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Implementing Crop Evapotranspiration in RDI for Farm-Level Drought Evaluation and Adaptation under Climate Change Conditions

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Abstract
Agricultural drought is a natural hazard, often leading to significant crop yield losses and jeopardising food security. Climate change is anticipated to increase the duration and the magnitude of drought events, augmenting also their adverse effects. Recent studies, as well as policy initiatives, emphasise the need of proper farm-level management, for efficient mitigation of drought effects and adaptation to climate change. Towards this objective, robust, practical and comprehensible tools should be employed to support decision making process. In this paper, the Crop Reconnaissance Drought Index (CRDI) is introduced, aiming at assisting in agricultural drought analyses, focusing on specific crops. The proposed CRDI is an adjustment of the widely used Reconnaissance Drought Index (RDI), in which the utilised parameter of reference evapotranspiration is replaced by crop evapotranspiration. Along with this amendment, other issues regarding the calculation of CRDI are discussed, such as the selection of appropriate reference periods and methods of crop evapotranspiration assessment. The significance and the advantages of CRDI are illustrated through an application, considering different crops under Mediterranean conditions, in three regions of Greece.

Keywords Crop Reconnaissance Drought Index (CRDI) · Farm-level drought adaptation · Crop evapotranspiration · Agricultural drought · Drought indices · Climate change

1 Introduction

According to several studies and reports, there is strong evidence that the anticipated climate change will cause more intense and prolonged droughts in many parts of the globe (IPCC 2012;

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EEA 2017). One of the most vulnerable sectors to drought episodes is agriculture, while proper agricultural water management is an important issue due to the expected intensification of the existing risks (Iglesias and Garrote 2015). The increased drought risk may induce uncertainty for water availability, affecting the sustainability of irrigated agriculture (Minhas et al. 2020).

Farm-level adaptation to climate change is a crucial aspect for retaining sustainable agriculture, especially in regions with higher anticipated impacts on specific crops (Mylopoulos et al. 2009; Saadi et al. 2015), while appropriate in-field improvements and eco-efficient actions based on rational analysis will have positive effects on a farmer's individual utility (de Frutos Cachorro et al. 2018; Maia et al. 2016; Cetinkaya et al. 2008). Recently, the European Union declared adaptation as a clear objective of the common agricultural policy for 2021–2027, providing opportunities for implementing a wide variety of measures at farm-level, including the use of adapted or heritage crops for reducing drought impacts, improved irrigation techniques for increasing water efficiency and promoting organic farming practices to enhance water storage capacity and improve resilience against droughts (EEA 2019).

The anticipated increase of drought events, including multi-year droughts, will have significant effects in agriculture (Al-Faraj and Tigkas 2016), while the highest economic risks are expected in cultivation of drought-sensitive crops with a high financial value, located in regions with increasingly uncertain water supply (Salmoral et al. 2019). Farm-level drought impacts may affect a farmer's crop plan for years to come, which should be an important consideration for policy makers and administrators (Peck and Adams 2010). Using adequate drought assessment tools, for devising proper information available to the farmers, is essential for proactive management and improving drought resilience (Fusco et al. 2018). Furthermore, farmers' adaptive capacity to drought may be augmented through research and policy initiatives (Knutson et al. 2011), while the availability of efficient, reliable and comprehensible tools is important to amalgamate the relevant data and assisting strategic planning and decision making (Chavez-Jimenez et al. 2013).

Adaptation plans to drought and climate change involve complex procedures and estimates related to various factors and parameters. The assessment of drought impacts on specific crops, under certain conditions, is a key-factor in identifying farm-level adaptability and estimating the viability of alternative options. Employing drought indices is the typical approach for analysing drought characteristics, for any type of drought (meteorological, hydrological, agricultural), identifying the physical characteristics of the phenomenon and linking to their impacts (Rossi and Cancelliere 2013; Tsakiris et al. 2013). More specifically, agricultural drought links various characteristics of meteorological drought to agricultural impacts (Wilhite and Glantz 1985), therefore many indices principally designed for meteorological drought analysis have been also proven efficient for agricultural drought characterisation (Tigkas et al. 2019).

The Reconnaissance Drought Index (RDI) is based on two meteorological parameters, precipitation and evapotranspiration (Tsakiris et al. 2007). It has been extensively used worldwide in several drought studies, while a modified version employing effective precipitation (Effective Reconnaissance Drought Index - eRDI) has been recently proposed (Tigkas et al. 2017). The fact that RDI incorporates evapotranspiration is considered an advantage towards its accuracy for agricultural drought analysis, compared to other meteorological indices that use only precipitation, as evapotranspiration is important for an accurate evaluation of the phenomenon (Teuling et al. 2013; Zarei et al. 2016). Furthermore, many studies have shown that RDI is also more robust under climate change conditions, as it takes into account temperature along with precipitation (Merabti et al. 2018; Al-Faraj et al. 2015; Shokoohi and Morovati 2015; Zarch et al. 2015).

The formulation of RDI, as a meteorological drought index, is originally based on the concept of reference evapotranspiration, which provides a general measure of the evaporative atmospheric demand, based on the climatic conditions (Tsakiris et al. 2007). Apart from meteorological drought analysis, such an approach can be also suitable for regional agricultural drought assessment (Tigkas and Tsakiris 2015). However, farm-level adaptation should focus on specific crops and their characteristics, as well as investigating the potential drought impacts in cases where alternative solutions might be selected.

Towards the above considerations, in this paper, an adjustment of RDI formulation is proposed, namely the Crop Reconnaissance Drought Index (CRDI), by incorporating crop evapotranspiration. The objective of this modification is to increase the soundness and the accuracy of the original index in identifying drought impacts for specific crops, suitable for devising farm-level drought management plans. Hence, CRDI may form a practical and comprehensible tool for enabling policy makers, insurance organisations and other involved parties, as well as the farmers, to take informed decisions and implement rational actions for mitigating drought impacts. The proposed CRDI retains the advantages of the original index related to its use under climate change conditions, which provides an additional asset in order to be used for long-term adaptation plans. The significance and the advantages of this amendment is evaluated and discussed through an application, considering different crops (winter wheat, tomato, olive and cotton) in three regions of Greece.

2 Material and Methods

2.1 Evapotranspiration Concepts

Evapotranspiration is the term expressing the cumulative water flux from soil and from plant transpiration to the atmosphere. Several approaches have been proposed for estimating evapotranspiration, including physically based methods, analytical methods based on climate variables and empirical methods (Strzepek and Yates 1997). A modified version of the analytical approach initially proposed by Penman (1948), the FAO Penman-Monteith method (FAO P-M), was adopted by FAO since 1970s (Doorenbos and Pruitt 1977). Later, FAO further revised and redefined the approach (Smith et al. 1991; Allen et al. 1994), using surface resistance (r_a) and aerodynamic resistance (r_s) along with the original Penman-Monteith equation. FAO-56 paper (Allen et al. 1998) addresses in detail several issues, defining reference evapotranspiration (or reference crop evapotranspiration; ET_o) that deals with the evapotranspiration from a reference surface with specific characteristics, resembling closely an extensive surface of green, well-watered grass of uniform height, actively growing and completely shading the ground, defined as "*a hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s m*$^{-1}$ *and an albedo of 0.23*".

Currently, FAO P-M is generally accepted as the standard method for estimating evapotranspiration worldwide (Pereira et al. 2015). Several parameters are required for applying FAO P-M, including solar radiation, air temperature, humidity and wind speed, as well as the location (altitude and latitude) of the measurement site. Data requirements are higher compared to other methods, however, FAO P-M is still considered more reliable, even if some of the parameters are approximated, provided that at least air temperature (minimum and maximum) is available. ET_o can be estimated from the following FAO P-M equation (Allen et al. 1998):

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \tag{1}$$

in which R_n is the net radiation at the crop surface (MJ/m^2·day), G is the soil heat flux density (MJ/m^2·day), T is the mean daily air temperature at 2 m height (°C), u_2 is the wind speed at 2 m height (m/s), e_s is the saturation vapour pressure (kPa), e_a is the actual vapour pressure (kPa), e_s-e_a is the saturation vapour pressure deficit (kPa), Δ is the slope of the vapour pressure curve (kPa/°C) and γ is the psychrometric constant (kPa/°C).

FAO P-M, apart from calculating evapotranspiration from the reference surface, can be used for the direct calculation of any crop evapotranspiration (ET_c), as the surface and aerodynamic resistances are crop specific. The evapotranspiration rates of the various crops are related to the evapotranspiration rate from the reference surface using crop coefficients (K_c), according to the concept initially proposed by Jensen (1968), as:

$$ET_c = K_c \cdot ET_o \tag{2}$$

K_c is a dimensionless coefficient representing the aggregative difference of physical and physiological factors between crops and the reference surface. The use of this concept was widely adopted by researchers and irrigation managers, especially after FAO-24 publication, in which K_c values for several crops were included (Doorenbos and Pruitt 1977).

There are two main approaches for calculating ET_c, by using either single or double crop coefficient. In the single crop coefficient approach, the difference in evapotranspiration between the crop and the reference surface is combined into one coefficient, while in the dual crop coefficient approach it is split into two factors describing separately the differences in evaporation and transpiration components (Allen et al. 1998).

Crop evapotranspiration can be considered under standard or non-standard conditions (Allen et al. 1998). In the first case, optimal agronomic conditions are taking place, without constraints by diseases, fertilisation problems, water deficits, insufficient soil conditions, etc., providing full yield potential for the specific climate. When non-standard conditions are considered, i.e. there are issues preventing the smooth crop development process (pests, diseases, water shortages, soil fertility / toxicity / waterlogging problems, non-optimal crop management practices, etc.), an adjusted K_c value should be used, incorporating a proper crop stress factor.

Typically, the values of K_c can be represented by curves, which are divided in segments corresponding to the initial development ($K_{c\text{-}ini}$), mid-season ($K_{c\text{-}mid}$) and late-season ($K_{c\text{-}end}$) crop growing stages. K_c values provided in FAO-56 are considered valid, supported also by the fact that several recent studies on the matter have reported K_c values which are generally close to FAO-56 (Pereira et al. 2015).

2.2 Crop Reconnaissance Drought Index

2.2.1 Original RDI

The RDI is a drought index based on two meteorological parameters: precipitation and reference evapotranspiration. It is structured in three forms, each one providing different information and insights regarding drought and climatic conditions of the region under study. The initial form (α) is expressed as the ratio of precipitation to reference evapotranspiration, both accumulated for a period of k months:

$$\alpha_k^{(i)} = \frac{\sum_{j=1}^{k} P_{ij}}{\sum_{j=1}^{k} ETo_{ij}}, \mathrm{i} = 1(1)\mathrm{N} \text{ and } \mathrm{j} = 1(1)\mathrm{k} \tag{3}$$

in which P_{ij} and ETo_{ij} are the precipitation and reference evapotranspiration of the j-th month of the i-th year and N is the total number of years of the available timeseries.

It has been shown that α_k is suitable as a climate change indicator, which can be used either annually or for specific seasons of the year (Tigkas et al. 2013). It is noted that the long-term average of the annual values of α ($\overline{\alpha}_{12}$) represents the aridity index of the area.

Based on the timeseries (N years) of α_k, a normalised series ($\mathrm{RDI_n}$) may be derived (second form), expressed as the ratio of α to the arithmetic mean ($\overline{\alpha_k}$) for N years, minus 1.

The standardised RDI ($\mathrm{RDI_{st}}$) is the third form of the index, calculated through a standardisation procedure of the α_k values, producing a normally distributed timeseries with a mean of zero and standard deviation of unity (Tsakiris et al. 2007; Tigkas 2008). According to various studies in many locations, FAO P-M can be ideally employed for RDI calculation; however, temperature based methods, such as Hargreaves or FAO P-M using only temperature data, can be also applied, without significant effects on $\mathrm{RDI_{st}}$ results, for periods greater than 3 months (Vangelis et al. 2013; Mohammed and Scholz 2017; Zarei and Mahmoudi 2017).

The RDI can be calculated for various time scales, while its results may be interpreted through standard drought categorisation (Table 1). The latter is particularly important for strategic management, since the outcomes are comprehensible by non-experts, facilitating decision making process.

2.2.2 CRDI Formulation

In the proposed adjustment of RDI, namely the Crop Reconnaissance Drought Index (CRDI), the initial form of the modified index (α_c) is calculated by replacing reference evapotranspiration (ETo) by crop evapotranspiration (ETc), as follows:

Table 1 Drought characterisation based on RDI or CRDI values

$\mathrm{RDI_{st}}$ or $\mathrm{CRDI_{st}}$ value	Drought class
> 2.00	Extremely humid
1.50 to 1.99	Severely humid
1.00 to 1.49	Moderately humid
0.00 to 0.99	Near normal (mildly humid)
−0.99 to 0.00	Near normal (mild drought)
−1.49 to −1.00	Moderate drought
−1.99 to −1.50	Severe drought
< −2	Extreme drought

$$\alpha_{ck}^{(i)} = \frac{\sum_{j=1}^{k} P_{ij}}{\sum_{j=1}^{k} ETc_{ij}}, \mathrm{i} = 1(1)\mathrm{N} \text{ and } \mathrm{j} = 1(1)\mathrm{k} \tag{4}$$

The other forms of CRDI are calculated in a similar manner to the original index. Therefore, the normalised expression of the index ($CRDI_n$) is calculated by the following equation:

$$CRDI_n(k) = \frac{a_{ck}}{\overline{a}_{ck}} - 1 \tag{5}$$

in which $\overline{a}_{ck}$ is the long term average of a_{ck}.

The standardised form ($CRDI_{st}$) is calculated through a standardisation technique. The most simple approach is to apply the following equation, provided that the values of a_{ck} follow the log-normal distribution:

$$CRDI_{st}(k) = \frac{y_k - \overline{y}_k}{\widehat{\sigma}} \tag{6}$$

in which y_k is equal to the $\ln a_{ck}$, while $\overline{y}_k$ is its average and $\widehat{\sigma}$ is its standard deviation, respectively.

The above standardisation approach is not suitable, if cumulative precipitation values equals to zero. In such a case, gamma distribution can be considered, applying the approach proposed by Tigkas (2008) and Tsakiris et al. (2008). Based on $CRDI_{st}$ values, drought categorisation is performed using the drought classes presented in Table 1.

2.2.3 Considerations on CRDI Calculation

The use of evapotranspiration in RDI and, accordingly, in CRDI intends to represent the potential (maximum) evaporative demand, therefore ET_c should be considered under standard conditions, i.e. without limitations on crop development under the given climatic conditions, related to water availability, crop density, soil conditions and plant pressures by diseases, weeds or insects. In addition, considering ET_c under standard conditions has the advantage of allowing the straightforward transferability of K_c values derived by previous studies to different locations (Pereira et al. 2015). Nevertheless, although considering ET_c under non-standard conditions is not the primary recommendation for CRDI, it may be used in specific cases, for instance, on investigating scenarios under non-optimal crop development.

In CRDI calculation, the single K_c approach is recommended to be employed, combining the difference in evapotranspiration between the cropped and reference surface in one coefficient. This is because the accumulated evaporation and transpiration amount provides sufficient information for the purpose of the index, without introducing further computational complexity.

A key element in the calculation of CRDI, is that the time scale and the specific reference periods (k months) used for its calculation must coincide, or be rationally related, with the development period of the crop under study. For instance, if a winter wheat cultivation is considered, with crop development period from November to June, then the specific 8-month period can be used for assessing CRDI. Though, emphasis could be alternatively given to important crop development stages, e.g. the 2-month period April–May, during which drought stress may cause significant issues affecting the final yield. Nevertheless, the selection of non-critical periods for crop development, e.g. the entire year, may lead to inconclusive outcomes, because the conditions that do not overlap with crop development will provide excessive input for the calculation of the index.

3 Results and Discussion

3.1 Application

As previously mentioned, the use of CRDI provides a conceptually more sound drought characterisation, related to RDI, in farm-level analysis, where specific crops are examined. In the following application, the differences between the two indices are examined, in order to identify the significance and the advantages of the proposed modification for each form of the index, considering different crops in various areas.

Both RDI and CRDI were assessed under Mediterranean conditions in three regions of Greece: Crete (southern Greece), Thessaly (central Greece) and Thrace (north-eastern Greece). The average annual climate characteristics of each region are presented in Table 2, based on the available meteorological data for a timeseries of 45 years (1955–2000).

For the case of CRDI, ETc was estimated in each region for four typically cultivated crops in Greece, winter wheat, tomato, olive and cotton. The K_c values reported by Allen et al. (1998) for the initial development, mid-season and late-season stages for tomato, winter wheat and cotton, respectively, were adopted. For olive, the K_c average monthly values for semi-intensive orchards proposed by Tanasijevic et al. (2014) were used (Table 3).

The reference periods selected for RDI and CRDI calculation correspond to the typical growing season for each crop, i.e. April–August for tomato, November – June for winter wheat, April – October for cotton, while the entire year is considered for olive. The calculation of the drought indices performed using Drought Indices Calculator - DrinC software (Tigkas et al. 2015).

Figures 1, 2, and 3 present indicative cases of RDI and CRDI values (initial and standardised forms) for reference periods corresponding to specific crops for each region. As expected, RDI and CRDI timeseries have high correlation ($r > 0.99$). However, although the standardised values are generally close between the two indices, alpha values (initial form) have different level of departures for each index, depending on the specific case (crop, season and region).

According to the summary of the results presented in Table 4, the variation level between the indices is different, depending on the form of the index, as well as the region and crop under study. More specifically, the Root Mean Square Error (RMSE) for tomato (growing

Table 2 Climate characteristics of the study areas

	Annual average (mm)		Aridity index	Climate type
	P	ETo		
Crete	484	1024	0.47	semi-arid
Thessaly	418	1263	0.33	semi-arid
Thrace	542	1083	0.50	dry - sub humid

Table 3 Implemented K_c values for each crop (tomato, winter wheat, cotton and olive)

	Initial development ($K_{c\text{-ini}}$)				Mid-season ($K_{c\text{-mid}}$)				Late-season ($K_{c\text{-end}}$)			
Tomato	0.6				1.15				0.8			
Winter wheat	0.7				1.15				0.25			
Cotton	0.35				1.20				0.5			
	$K_{c\text{-Jan}}$	$K_{c\text{-Feb}}$	$K_{c\text{-Mar}}$	$K_{c\text{-Apr}}$	$K_{c\text{-May}}$	$K_{c\text{-Jun}}$	$K_{c\text{-Jul}}$	$K_{c\text{-Aug}}$	$K_{c\text{-Sep}}$	$K_{c\text{-Oct}}$	$K_{c\text{-Nov}}$	$K_{c\text{-Dec}}$
Olive	0.50	0.50	0.65	0.60	0.55	0.50	0.45	0.45	0.55	0.60	0.65	0.50

season Apr. – Aug.) and cotton (growing season Apr. – Oct.) is relatively low, up to 0.064 and 0.104, respectively, for all regions and forms. For olives (growing season during the entire year) RMSE reaches 0.313 (Thessaly) to 0.468 (Thrace) for the initial form, while for normalized and standardised forms of each index remain low (up to 0.004). For winter wheat (growing season Nov. – Jun.), RMSE values for the initial form is between 0.203 (Thessaly) and 0.336 (Thrace), while for normalised form is between 0.011 to 0.015 and for standardised form is higher, from 0.039 to 0.047. It is also interesting to note that the Mean Bias Error (MBE) is practically zero for all the examined crops and regions regarding both normalised

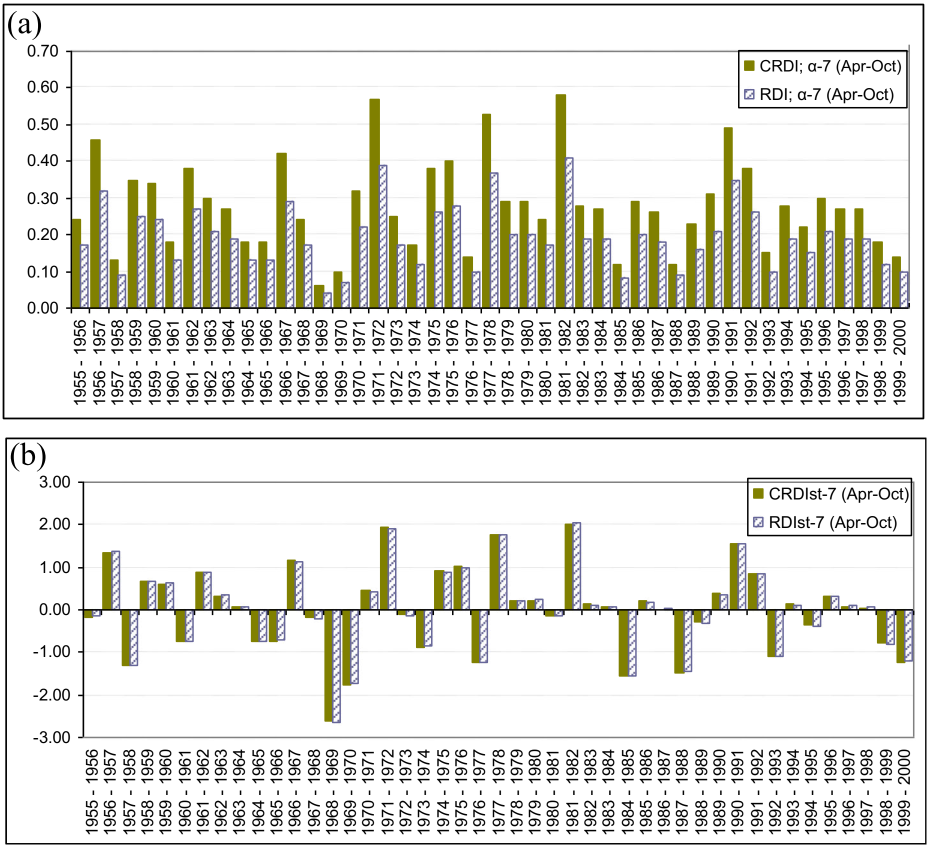

Fig. 1 RDI and CRDI values for the 7-month reference period April – October in Thessaly, for cotton: **a** initial form of the indices and **b** standardised form of the indices

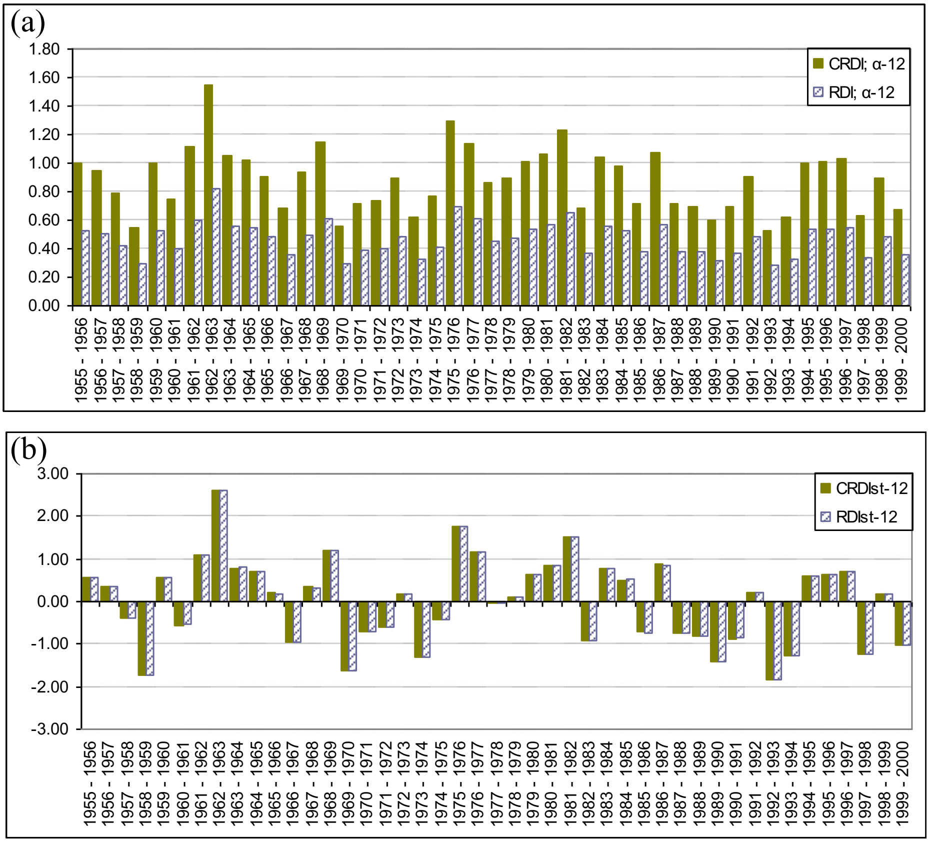

Fig. 2 RDI and CRDI values for the 12-month reference period in Crete, for olive: **a** initial form of the indices and **b** standardised form of the indices

and standardised forms of the indices, indicating their close long-term correlation. As for the initial form of the indices, MBE follows a similar pattern to RMSE values.

3.2 Discussion

The results of the case study show that the outcomes of RDI and CRDI are closely correlated. However, the differences between the initial forms of the two indices indicate that CRDI can clearly demonstrate the stress level which the specific crop may experience, under the given conditions. In fact, the values of the initial form for both indices illustrate water shortages during the selected reference period, i.e. values greater than one signify a water surplus (the cumulative precipitation was greater than the cumulative evapotranspiration for the specific period), while values less than one denote a water deficit (the cumulative precipitation was less than the cumulative evapotranspiration for the specific period). Consequently, in RDI, α_k values provide a general figure of the meteorological conditions and the water balance of the system. On the other hand, in CRDI, α_{ck} values are directly related to the water requirements of the specific crop under study, so they can indicate water stress issues and their magnitude, either during the entire crop growing season or focusing on particular, critical crop development stages.

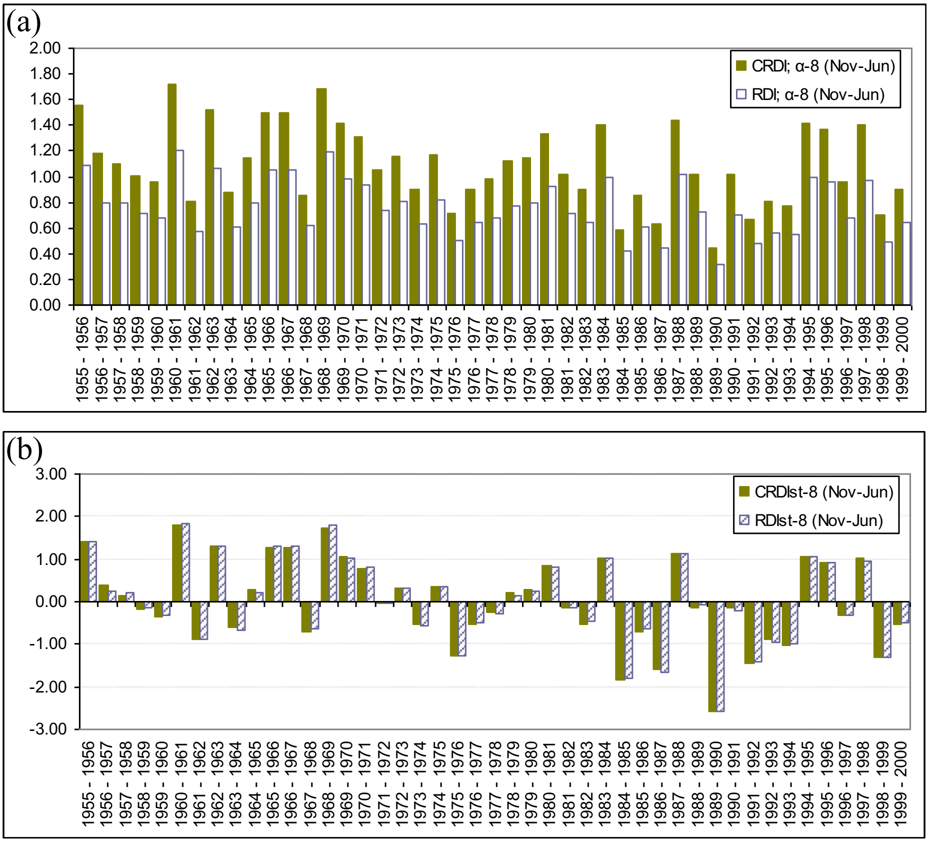

Fig. 3 RDI and CRDI values for the 8-month reference period November – June in Thrace, for winter wheat: **a** initial form of the indices and **b** standardised form of the indices

Table 4 Summary results of the differences between the forms of RDI and CRDI

	α - α_c		RDI_n - $CRDI_n$		RDI_{st} - $CRDI_{st}$	
	RMSE	MBE	RMSE	MBE	RMSE	MBE
Crete						
Winter wheat	0.277	−0.267	0.011	0.000	0.040	0.000
Tomato	0.036	−0.029	0.013	0.000	0.015	−0.001
Olive	0.426	−0.413	0.004	0.000	0.011	0.000
Cotton	0.087	−0.076	0.014	0.000	0.019	−0.001
Thessaly						
Winter wheat	0.203	−0.193	0.015	0.000	0.039	0.000
Tomato	0.060	−0.052	0.015	0.000	0.021	0.000
Olive	0.313	−0.302	0.005	−0.001	0.014	0.001
Cotton	0.092	−0.084	0.012	0.001	0.023	0.000
Thrace						
Winter wheat	0.336	−0.323	0.014	0.000	0.047	0.000
Tomato	0.064	−0.061	0.012	0.000	0.032	0.000
Olive	0.468	−0.456	0.004	0.000	0.010	0.000
Cotton	0.104	−0.098	0.013	−0.001	0.030	0.000

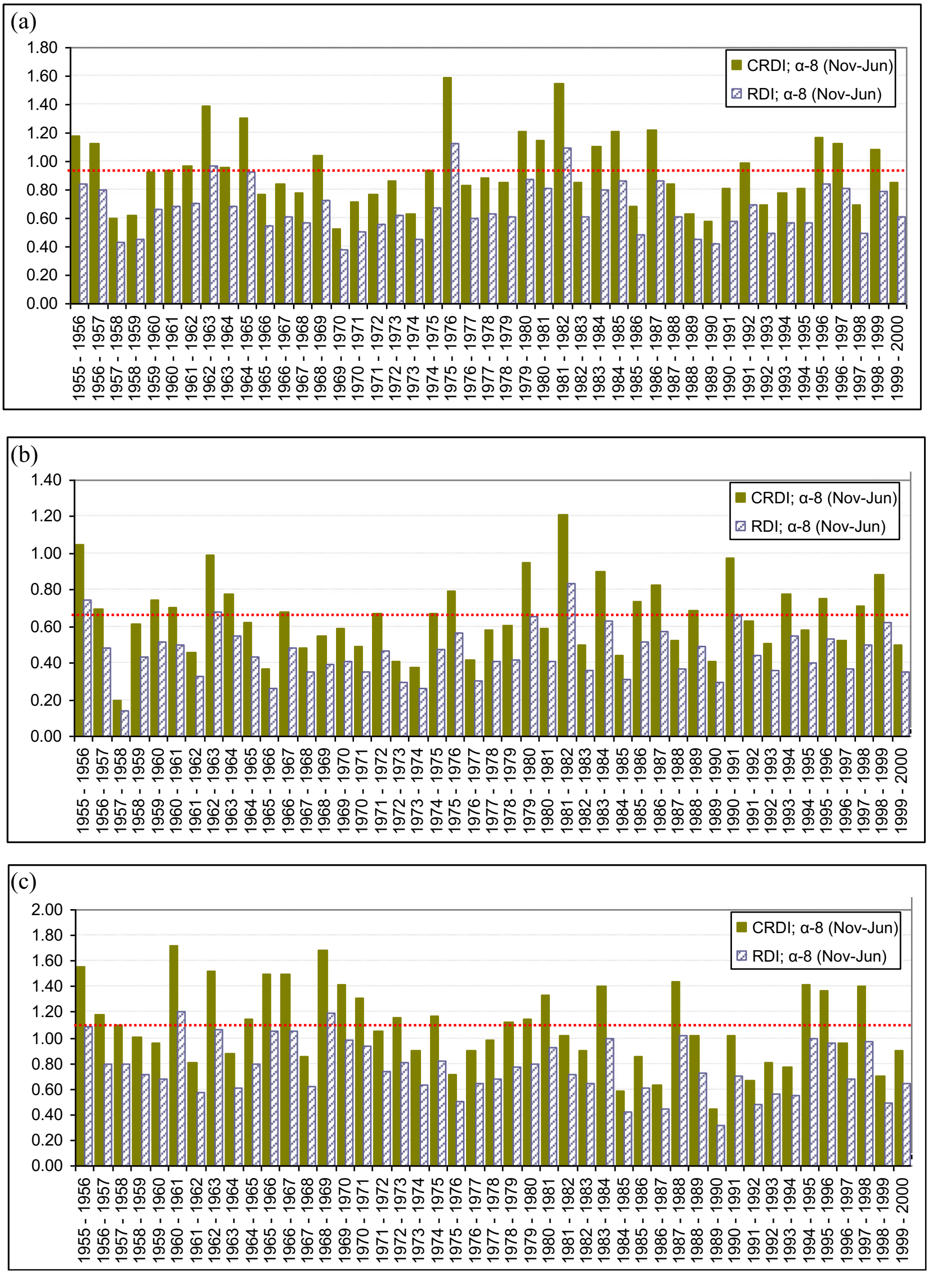

Fig. 4 Initial forms of RDI (α) and CRDI (α_c) values for the 8-month reference period November – June for winter wheat in: **a** Crete, **b** Thessaly and **c** Thrace – Red doted lines indicate average α_c

Therefore, the information provided by α_{ck} timeseries, along with drought categorisation (Table 1) based on $CRDI_{st}$ values, built up a concise and sound basis for identifying vulnerable crops in specific regions. Moreover, α_{ck} timeseries demonstrate the suitability of each crop for the given conditions, as well as under climate change. Similarly to the approach proposed for

RDI (Tigkas et al. 2013), α_{ck} can be used for identifying seasonal climate variations, though, in this case, the adaptability of alternative crops under climate change conditions can be assessed. Additionally, seasonal climate shifts that may have a long-term effect on crop growing season (e.g. altering planting dates), may be also investigated.

For example, as it can be seen in Fig. 4, the long-term average of α_{ck} for winter wheat (reference period November – June) varies for the different locations of the case study. In Thrace and in Crete, the average α_{ck} is close to the unity (1.09 and 0.94, respectively), while in Thessaly it is significantly lower (0.64). As winter wheat may be a rainfed crop in Mediterranean conditions, the above information indicates that in the first two areas the specific crop can be a suitable cultivation, while in the third case supplementary irrigation seems to be required to meet crop water needs. Obviously, as it can be deducted from Fig. 4, the above information cannot be derived based on RDI (α_k timeseries), as its values has significant departure from the corresponding α_{ck} values.

It should be stressed, that the choice of suitable crops for specific regions in the framework of an adaptation plan to drought and climate change, requires a thorough and complex assessment, including economic and environmental factors. The aforementioned input that is provided by CRDI can be a suitable component within such an adaptation plan, providing transparent outcomes regarding system vulnerability and drought risk assessment, assisting decision making process towards efficient drought management.

4 Conclusions

In this study, the Crop Reconnaissance Drought Index (CRDI), an adjustment of the widely used RDI index, is introduced. The proposed index aims at addressing farm-level drought assessment, focusing on specific crops, while taking into account climate change conditions. The principal component of this modification consists in replacing the reference evapotranspiration, which is used in RDI, with crop evapotranspiration. Another important difference is the selection of the appropriate reference periods for the calculation of the index, which must coincide with crop growing season or with important crop development stages.

The CRDI cannot be considered as an all-purpose replacement of RDI, as it is designed for crop-specific agricultural drought analyses, and it is not a general meteorological index. However, for the cases that it is designed, it has sound theoretical basis providing enhanced accuracy and validity compared to the original index. Furthermore, it retains the advantages of RDI, having the same data requirements, comprehensive outcomes based on robust drought categorisation and similar computational simplicity, since ET_c is recommended to be assessed through the single crop coefficient approach. Furthermore, K_c values are readily available in the literature and can be directly applied / transferred to different locations for CRDI calculation, according to the proposed methodology.

Based on the presented results, it is deduced that the normalised and standardised forms of RDI and CRDI are not expected to have significant differences, although CRDI results are considered to have more valid basis, referring to the specific crops under study, thus being more accurate. Regarding the initial form α_c, it is particularly useful, as it can directly spot water stress issues, indicate the level of suitability of specific crops under the given conditions and, also, identify seasonal long-term trends suggesting climate change conditions that may affect the adaptability of crops.

The proposed CRDI is expected to be a useful tool, in line with recent research and policy initiatives emphasising farm-level planning, assisting decision making process and agricultural drought management, as well as being a suitable component in climate change adaptation plans.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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