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The role of conservation agriculture in mitigation and adaptation to climate change

Uloga konzervacijske poljoprivrede u ublažavanju i prilagodbi klimatskim promjenama

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THE ROLE OF CONSERVATION AGRICULTURE IN MITIGATION AND ADAPTATION TO CLIMATE CHANGE

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Scientific review

Pregledni znanstveni članak

SUMMARY

Climate change (CC) is undoubtedly induced and accelerated by human activity and can pose a serious threat to mankind by reducing food production. Significant weather aberrations in form of the uneven precipitation pattern, more frequent and intense occurrence of temperature fluctuations accompanied by changes in wind intensity and frequency, amount of clouds, intensity and quality of sunlight can be expected. Maybe the most vulnerable sector affected by CC is agriculture. So, it is important to mitigate and adapt to a new situation through different and most adaptable agricultural strategies. Accordingly, scientists, experts, politicians, decision-makers, and others increasingly emphasize the need for further development of sustainable agricultural production, whose management will be compatible with different ecosystems (agroecosystem compliance with global ecosystems), while simultaneously restoring degraded agricultural land. One of the best solutions for sustainable agricultural production, under CC conditions, can be Conservation agriculture. Climate change is not only an abstraction, which is why one of the most important roles of conservation agriculture today is its ability to adapt and mitigate these changes. The basis of conservation agriculture production is in management set on three fundamental postulates, which contextually unify climate-soil-plant, while respecting agroecological and socio-economic differences.

Key-words: climate change, agricultural strategies, adaptation and mitigation, conservation agriculture, sustainability

WEATHER AND CLIMATE RELATIONS

According to the basic definition, the weather is short-period atmospheric conditions over the narrow area. These conditions usually last for a day or seven days maximum. The common definition of climate, on the other hand, defines it as an atmospheric condition of a specific, but wider area measured for at least 30-year period of time (Farmer, 2015). This 30-year period is most commonly used unit of measure, but it is not strictly defined, because climate can be also analysed in a mid-time period, for example of 10 years or similar (special reports for specific needs). These terms, "weather" and "climate" should be strictly distinguished because they are not the same. Weather is a term for every-change in atmosphere and climate is a term for average values of atmosphere without "every-change" effect.

Aberrations of weather and climate in a short-term period are not Climate change (CC) and this is the most

common mistake in understanding the weather-climate-climate change relations.

In case when average climate is changing on a statistically significant level in a period of a few decades or longer (century or millennia), then it is possible to talk about CC. This more general definition of CC does not include anthropogenic factor or human activity from the very beginning of agriculture. Many scientists and science institutions can offer their own definitions of CC but almost all of them include direct or indirect human activity (Rahman, 2013). Accordingly, human activities over the last century are the main culprit for increasing variability of weather and climate (IPCC, 2007; DCCCE, 2012). Today two different and opposite theories (still without scientific

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consensus) about causes and consequence of CC exist (Jug et al., 2017). According to the first theory, CC is not a novelty and it has appeared in more or less regular cyclical intervals over the last 400,000 years (Farmer, 2015) and it is usually named "natural causes" of CC. The second theory or "anthropogenic" theory of CC is supported by the majority of scientists, and according to the aforementioned, human influence makes the current climate change unique in the rapidity of the changes (IPCC, 2014a). If someone compares changes in the temperature, those occurring today are rapidly changing in comparison to the past when temperature changes were much slower even up to 30 times (Flannery, 2005). About the possible causes of CC there is no absolute consensus and there is also a lot of scepticism on the issue of CC, which has resulted with the creation of various conspiracy theories and unconstructive and unproductive actions. Scientific and professional, individual and collective, political and economic engagement is still insufficient to prove negative CC effect.

The phrase "global warming", or "global cooling" as a synonym, is often used instead of the term CC, which is essentially incorrect, but it can be inferred from where someone derives such misconception. The increase in average air temperature is sensitively most explicit and instrumentally visible global change. Global warming is a statistically significant increase in global air temperature resulting from natural and anthropogenic influences (over decades or longer). This phenomenon is a consequence of greenhouse effect and should be observed globally, not in the context of local and/or seasonal aberrations of meteorological elements (Figure 1).

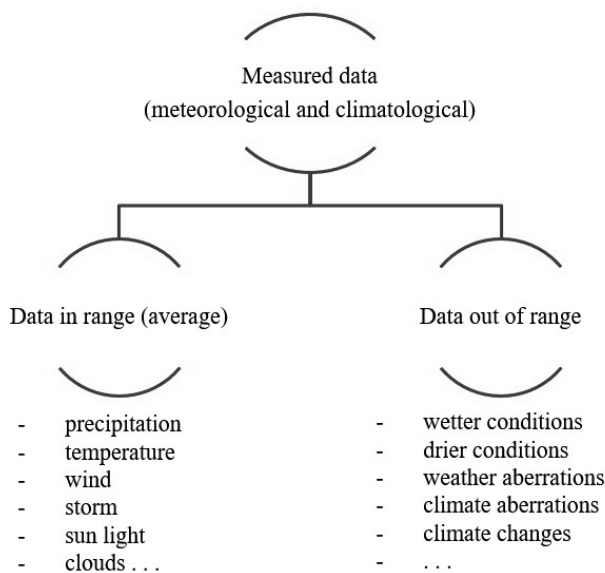


Figure 1. Scheme of meteorological and climatological data relations

Slika 1. Shema odnosa meteoroloških i klimatoloških podataka

According to the "logical" structure of development of CC (Figure 2), as some scientists claim, global warming is only a step towards the next occurrence on a global scale - "global cooling". Global cooling is the process of decline in the average temperature of the Earth at a statistically significant level as a direct consequence of global warming (disturbance in the atmosphere and oceanic circulation) (Jug, 2016).

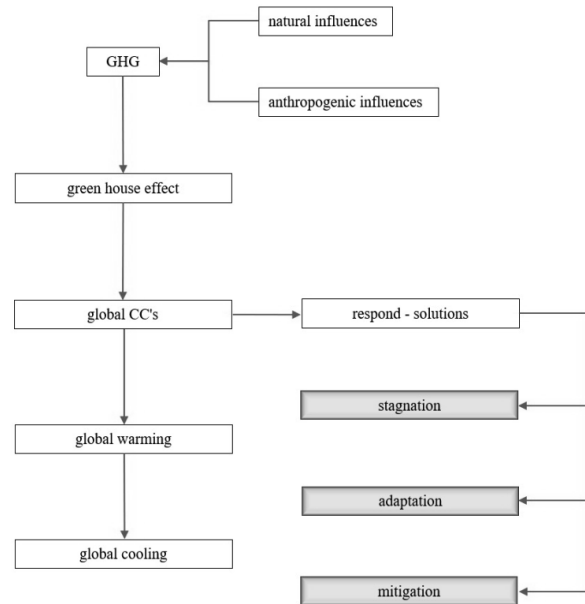


Figure 2. Flowchart of climate change

Slika 2. Dijagram toka klimatskih promjena

CLIMATE CHANGE – THREATS ON A GLOBAL AND LOCAL SCALE

On a global scale, CC are one of the most dangerous and degrading threats in the world whose negative influences are visible in every natural, social and economic sector. Maybe the most visible and degrading influence of CC is on the agriculture sector and on its main role, in food production for a growing population (Aune, 2012). Each climatic system consists of climatic components (atmosphere, hydrosphere, cryosphere, biosphere and pedosphere) entering into mutually very complex relations. Violation of harmony in only one of the components causes a disturbance of the whole climate system and if these disorders occur on a global scale, then one can speak about global climate disturbances or changes (Bazzaz, 1990; Goosse et al., 2010; Tan and Yew, 2015). Over the last 20 years, mankind has witnessed a more pronounced influence on adverse weather and climatic conditions, which have been more or less reflected on the economy, environment and other aspects, and perhaps most of all on agricultural production (Jug and Güttler, 2015). According to the IPCC (2014b), the global air temperature in the 20th century has risen by 0.6°C, which is largely attributable to human activity (Lai and Cheng, 2010; Australian Academy of Science, 2015;

Anderson et al., 2016), but on a statistically significant level only on the short range (Stips et al., 2016). In addition, according to IPCC (2007), climate models predict an increase in the atmospheric ground temperature by an additional 1.4-5.8°C and increase in global precipitation ranging from 5% to 25% by the end of the 21st century. Apart from other changes at the regional and local level, significant changes in the precipitation

regime can be expected, as well as more frequent and intense occurrence of temperature and precipitation extremes, accompanied by changes in wind intensity and frequency, amount of clouds, intensity and quality of sunlight and so on. Interrelations of "usual" and "unusual" weather conditions on a global, regional and local scale are represented in Figure 3.

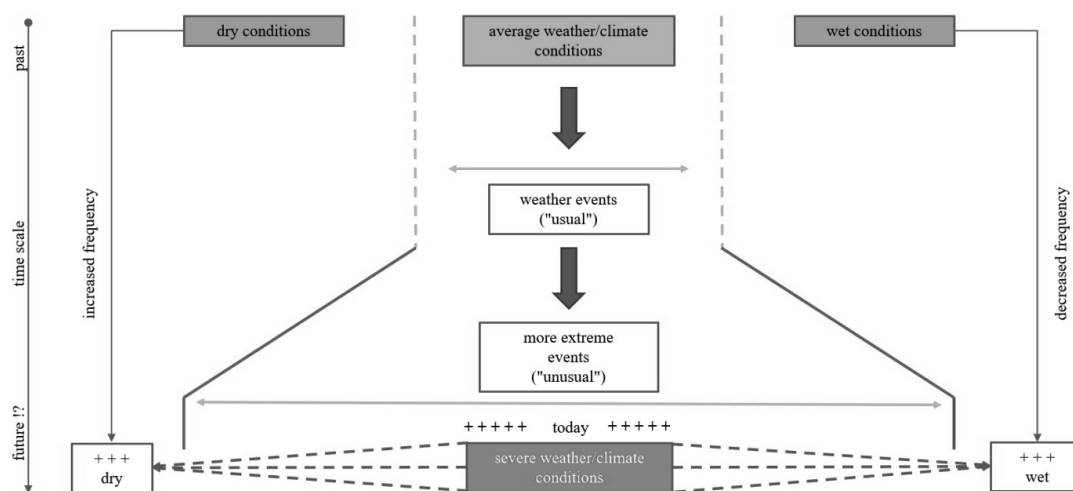


Figure 3. Relation of weather and climate in average and severe conditions

Slika 3. Odnos vremenskih i klimatskih prilika u prosječnim i ekstremnim uvjetima

The southern, south-eastern and eastern regions of Europe belong to the area of the world that is significantly vulnerable to CC (IPCC, 2001; Behrens et al., 2010; Anders et al., 2014). In these regions, a further increase in temperature of about 2°C in winter, and 2-3°C in the summer periods above the current average is predicted. It is also expected that precipitation will decrease by 5 to 15%, especially in the warm period of the year and, consequently, reduce soil moisture by 15-25% (IPCC, 2001) and according to Polade et al. (2017) there will be a reduction in precipitation from 1% to 38% over Mediterranean climate regions.

CAUSALITY OF AGRICULTURE AND CLIMATE CHANGE

The main sources of greenhouse gases (as the most important elements of CC) are the following sectors: combustion of fossil fuels, industrial processes, waste disposal, deforestation and agricultural production (crop and animal production). It is estimated that agriculture is involved with at least 20% in total environmental pollution (IPCC, 2014b). According to EEA (2011, 2012), out of the total amount of greenhouse gases in the EU, about 10% came from agriculture, which is the 4th largest emission activity, after the energy production,

industry and transport. At the same time, CC have an overall global impact and the most vulnerable sectors are agriculture, water, health, forestry and biodiversity, as well as critical ecosystems (Jug and Güttler, 2015). Furthermore, there are projected changes in distribution, intensity and frequency of extreme phenomena such as heat waves and droughts. Global climate aberrations are estimated to be responsible for 32% to 39% of yield variability (Ray et al., 2015.). Agriculture is a human existential basis, and at the same time, the polluter of the environment and the victim of the polluted (degraded) environment. This paradox is a result of a specific role of agriculture: environmental polluter and food producer. The impact of direct and indirect factors on CC in the agriculture sector derives from: deforestation, desertification, loss of biodiversity, soil erosion, loss of organic matter, salinization, soil acidification, etc. (EC, 2006; Wheeler and von Braun, 2013; Gomiero, 2016; Mieszkowska, 2016). Agriculture, therefore, with its primary activity affects soil, water and air pollution, which in combination with other factors or components affects CC. On the other hand, global CC affects agriculture at the local and global level, but also in direct (physical, chemical and biological degradation) and indirect (economical, sociological, technical, technological, political and other) ways (Jug, 2016). According to

FAO (2007), the following main consequences of CC in agriculture can be expected at the global level e.g. decrease in yield, reducing the share of agriculture in GDP, fluctuations in prices on the world market, increase in world hunger, migration and social unrests. The impact of CC on crop production is reflected through the following (Figure 4): changes in average air temperature, precipitation and its distribution, increased development

of diseases, weeds and pests, soil degradation (physical, chemical and biological components), reduction of number of frost days and elongation or shortening of growing season (Lenka et al., 2015; Liu et al., 2018). The loss of biodiversity, agro-biodiversity and the spread of invasive species are among the most harmful effects of CC (Javeline et al., 2013).

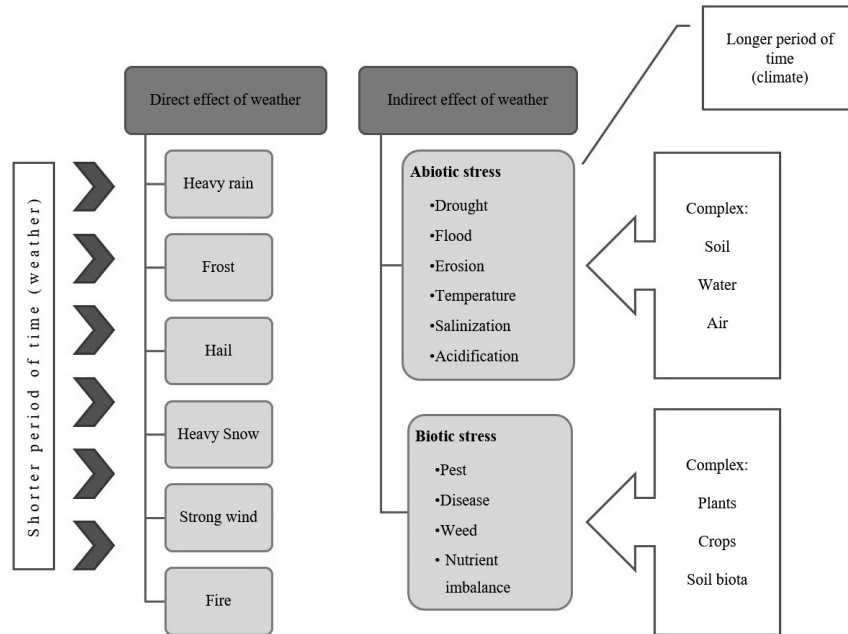


Figure 4. How weather and climate affect cropping systems?

Slika 4. Kako vremenske prilike i klima utječu na sustav uzgoja usjeva?

AGRICULTURAL STRATEGIES AND POSSIBILITIES FOR ADAPTATION AND MITIGATION OF NEGATIVE INFLUENCE OF CLIMATE CHANGE

Vulnerability of agriculture to CC is reflected through variability, seasonality, changes in mean precipitation and water availability, and the emergence of new pathogens and diseases (Fischlin et al., 2007) (Figure 5).

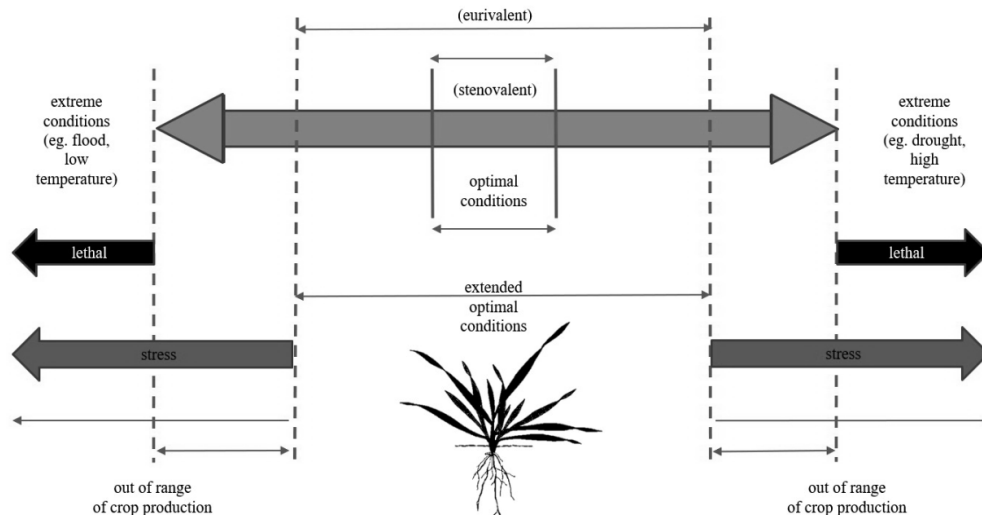


Figure 5. Intensity of agroecological factors of crop production (mainly soil, water, temperature, climate)

Slika 5. Intenzitet agroekoloških čimbenika biljne proizvodnje (uglavnom tlo, voda, temperatura, klima)

Iglesias et al. (2007) reported possible positive effects of CC: longer growth period, faster growth times, new crops introduction in cold areas, and potential negative effects: reduced availability of water, increased thermal stress due to ambient temperatures, increase in weeds, pests and diseases, problem with flowering (absence of vernalisation), increased salinization, increased frequency of droughts, etc. Agriculture, in modern times, has tried to find best-option pathways to minimise the impacts of CC through different adaptation and mitigation strategies (Jug, 2013). These measures are implemented, on different levels respectively, by individuals, local institutions collectively or through

national level policy decisions which provide finance, research and development, and knowledge transfer, and property rights or legal frameworks to enable individual or collective action (Wreford et al., 2010). Defining strategies need to take into account general conditions, which predominantly include economic and social development (knowledge, tradition, existing technology, science implementation etc.) and specific/agroecological conditions (climate, soil, water, crop, biology etc.). Basically, two main groups of primary approaches (or two different ways) for adapting cropping system to changing conditions in crop production exist today (Figure 6).

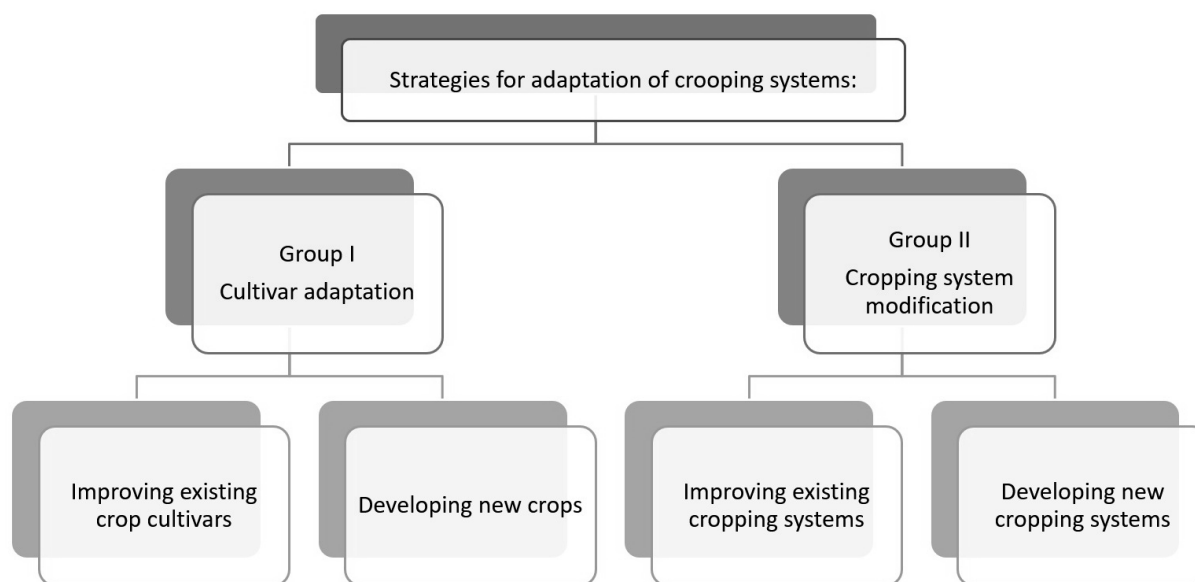


Figure 6. Main group of strategies for adaptation of cropping systems to CC

Slika 6. Glavne grupe strategija prilagodbe sustava uzgoja klimatskim promjenama

These approaches include a number of specific strategies/measures/procedures, and main measures for modification of cropping systems (Figure 6, Group II) and they are as follows:

- conservation/reduced/adapted soil tillage,
- crop rotation,
- reduced soil erosion (caused by wind and water),
- promotion of soil biogenity,
- reduction of energy consumption,
- reduction of CO₂ emissions (crops and plants remain),
- prohibition of burning the crop residues,
- using crop residues for soil surface protection and preservation,
- reduction of the required number of machinery and time for tillage operations,
- controlled/limited/optimized machinery and equipment traffic,

- growing or introduction of tolerant (to modified conditions) crops (cultivars, adapting planting dates),
- intercropping crops (cover, catch and cash crops),
- integrated pest management,
- proper water management,
- weather (and climate) forecasting adaptation, etc.

CONSERVATION AGRICULTURE – IS IT THE BEST SOLUTION AND RESPONSE TO CLIMATE CHANGE?

Conservation agriculture (CA) represents one of the most significant strategies to combat CC, which has been in service to sustainability of agriculture (FAO, 2011; González-Sánchez et al., 2012; Choudhary et al., 2016; González-Sánchez et al., 2017). Conservation agriculture was originally designed in the last century (1930s), in the so called “dirty thirties” as a response

to large-scale soil degradation (Baveye et al., 2011). CA is primarily designed for a large-scale farm, equipped with heavy and large machinery and with excessive use of herbicides. After being adopted in North and South America and Australia, CA was rapidly spread to the whole world (Palm, et al., 2014). According to Kassam et al. (2015), application of CA at a global level, in 2013, covered about 157 M ha, which in comparison to 106 M ha from 2008/09 makes an increase of 47%. Europe, with about 2.0 M ha cropland under CA is on the penultimate place in comparison to the other continents. Thanks to the governments' efforts and institutions such as EC (European Commission) and, ECAF (European Conservation Agriculture Federation), from 2008/09 to 2013 CA area significantly increased, even by some 30% (Kassam et al., 2015). Further progress in acceptance of CA can be expected in the upcoming period.

"CA principles are universally applicable to all agricultural landscapes and land uses with locally adapted practices. CA enhances biodiversity and natural biological processes above and below the ground surface. Soil interventions such as mechanical soil disturbance is reduced to an absolute minimum or avoided, and external inputs such as agrochemicals and plant nutrients of mineral or organic origin are applied optimally and in ways and quantities that do not interfere with, or disrupt, the biological processes.

CA facilitates good agronomy, such as timely operations, and improves overall land husbandry for rainfed and irrigated production. Complemented by other known good practices, including the use of quality seeds, and integrated pest, nutrient, weed and water management, etc., CA is a base for sustainable agricultural production intensification. It opens increased options for integration of production sectors, such as crop-livestock integration and the integration of trees and pastures into agricultural landscapes" (FAO, 2015).

CA management is set in three basic postulates, which contextually unify climate-soil-plant, taking into account agroecological and socio-economic differences. According to FAO (2015), CA is characterised and based on three main principles as follows.

- permanent or semi-permanent soil cover (using either a previous crop residue or specifically growing a cover crop for this purpose. Usually, CA implements three categories of ground organic soil cover: 30-60%, >60-90% and >90% (Derpsch, 2003), measured after the complete tillage and seeding operation. According to Derpsch (2003), soil coverage less than 15% crop residue or 550 kg ha⁻¹ of small grain residue is recognised as a Conventional tillage; coverage between 15 and 30% or 550 to 1100 kg ha⁻¹ as a Reduced

tillage systems and soil tillage which leaves a minimum of 30% of crop residue on the soil surface or at least 1100 kg ha⁻¹ of small grain residue on the surface as a Conservation tillage systems),

- minimum soil disturbance through tillage (just enough to get the seed into the ground, namely less than 25% of the cropped area),
- diversification of regular crop rotations (crops grown in sequences or implementation of associations and mix of perennial or/and legume or/and non-legume crops to help combat the various biotic constraints. Rotation should involve at least 3 different group of crops: cereals, wide spaced crops and legumes; or as an example: winter wheat-maize-soybean).

CA also uses or promotes where possible or needed various management practices listed below:

- utilization of green manures/cover crops (GMCC's) to produce the residue cover,
- no burning of crop residues,
- integrated pest management,
- controlled/limited human and mechanical traffic over agricultural soils.

CA and its aforementioned basic principles are universally applicable in all agroecological conditions and landscapes with necessary adaptation to the specific local and practical conditions. Advantages of CA, in comparison with Conventional agriculture (Christensen and Johnston, 1997; Hobbs, 2008; Busari et al., 2015; Joseph and Issahaku, 2015), can be roughly divided as:

- short-term advantages: increased water infiltration and improved soil structure, lower trafficability and compaction, reduced erosion by wind and water, reduced soil water evaporation, lower water saturation/drought stress, lower fuel, mechanization and labour costs,
- long-term advantages: increased soil organic matter content resulted in better soil structure, Cation Exchange Capacity (CEC), higher water holding and storage capacity, improved crop nutrition, higher and stable yields, lower costs, increased biological activity, lower weediness.

The main obstacles to the world-wide adoption of CA practices can be summarized as: insufficient knowledge (know-how, science to farmers), tradition, prejudice, inadequate policies (unrecognized specific needs for subsidies), inappropriate equipment and machinery, inappropriate ratio of land size and machinery size/price (Friedrich and Kassam, 2009; Jat et al., 2014; Farooq and Siddique, 2014; Jug et al., 2015, 2017). Complemented by other known good agronomy practices, including the use of quality seeds, and integrated pest, nutrient, weed and water management, etc., CA is a base for sustain-

able agricultural production intensification (FAO, 2015). The yield levels of CA systems are comparable with and even higher than those under conventional tillage systems (Jug et al., 2005, 2011), with respect to all principles of sustainable agricultural production (Jug et al., 2017). The principles are reduced use of agrochemicals reflecting on the biological component of soil and water quality (Laurent et al., 2011), carbon sequestration rate aid ranging from 0.2 to 1.0 t ha⁻¹ yr⁻¹ (Corsi et al., 2012; Kertész and Madarász, 2014; Srinivasarao et al., 2014), depending on the agroecological conditions and soil management methods (González-Sánchez et al., 2017), reducing the workload by 50%, which allows producers to save time, reduce fuel costs and machinery (Saturnino and Landers, 2002; Crabtree, 2010; Lindvall and Sonntag, 2010). Soil organic carbon can be a source of greenhouse gas emission through the formation of CO₂, CH₄ and N₂O and by applying the CA principle, the concentration of greenhouse gases is reduced, thereby affecting the mitigation of CC. Changes induced by CA related to the C dynamics in the soil, lead directly to an increase in soil C. Also, drastic reduction in the amount of tillage operation of the soil reduces CO₂ emissions and reduces mineralization process of the organic matter (Krauss et al., 2017). CA increases the vertical stratification of the soil organic matter and this stratification is taken as a quality recovery index of agricultural land degraded by soil tillage (Franzluebbers, 2002; Moreno et al, 2005; Blanco-Canqui and Lal, 2007). The beneficial effects on the environment derived from CA have been widely studied by scientist for decades, which are pertaining to erosion, in relation to the water use (Blanco-Canqui and Lal, 2007), regarding the biodiversity improvements and the fight against CC (González-Sánchez et al., 2012; Henneron et al., 2015) and changes in agricultural model due to problems caused by soil degradation (Van-Camp et al., 2004). CA represents the core components of a new alternative paradigm for the 21st century and calls for a fundamental change in a production system thinking.

Main reasons for the adoption of CA can be summarized as follows: (1) better farm economy (2) flexible agrotechnical possibilities for sowing, fertilizer application and weed control; (3) yield increases and greater yield stability (as long-term effect); (4) soil protection (5) greater nutrient efficiency. Briefly, CA offers a number of benefits to the producers, the society and the environment, but most importantly, its benefits are in a domain of efficient possibilities to combat CC through adaptation and mitigation strategies.

CONCLUSION

Since climate change (CC) is not restricted by narrow local or national borders or even wide borders on regional or global scale and since agriculture is extremely vulnerable to them, a common action to find adequate and effective measures or strategies to face them is an imperative. For successful approach to the adaptation and mitigation processes, it is neces-

sary to create adequate and useful strategies which will be developed through strong regional cooperation of experts with professional competence to reach the satisfying results in relation to the regional specificity of economic and social development, agroecological conditions, crop production and environment. It is important to emphasise that time to mitigate CC is expiring and the only remaining solution/option is the adaptation that must be based on the scientific facts. Conservation agriculture attracts more and more attention from numerous scientists around the world by offering a solution to the problems associated with CC.

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ULOGA KONZERVACIJSKE POLJOPRIVREDE U UBLAŽAVANJU I PRILAGODBI KLIMATSKIM PROMJENAMA

SAŽETAK

Klimatske su promjene nesumnjivo potaknute i ubrzane ljudskom aktivnošću i mogu predstavljati ozbiljnu prijetnju čovječanstvu smanjenjem proizvodnje hrane. U budućnosti se mogu očekivati značajna odstupanja vremenskih prilika u obliku neujednačenih oborinskih obrazaca, češćih i intenzivnijih temperaturnih oscilacija, promjene intenziteta i učestalosti vjetra, količine oblaka, intenziteta i kvalitete sunčeve svjetlosti. Poljoprivreda se ubraja u najranjivije sektore koji su pod izravnim utjecajem klimatskih promjena, zbog čega je iznimno bitno ublažiti njihov utjecaj i prilagoditi se novonastaloj situaciji primjenom različitih poljoprivrednih strategija. Prema tome, znanstvenici, stručnjaci, političari, donositelji odluka i drugi akteri sve više naglašavaju potrebu daljnjega razvoja održive poljoprivredne proizvodnje, čije će upravljanje biti kompatibilno s različitim ekosustavima (usklađenost agroekosustava s globalnim ekosustavima), uz istovremeno obnavljanje degradiranoga poljoprivrednoga zemljišta. Jedno od najboljih rješenja iz domene održive poljoprivredne proizvodnje, u uvjetima klimatskih promjena, može predstavljati konzervacijska poljoprivreda. Klimatske promjene nisu samo apstrakcija, zbog čega je jedna od najvažnijih uloga konzervacijske poljoprivrede u današnje vrijeme upravo njezina sposobnost prilagodbe i ublažavanja tim promjenama. Temelj konzervacijske poljoprivredne proizvodnje postavljen je na njena tri osnovna postulata, koji kontekstualno ujedinjuju klimu, tlo i biljku, uz uvažavanje agroekoloških i društveno-ekonomskih razlika.

Ključne riječi: klimatske promjene, poljoprivredne strategije, prilagodba i ublažavanje, konzervacijska poljoprivreda, održivost

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