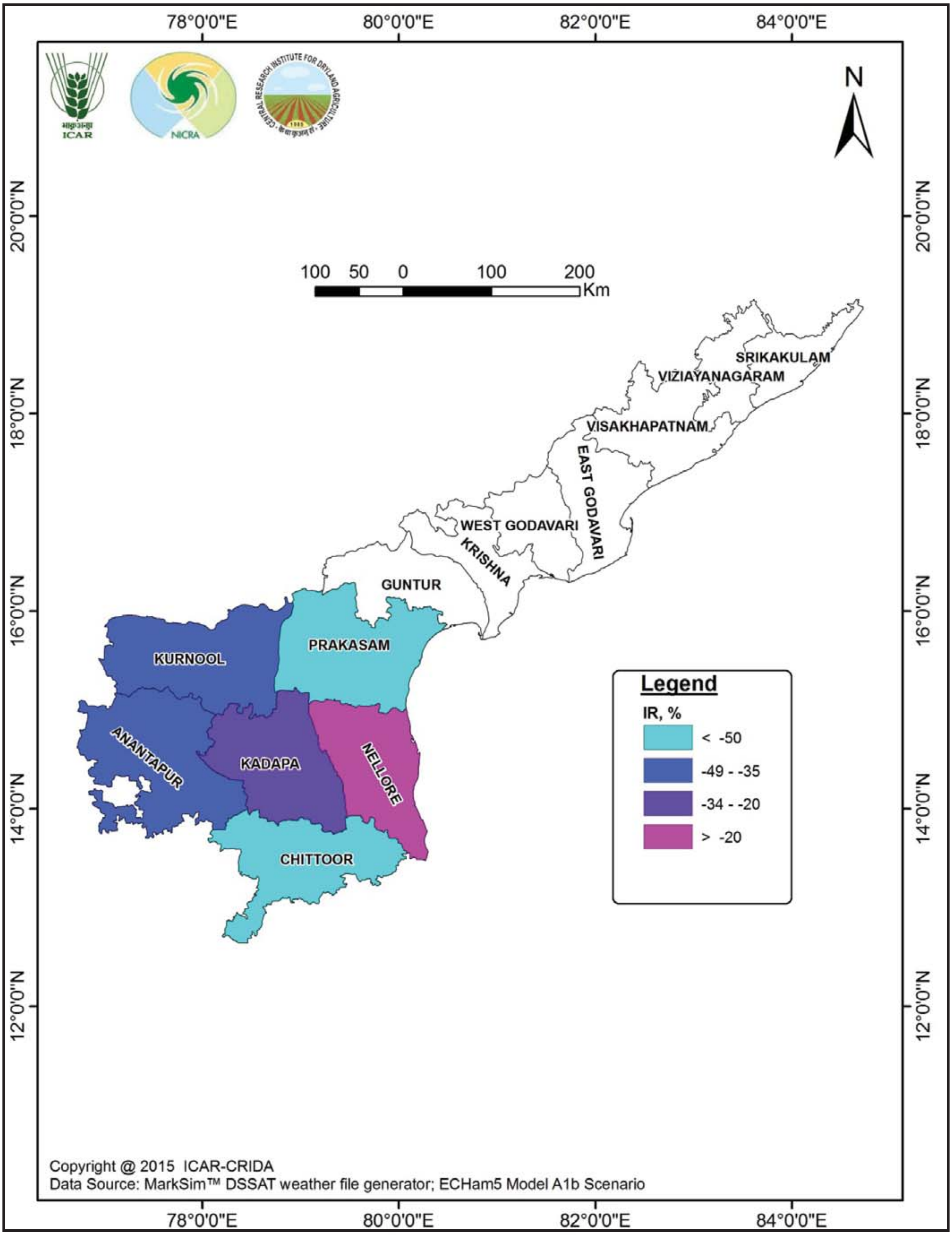

Fig.3.64 Percent decadal (2031-2040) deviation of irrigation requirement (IR) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

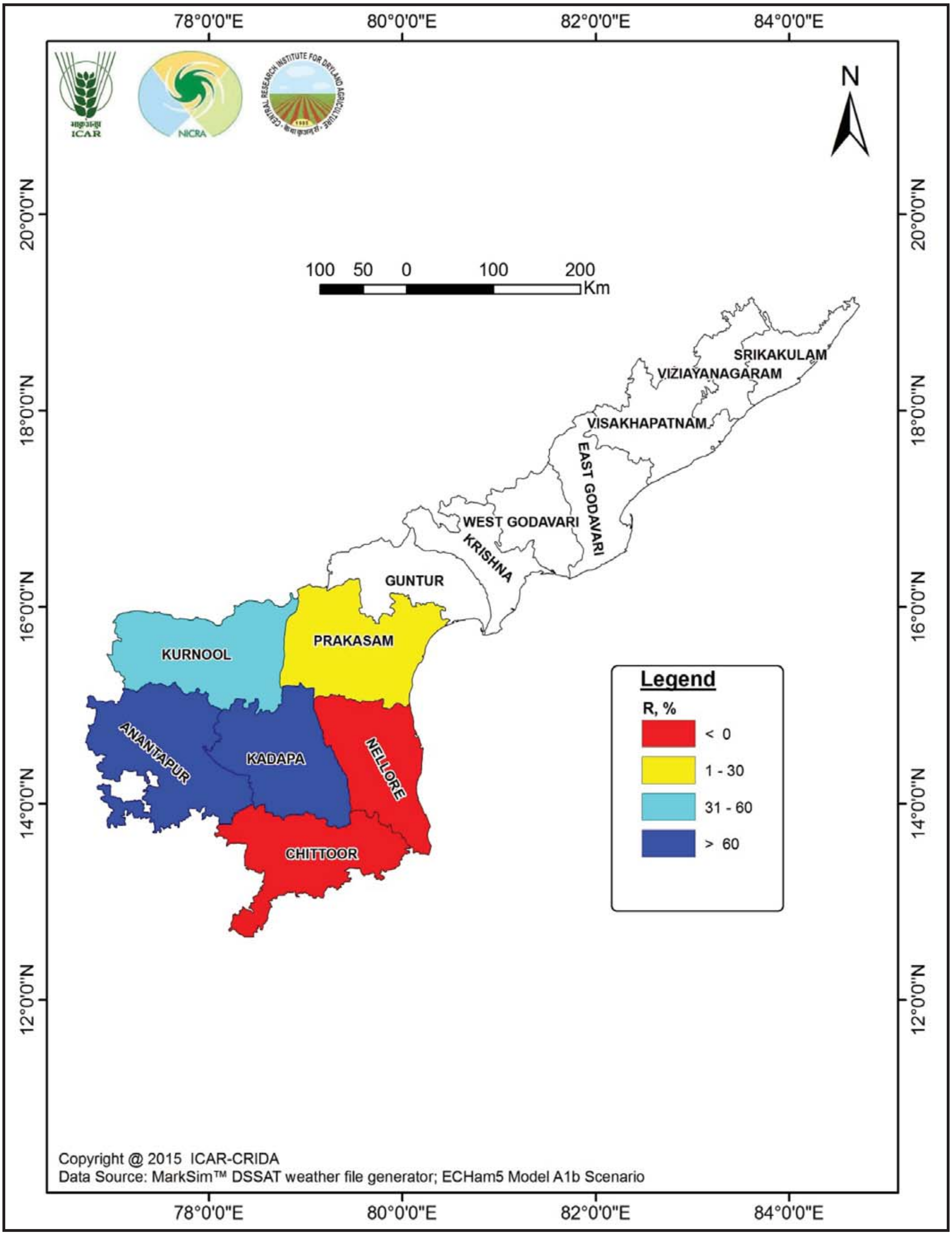

Fig.3.65 Percent decadal (2041-2050) deviation of rainfall (R) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

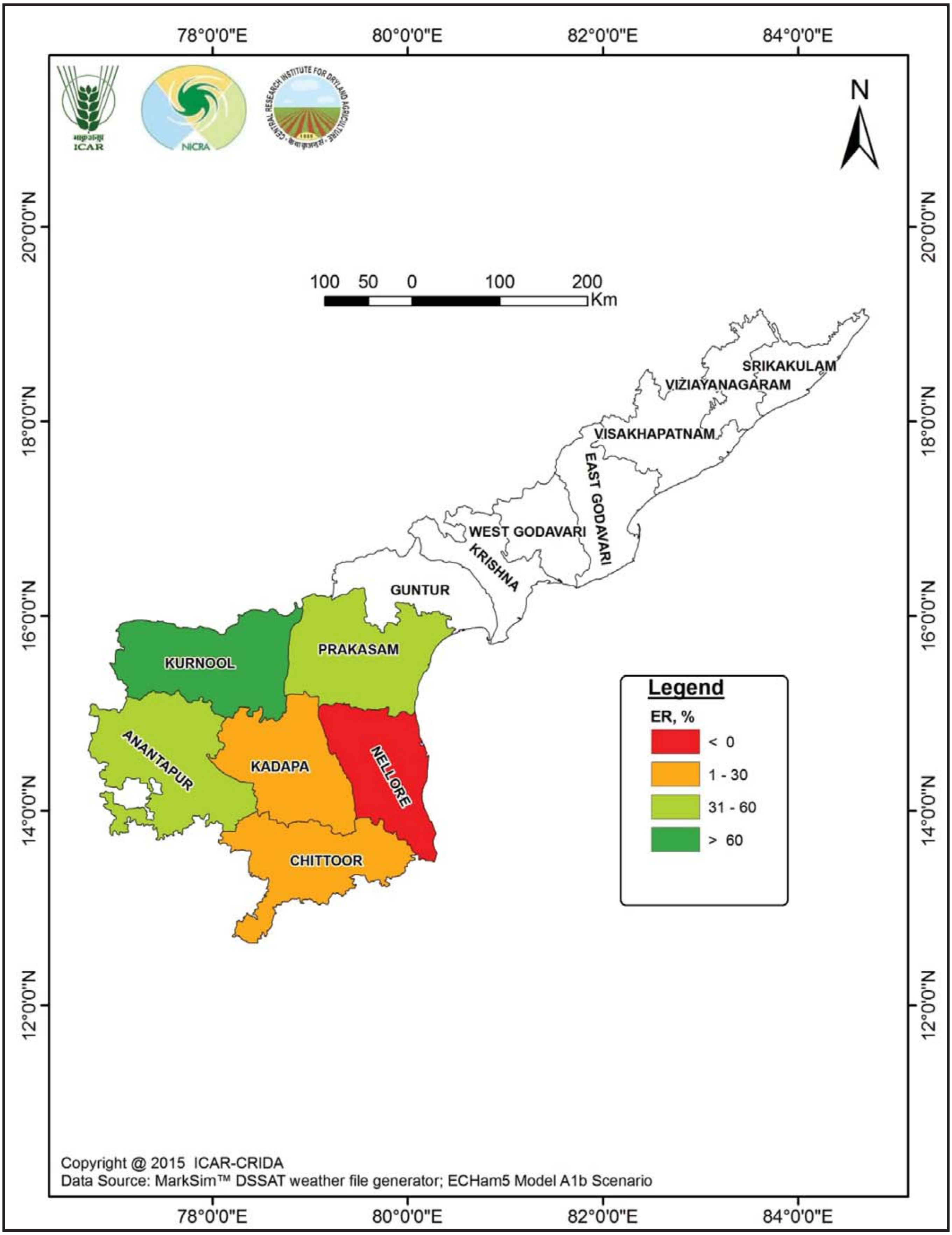

Fig.3.66 Percent decadal (2041-2050) deviation of effective rainfall (ER) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

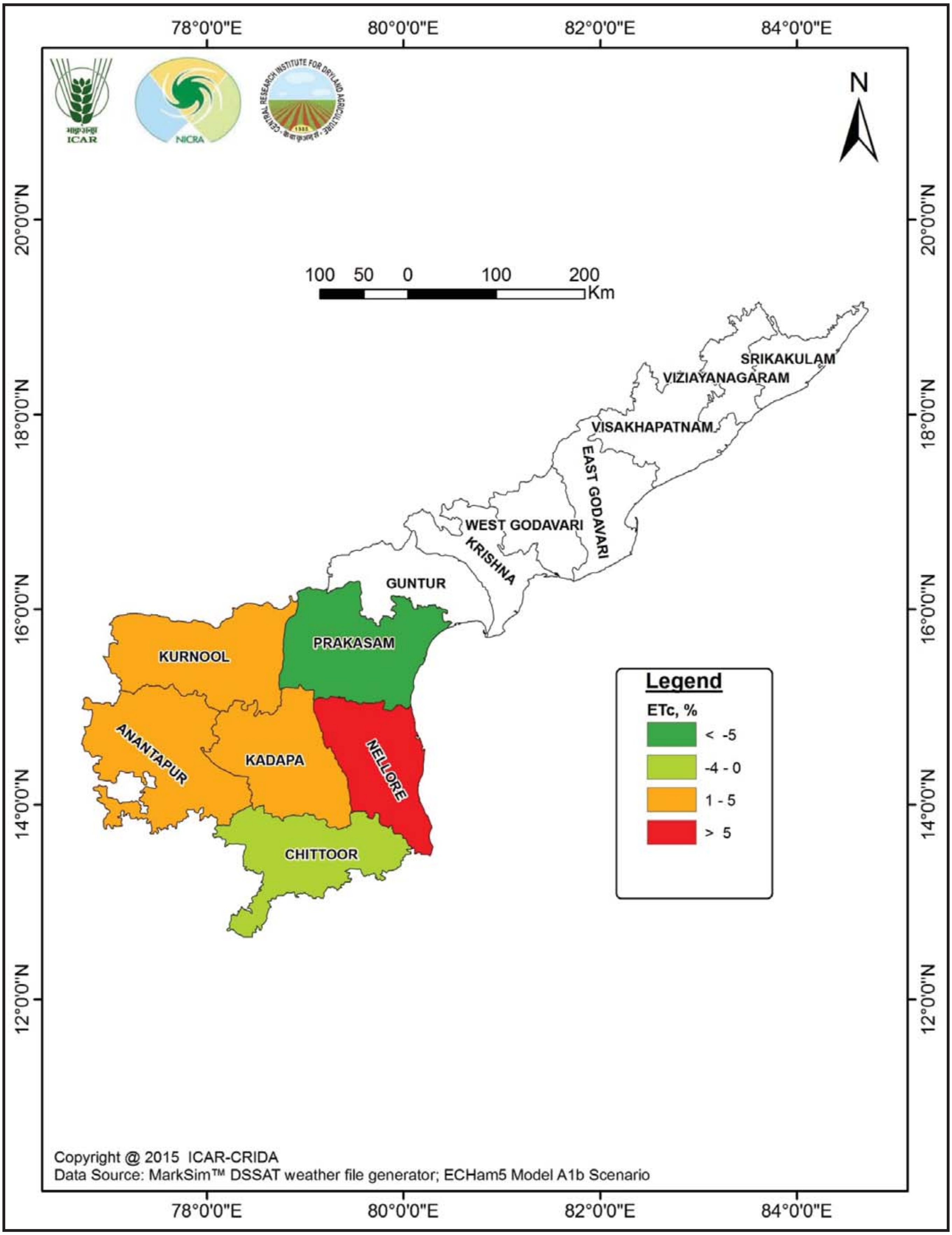

Fig.3.67 Percent decadal (2041-2050) deviation of crop evapotranspiration (ETc) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

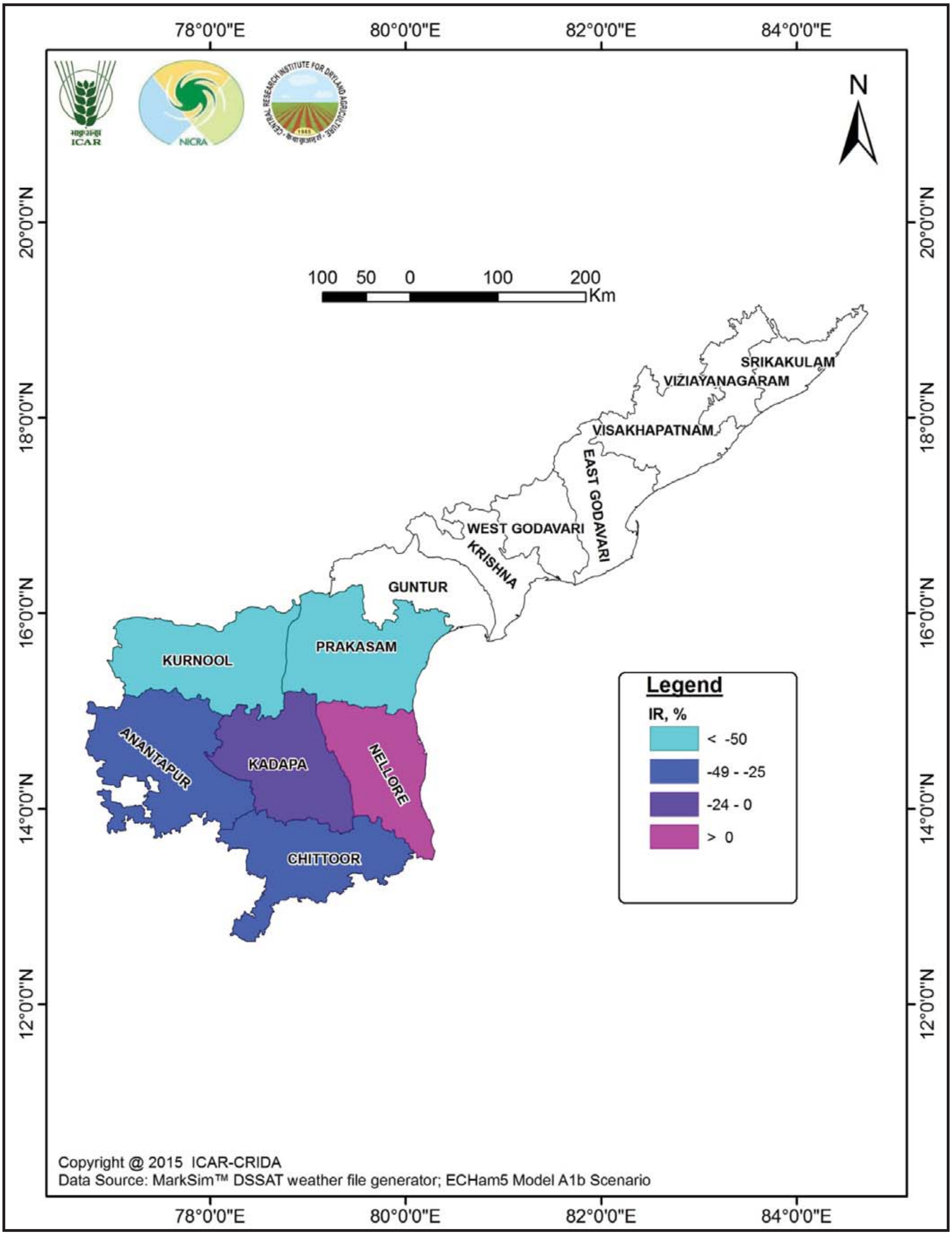

Fig.3.68 Percent decadal (2041-2050) deviation of irrigation requirement (IR) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under normal sowing in rainfed districts of Andhra Pradesh

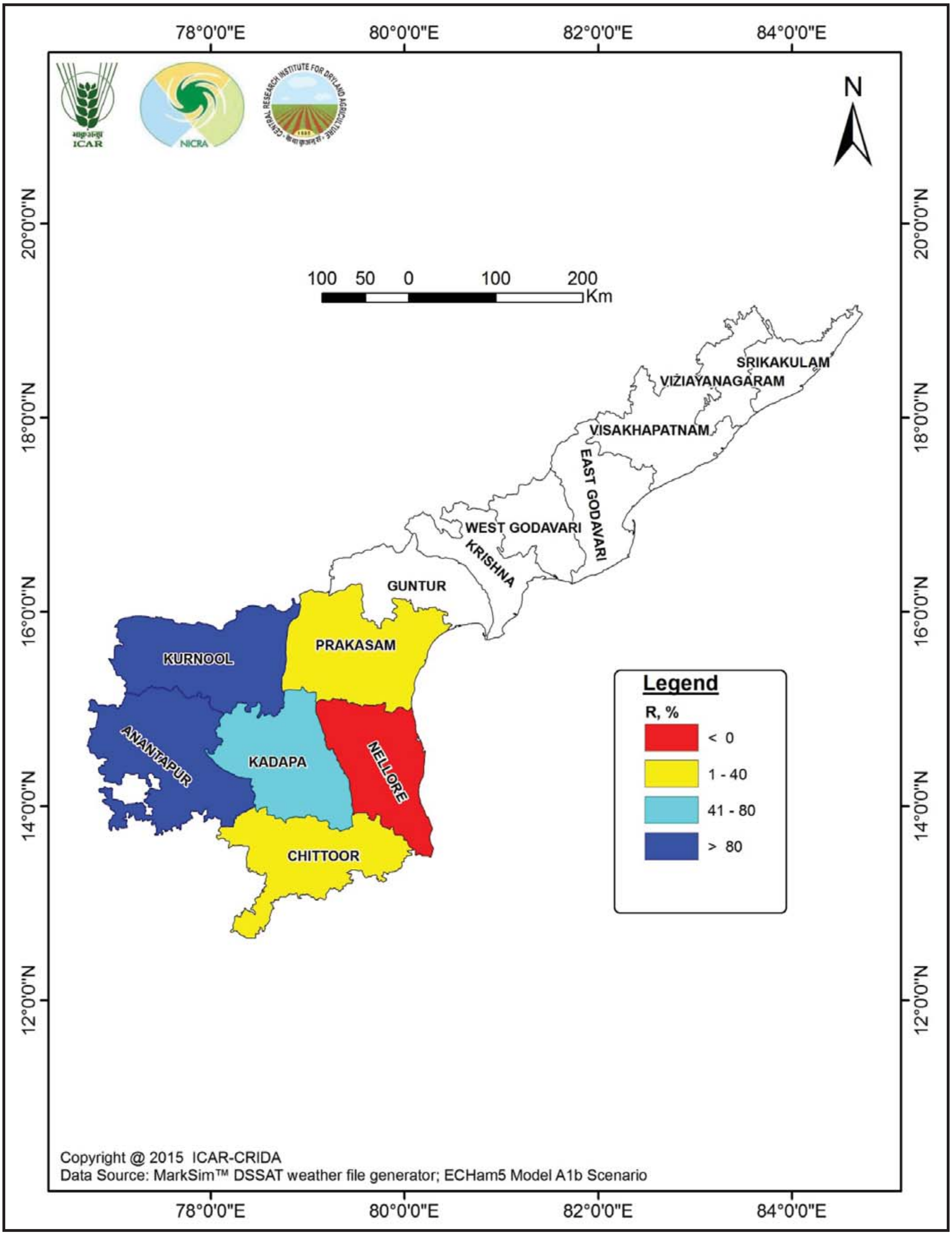

Fig.3.69 Percent decadal (2041-2050) deviation of rainfall (R) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

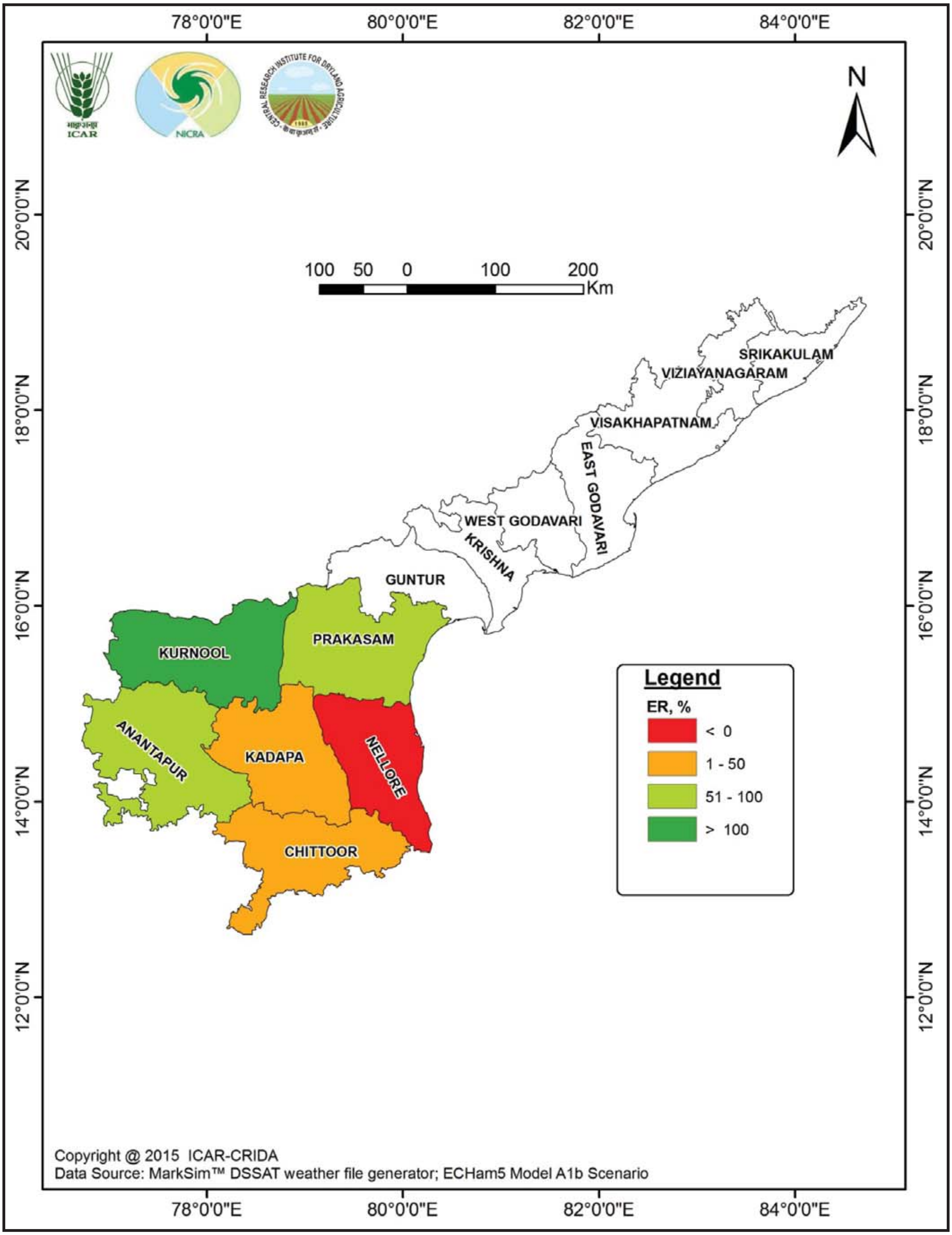

Fig.3.70 Percent decadal (2041-2050) deviation of effective rainfall (ER) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

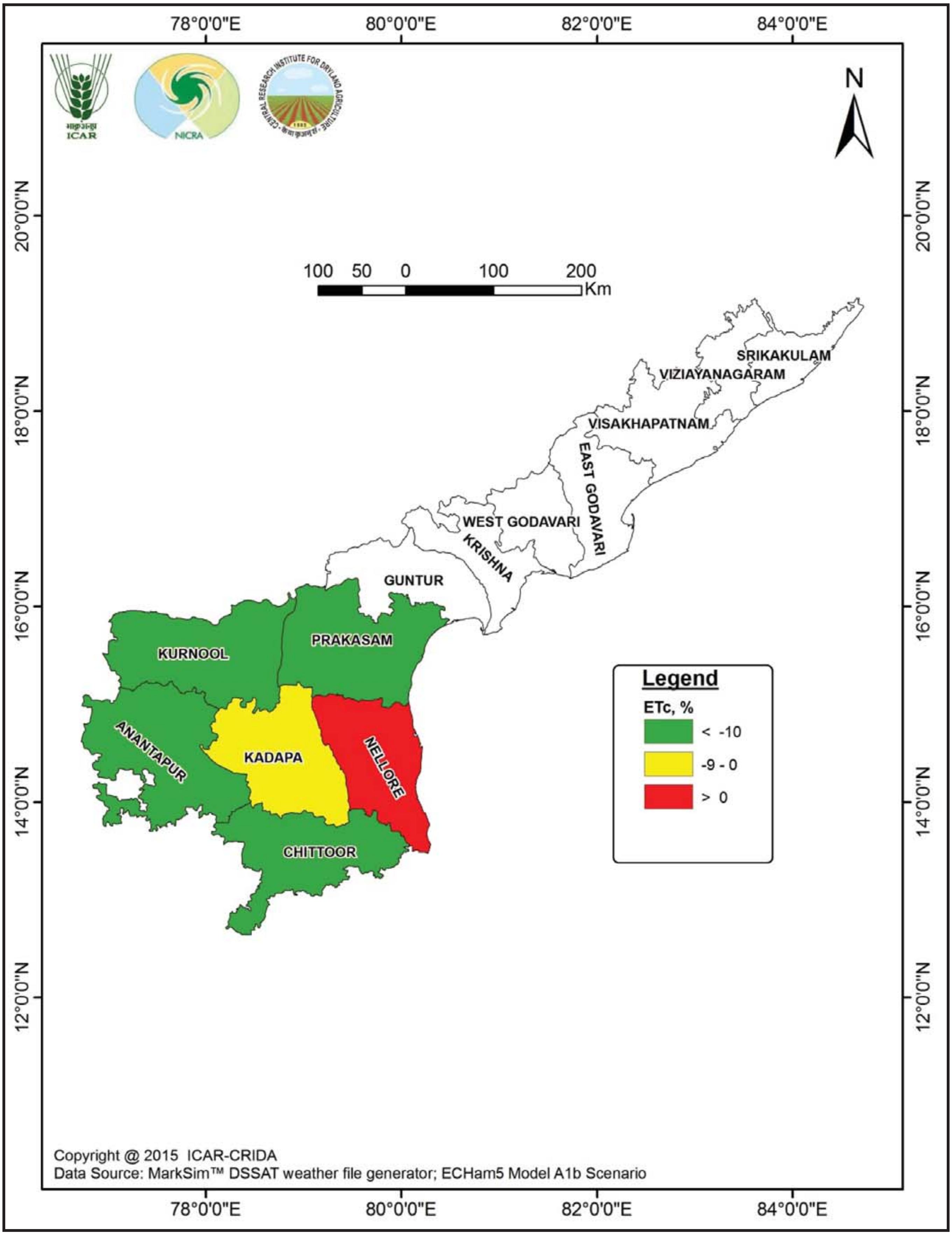

Fig.3.71 Percent decadal (2041-2050) deviation of crop evapotranspiration (ETc) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

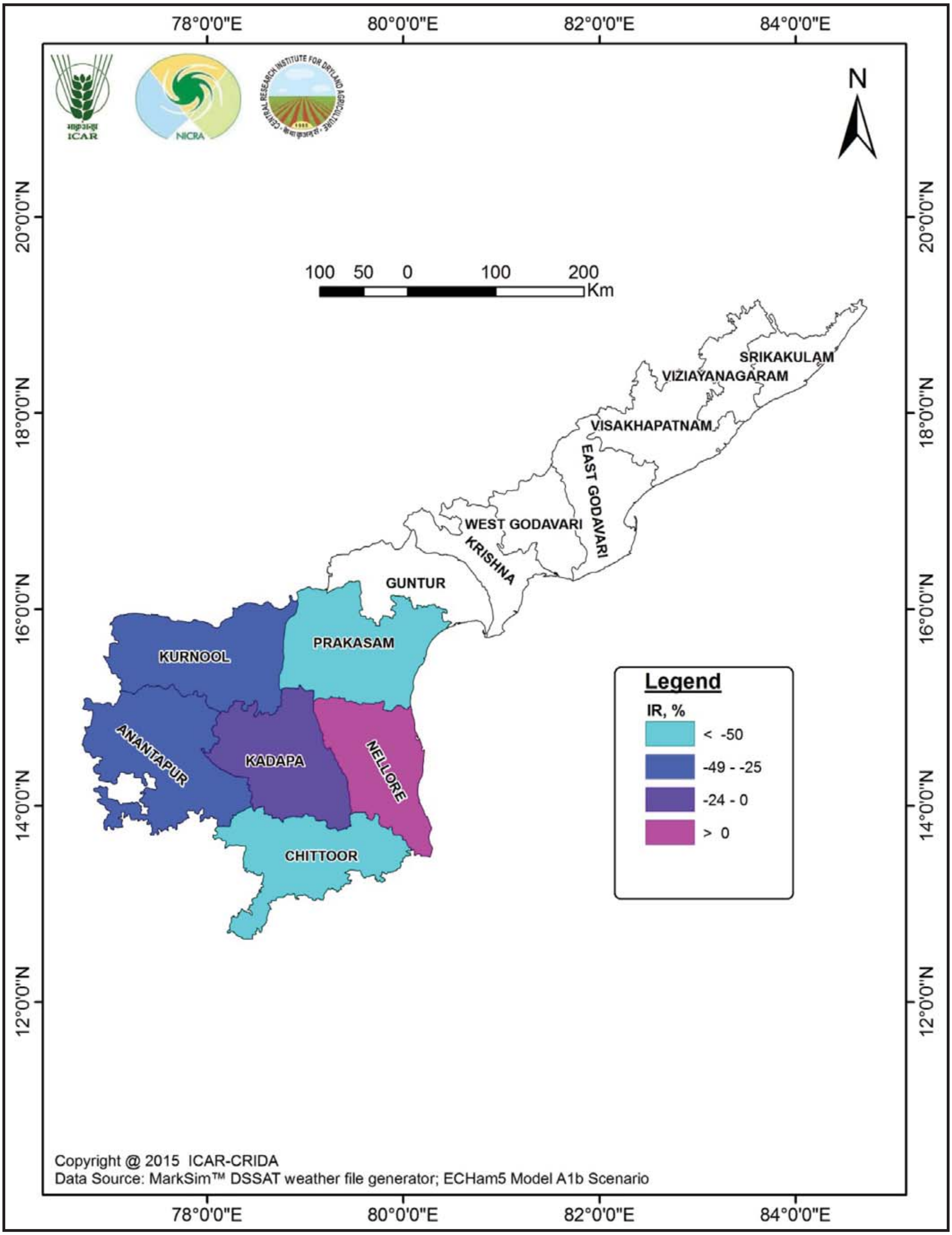

Fig.3.72 Percent decadal (2041-2050) deviation of irrigation requirement (IR) from base period (1961-1990) during crop growth period of groundnut and pigeon pea under late sowing in rainfed districts of Andhra Pradesh

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