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Agricultural Land Suitability Analysis of Metropolitan Peri-Urban Areas Now and into the Future — Case Study of City of Whittlesea, Melbourne, Australia

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Abstract: Pressures from urban development in metropolitan peri-urban areas has led to decline in agricultural activity. Methodologies that address the impacts of climate change on agriculture are better at creating adaptive capacity for local communities. Land Suitability Analysis (LSA) methodology has been used to investigate the bio-physical and climatic crop growth requirements by defining three main criteria: soil, landscape and climate. The analysis creates a spatial composite map that displays areas of various suitability ranked from 0 to 10. The timeframe includes baseline, and 2030, 2050, and 2070 based on higher emission scenario projections RCP8.5, and includes irrigated and non-irrigated models. This paper presents the versatility LSA maps of ten commodities: Phalaris, Perennial Ryegrass, Lucerne, Brassicas, Citrus, Plums, Cherry, Raspberry, Cut Flowers, and Blue Gum. The case study area was City of Whittlesea, a Council in Northern Metropolitan Melbourne. The results indicate that agricultural land is highly suitable and versatile. The purpose of the analysis is to inform decision-makers and create the opportunity to discuss future agricultural development initiatives, which account for climate change as an enabler of agricultural activity. In conjunction with this approach, overarching strategies that ensure climate change adaptation are equally important.

Key words: land suitability analysis, peri-urban agriculture, climate change adaptation

1. Introduction

Peri-urban areas have received much attention from researchers and policy makers for their potential role in addressing food security issues, landscape preservation, cultural value, and resource management [1-4]. The dichotomy between urban and rural environments has resulted in limited recognition of the unique characteristics of peri-urban areas. Therefore, any discussion has been hampered due to a lack of agreement on the role of these spaces, oversimplification of existing relationships and conflicts, and inadequate institutional and organizational structures [5].

Agriculture in peri-urban areas is confronting two main challenges, one related to changes of the overall industry, and the other related to location [6]. The proximity to the city creates tension between urban and rural land-use due to urban sprawl, land fragmentation, land banking, and land prices. The benefits of preserving, maintaining, and protecting peri-urban metropolitan areas for agriculture have both economic and non-economic value. This includes, local business retention and employment, resource use efficiency in production and processing of agricultural commodities, ecosystem functions (water, soil quality, and air, biodiversity), quality of life, recreation and heritage, community coherence, education, health, and tourism opportunities [7]. With urgent needs to build adaptive capacity for climate change, peri-urban areas could become transformational spaces.

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Incorporating Geographical Information Systems (GIS) utilization, land-use planning can be coupled with Land Suitability Analysis (LSA) to categorize spatial patters of land-use according to specific requirements — agricultural land-use [8, 9], wildlife habitat [10], environmental impact assessment [11], and planning [12-14]. Moreover, the LSA approach is based on the land's intrinsic bio-physical characteristics which act as constraints to land-use and can be easily presented in a non-technical manner making it attractive to a wide range of users — planners, land managers, farmers, and policy makers [15]. LSA is not only a representation of databases and spatial information, rather it represents a participatory approach which adds a social dimension that, at times, has been neglected [16].

Based on the context presented and the approach mentioned, LSA represents a tool for decision makers to make informed decision that account for modifications in agricultural land suitability considering climate change at a local level. The methodology in this instance is explained by application in the City of Whittlesea Council, in Melbourne, Victoria (for a complete methodological explanation and other applications [17, 18].

2. The Need for Climate Change Adaptation in the Agricultural Sector

The impact relationship between climate change and agriculture is not straightforward. The non-climatic factors of production such as breeding, use of irrigation, fertilizer and pesticide use, and disease incidence have a greater impact on production in the short-term than climatic changes. On the other hand, the most notable impacts of climate change on the short-term are extreme weather events such as drought, floods, and fires. On the long-term, continuous increase in temperatures that lead to higher day and night difference with negative impact on certain crops, and potential losses to pests, weeds, and diseases. Climate change has also positive impacts on crops such as reduced frost occurrence and improved yield due to increased CO_2 levels which assists especially C_3 plants [19]. Such climatic changes could alter agricultural activity, especially in marginal areas, resulting in the need to relocate agricultural production in areas better suited to future changes in climate. One example is the current "*foodbowl*" of Victoria, Murray-Darling basin, where higher temperatures, hotter and more frequent hot days, prolonged periods of extensive drying and increased occurrence of extreme events will continue to put pressure on agricultural production [20]. In this context, peri-urban metropolitan Melbourne has the opportunity to contribute to Melbourne's food security, where climate impacts will be less severe.

For the agricultural sector, adaptation implies a flexible, risk-based approach that incorporates future uncertainty and is based on an active role of Local Government to provide vision, support and implementation. Importantly, the initial efforts need to prepare farmers with alternative options suitable for a range of uncertain future local climate changes [21]. Local Government could show leadership in three main areas. These include shifting strategies from mitigation only to adaptation, pushing for reform of planning frameworks at higher levels of government, and enabling adaptation throughout council functions [22].

There are arguments that the Australian Government has delivered short-term responses to mounting evidence that the impacts of European-style farming practices have been damaging the Australian environments. The crops and livestock introduced coupled with intensification of input use has resulted in soil and water degradation (soil erosion, salinization, and acidification), pest plant and animal problems, and disregard for native vegetation [23]. Globalization and neo-liberal economic rationale has left rural areas and peri-urban metropolitan areas struggling with loss of jobs and growing social inequalities, where poverty is largely differentiated by postcode [24]. The position of competitors such as United States and European Union (EU) that continue to protect their agricultural sector coupled with exposure of Australian farmers to international market forces has lowered the economic viability of many small farm families [25]. Furthermore, lack of political commitment and broader vision of those within the agricultural sector can result in decrease resilience in the face of climate variability.

3. A Case for Multifunctional Agriculture in Peri-Urban Areas

The adaptive capacity of farmers to changes in markets, consumer preferences, and climate change can be explored through new modes of agricultural activity. One of the most topical theoretical concepts is Multifunctional Agriculture (MFA). It is a concept that investigates the contribution of agriculture to local economies that go beyond the traditional function of food and fibre provision; it considers goods and services such as conservation of environmental resources, amenity, recreation, protection of biodiversity and rural landscapes, and social care and cohesion [26, 27]. The concept of MFA has been coined to address these multiple façade of agriculture that go beyond "*productivism*" [28]. The necessity to address agriculture in the wider context of sustainable development is due to agriculture having negative impacts on the environment which could be addressed by a more integrated and holistic approach to agricultural activity. Therefore, the main functions of agriculture under MFA are food security; environmental functions viewed through positive and negative externalities, economic functions which include primary production together with products and services with wider economic effects, and socio-cultural functions that address viability of rural communities, cultural values and farmer's livelihoods [29].

3.1 Possibility of MFA Expression in Metropolitan Peri-Urban Areas

The transitional character of MFA in Australia has been conceptualized by Holmes (2008) [30] and described as *multifunctional rural transition* (MRT). He argues that MRT represents the radical re-orientation of production, consumption and protection values. The driving forces include *agricultural overcapacity, new market-driven amenity values,* and *changing societal values towards sustainability and preservation*. *Agricultural overcapacity* is linked to the production goal, 80 per cent of farm profit is attributed to 10 per cent of Australian farmers. In part, this is due to farm amalgamation where large farms are the dominant type, and due to increase in small-scale hobby-farming type as a response to urbanization [31]. *New market-driven amenity values* is linked to the consumption goal — rural land is increasingly valued for its aesthetic, pristine or near-pristine qualities. Therefore, certain rural areas are recognized for their heritage, connectivity and uniqueness. *Changing societal values towards sustainability and preservation* is linked to the protection goal — concerns about sustainability, habitat preservation, indigenous rights lead to modes of integrating environmental services within agricultural production. Metropolitan peri-urban areas, characterized by intense competition between production, consumption, and protection values, have the possibility to transition towards MFA due to immediate metropolitan demand, access to resource and waste disposal, market differentiation, and demand for rural residential, country estates, and recreational activities. Service corridors and other infrastructure for transport, utilities and education can further facilitate alternative trajectories [32].

Metropolitan peri-urban areas are defined by unique characteristics that can be reflected in agricultural production, marketing, and consumption. Arguments to protect high quality agricultural land already exist. Food production within peri-urban areas optimises the use of natural resources, gives access to valuable waste streams such as recycled water and organic wastes, and contributes $2.45 billion/annum to the city's regional economy creating 21,000 Full-Time Equivalent Jobs.

Local economies benefit from maintaining local agricultural profile through job creation, multiplier effect, farmland preservation, farm viability, increased resilience, and diversity of supply chains acting as a buffer for future shocks by climate change and market distortions [33]. MFA could give directions on how to create a more prosperous and innovative local agricultural community.

4. Case Study Area and Methodology

The case study area is City of Whittlesea, located 20 km from Melbourne CBD with a current population of approximately 220000 residents [34]. ~~Overall~~Future population growth in the municipality is estimated to be 78 percent by 2041, with two suburbs projected to become major future growth areas, Donnybrook and Wollert. These areas are surrounded by farming ~~zones~~ and the conflicts between urban and rural uses of land have been largely left unaddressed. Farming occurs on small blocks and in the proximity to the Urban Growth Boundary. Land banking together with idle land and 'lifestyle' farming reduces overall agricultural productivity potential. The agri-businesses in the municipality are predominantly engaged in extensive meet production (beef and lamb), and limited horticultural production (mainly mushrooms, some vegetables, pome fruit, and stone fruit). The total area of agricultural holding is approximately 13000 ha, agricultural activity is mainly concentrated in the north of the municipality [35]. The number of agribusinesses has continued to decrease since 2011 from 179 to 143 in 2016. Most agri-businesses have a small to medium turnover size, less than $50,000, and most of these agribusinesses are family farms that do not employ external labour (84 percent), and 15 percent employ between one and four people [36].

4.1 Methodology

Through integration of Multi-Criteria Evaluation (MCE) with Analytical Hierarchy Process (AHP) in GIS space, composite maps were created that rank land suitability on the basis of three criteria: soil, landscape, and climate. The scale is from 0 to 10 suitability, where 0 represent not suitable (0%) and 10 represents highly suitable (100%). Soil properties represent important factors in providing physical, chemical, and biological support for plant growth. The criteria considered across all commodities were pH, electrical conductivity, texture, drainage, and soil depth. The information has been sourced from Soils and Landform Mapping undertaken by the Victoria State Government [37] and Australian Soil Resource Information System (ASRIS). Landscape data used a Victorian wide Digital Elevation Model (DEM) sourced from NASA's Shuttle Radar Topography Mission hosted in conjunction with the United States Geological Survey at a resolution of 30 meters that provided information on slope, aspect and altitude [38]. Baseline climate data included climate variables over a period of 30 years. The World Meteorological Organization (WMO) uses the period of 1961 to 1990, which is also used by Australian meteorological references. Future climate projections were derived from the ACCESS 1.0 Global Climate Model [39, 40]. The higher emission scenario (RCP8.5) was chosen as representative. Ten commodities were chosen for the analysis: Phalaris, Perennial Ryegrass, Lucerne, Brassicas, Citrus, Plums, Cherry, Raspberry, Proteas, and Blue Gum. Versatility maps (for irrigation and non-irrigation models) have been created through weighted overlay of final commodity land suitability, where pastures received a weight of 0.3 (Phalaris 0.33; Perennial Ryegrass 0.33, Lucerne 0.34), Brassica of 0.2, Fruits of 0.35 (Citrus 0.25, Cherry 0.25, Plum 0.25, Raspberry 0.25), Cut flowers of 0.1, and Blue Gum 0.05 (weighting condition equals one). Built areas and public land have not been included in the results since they have no value in the discussion of future agricultural productivity.

The additional value of this methodology consists in public engagement with local farmers through the validation process. This step insures that results have local relevance and reflect local knowledge. Therefore, baseline maps have been presented to farmers in City of Whittlesea through a series of one-on-one consultations and one group workshop following individual interviews. A total of ten farmers have been interviewed individually. In phase one, the farmers were presented with initial baseline maps of the models created through literature consultation. They were asked a set of questions that related to the accuracy of the results. They were asked to describe local growing conditions, namely soil conditions, to estimate yields, and to list limiting bio-physical and climatic growing factors. The comments from individual consultations were translated into the models, and in the second phase, during the group consultation, participants were asked to assess the LSA weighted hierarchical tree (the complete LSA methodology is described elsewhere [18]) and final comments were recorded. The validation process was conducted from December 2016 to April 2017. All the comments served to modify the weights of the model to reflect local characteristics.

Important caveats accompany the methodology considering the scope of the analysis and data availability. The resolution of LSA maps is 1 km^2 and it is not intended to infer current and future conditions at site level. The methodology was developed as a tool for long-term policy making, as it is based on long-term climate change projections and does not take into account short-term seasonal changes. The main aim of this analysis is to assess the potential of agriculture into the future in order to make a case for the viability of protecting agricultural land or to signal the need for changes where agricultural suitability would deteriorate over time. At the same time, due to the difficulty of accounting for all farm management practices, the analysis focuses only on bio-physical and climatic influences on commodity growth. Finally, extreme events (extreme heat days, flooding conditions) and plant growth characteristics with no spatial data although important for crop growth, such as organic carbon, soil moisture accounting, and frost occurrence were not included in the analysis.

5. Results

In City of Whittlesea, annual average temperatures are expected to increase up to 3.5°C by 2070 (2.5°C by 2050) with higher increase for the summer months than winter months (Fig. 1a). Annual average precipitation is expected to decrease by 8 percent. Monthly changes indicate that precipitation in summer months will increase slightly (5 to 9 percent), with almost 30 percent increase in February, and decrease in the rest of the season, in winter by 10 to 12 percent, with almost 30 percent in June (Fig. 1b). This shift in precipitation patterns has important implications for agriculture since the seeding and growing season will be altered. The LSA models attribute more importance to annual precipitation, therefore the slight monthly variation did not cause the models to change drastically. Temperature increase has the benefit of reducing local frost incidence, leading to a possible positive effect on plant development.

5.1 Versatility Land Suitability Analysis Results

The capacity of land to grow multiple crops, defined as the versatility of all ten commodities is moderate to high for the irrigated models and moderate for the non-irrigated models (Fig. 2). The maps presented are for future climate scenario 2050 RCP8.5 since from preliminary LSA models it was clear that 2050 represents the timeframe when water needs will increase significantly. Table 1 summarizes classes of versatility suitability under irrigated and non-irrigated models, further grouped under high suitability (100 to 80 percent), medium suitability (70 to 50 percent), low suitability (40 to 10 percent), and restricted, for the entire municipality. In City of Whittlesea 56 percent of the municipality consist of land with agricultural potential, out of which highly suitable land increases from 60 percent to 68 percent. The most important comparison remains that of irrigated and non-irrigated models. Without any irrigation only 30 percent (baseline) to 42 percent (2070 RCP8.5) is classified as highly suitable.

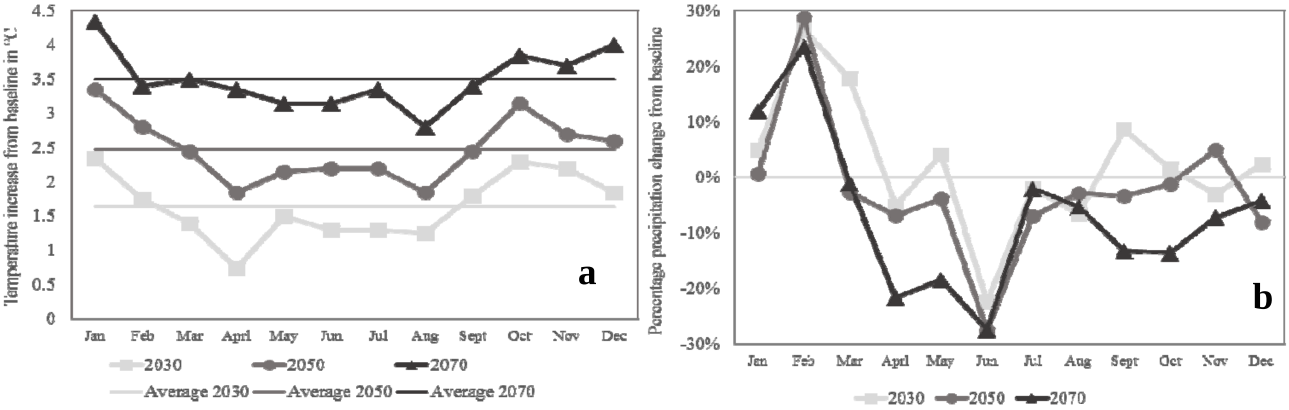

Fig. 1 Key climate variables used in Land Suitability Analysis and their variation with time; (a) Changes in mean surface temperature from baseline; (b) Percentage change of monthly average precipitation from baseline.

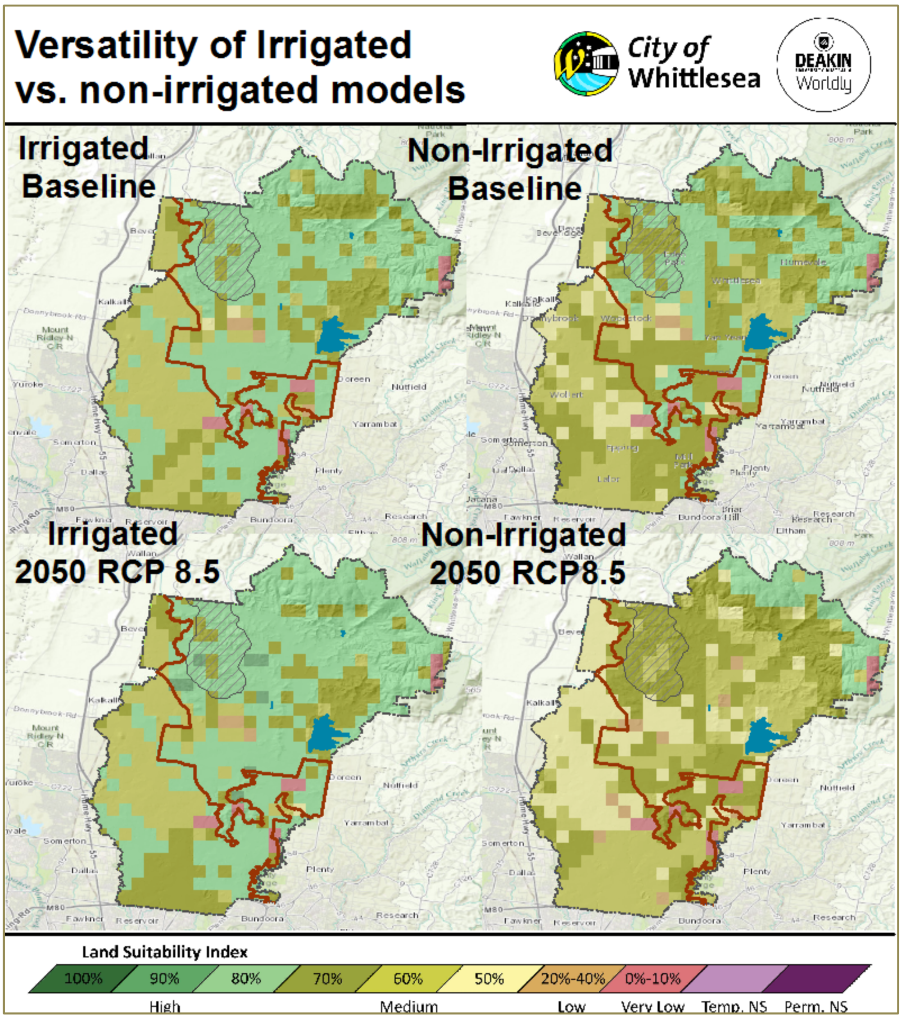

Fig. 2 Versatility land suitability comparing results for irrigated and non-irrigated models, baseline and 2050 (the commodities with irrigation include Brassicas, Citrus, Cherry, Plum and Raspberry).

Table 1 Versatility of usable land in City of Whittlesea municipality, irrigated models (top), non-irrigated models (bottom) using emissions scenario RCP 8.5.

% total Usable land	Baseline	2030	2050	2070
High Suitability	60.4	65.7	64.2	68.8
Moderate Suitability	36.6	31.5	33.0	28.4
Low Suitability	3.0	2.8	2.8	2.8

% total Usable land	Baseline	2030	2050	2070
High Suitability	30.8	40.6	40.1	41.8
Moderate Suitability	66.2	56.5	57.0	55.4
Low Suitability	2.9	2.9	2.9	2.8

The LSA indicates that given the changes in temperature and precipitation predicted by the climate change scenario RCP8.5, most commodities modelled will continue to be suitable as indicated by the land versatility results. This has two major implications. One relates to the importance of continuing soil health management practices given that projected climatic variability is not extreme. This is due, in part, to the use of average values rather than focusing on extremes. The other relates to the importance of supporting local agriculture given high versatility of agricultural land into the future. The functions of agriculture that go beyond production can offset other impacts of climate change, ranging from lower population density which reduces stress on natural resources and community services, trees planted on farm that serve multiple purposes, local food production creating local identity, local job creation and retention, and the protection of rural areas as cultural heritage. Multifunctional agriculture presents farmers with opportunities to expand into the non-commodity goods and services, thus encouraging local expressions of rural and peri-urban development.

5.2 Workshop Outputs

The validation of the LSA models through farmer's consultation has refined the understanding of local bio-physical and climatic conditions that otherwise might have been omitted. The common themes included the importance of the wind factor, soil limitation around Eden Park, importance of alluvial soils and black cracking clay soils along waterways, and impact of water availability.

Winds in City of Whittlesea average to 25 km/h (annual average 1993-2010), while wind gust can be as high at 122 km/h (annual average 2003-2017) [41]. Site specific soil conditions of Eden Park relate to the rocky relief which results in soils with poor structure and highly dispersible. Generally, farmers have indicated over-estimation of land suitability of that region. The weights within the model could not be altered without compromising relevance in other regions, therefore the agreement reached with the farmers was to indicate the land suitability limitation of Eden Park. Alluvial soils and black cracking clays have been recognised as a valuable resource, many farmers relying on their fertility along waterways (Marri Creek and Plenty River, plus tributaries) for favourable yield. The model has been adjusted to reflect this knowledge. Finally, concerns about irrigation water availability in the municipality, mainly for horticulture cultivation, led to the decision to create both irrigated and non-irrigated LSA models in other to quantify the impact of limited water access, currently and in the future.

The engagement of farmers in the validation process has been three-fold beneficial. First, local conditions could not be incorporated from literature alone. Second, farmers were able to voice their concern about the future of agriculture in the municipality in an open discussion. Lastly, the Local Government action towards addressing the issue of agricultural viability creates new collaboration opportunities. Of particular importance is the potential of recycled water use for irrigation through partnership with Yarra Valley Water and educational collaborations with Melbourne Polytechnic.

6. Conclusion

With pressures on the current "*foodbowl*" in Victoria, peri-urban metropolitan Melbourne has the opportunity to contribute to Melbourne's food security. As highlighted, the benefits of maintaining peri-urban agriculture have economic and non-economic benefits, including local business retention and employment, resource use efficiency in production and processing of agricultural commodities, ecosystem functions (water, soil quality, air, and biodiversity), quality of life, recreation and heritage, community coherence, education, health, and tourism opportunities. Versatility maps show that land suitability of all ten commodities is high, reflecting the inherent capacity for agricultural diversification. This analysis provides Local Government with the opportunity to take leadership in maintaining, supporting, and promoting local agriculture. The LSA is based on principles of stakeholders' participation in the validation process, which greatly enhances transparency, communication and discussion. The paper has also introduced the concept of multifunctional agriculture, defined as a means to increase farm viability in the broader context of sustainability, worth exploring in building a more prosperous local agricultural sector, and in building adaptive capacity to climate change.

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References

[1] I. Opitz, R. Berges, A. Piorr and T. Krikser, Contributing to food security in urban areas: differences between urban agriculture and peri-urban agriculture in the Global North, *Agriculture and Human Values* 33 (2016) (2) 341-358, doi: 10.1007/s10460-015-9610-2.

[2] V. Paül and F. H. McKenzie, Peri-urban farmland conservation and development of alternative food networks: Insights from a case-study area in metropolitan Barcelona, Catalonia, Spain, *Land Use Policy* 30 (2013) (1) 94-105, doi: https://doi.org/10.1016/j.landusepol.2012.02.009.

[3] D. A. Thompson, D. Simon and D. F. M. McGregor, *The Peri-Urban Interface: Approaches to Sustainable Natural and Human Resource Use*, London: Routledge, 2006.

[4] I. Zasada, Multifunctional peri-urban agriculture — A review of societal demands and the provision of goods and services by farming, *Land Use Policy* 28 (2011) (4) 639-648.

[5] D. L. Iaquinta and A. W. Drescher, Defining Periurban: Understanding rural-urban linkages and their connection to institutional contexts, in: *The Tenth World Congress of the International Rural Sociology Association*, Rio de Janeiro, 2000.

[6] R. M. Simón, M. A. Zazo, A. N. Morán and J. V. Hernandez, Pathways towards the integration of peri-urban agrarian ecosystems into the spatial planning system, *Ecological Processes* 3 (2014) (1) 1-13.

[7] C. Brinkley, Evaluating the benefits of peri-urban agriculture, *Journal of Planning Literature* 27 (2012) (3) 259-269, doi: 10.1177/0885412211435172.

[8] S. Kalogirou, Expert systems and GIS: An application of land suitability evaluation, Computers, *Environment and Urban Systems* 26 (2002) (2-3) 89-112.

[9] V. A. Sposito, R. Faggian, H. Romeijn and M. Downey, Expert systems modelling for assessing climate change impacts and adaptation in agricultural systems at regional level, *Journal of Applied Sciences* 3 (2013) 369-380.

[10] R. Store and J. Kangas, Integrating spatial multi-criteria evaluation and expert knowledge for GIS-based habitat suitability modelling, *Landscape and Urban Planning* 55 (2001) (2) 79-93.

[11] D. Moreno and M. Seigel, A GIS approach for corridor siting and environmental impact analysis, in: *Proceedings from the Third Annual International Conference*, San Antonio, Texas, 1988, pp. 507-514.

[12] R. L. Church, Geographical information systems and location science, *Computers and Operations Research* 26 (2002) (6) 541-562.

[13] R. Janssen and P. Rietveld, *Multicriteria Analysis and Geographical Information Systems: An Application to Agricultural Land Use in the Netherlands*, Dordrecht: Kluwer Academic Publishers, 1990.

[14] W. Miller, W. M. G. Collins, F. R. Steiner and E. Cook, *An approach for greenway suitability analysis*, *Landscape and Urban Planning* 42 (1998) (2-4) 91-105.

[15] I. Brown, W. Towers, M. Rivington and H. I. J. Black, Influence of climate change on agricultural land-use potential: adapting and updating the land capability system for Scotland, *Climate Research* 37 (2008) (1) 43-57.

[16] F. Harvey and N. Chrisman, *Boundary objects and the social construction of GIS technology*, *Environment and Planning A*, 30 (1998) (9) 1683-1694.

[17] V. A. Sposito, R. Faggian and H. Romeijn, Systemic regional development in planning practice – Climate change impacts and adaptation in Victoria, Australia, *Informationen zur Raumentwicklung* 1 (2013) 85-96.

[18] V. A. Sposito, H. Romeijn and R. Faggian, Development of regional production areas in a changing climate: A case study of Gippsland, Australia, *Appl. Spatial Analysis* (2015).

[19] J. R. Porter, L. Xie, A. J. Challinor, K. Cochrane and S. M. Howden et al., Food security and food production systems — Climate change 2014: Impacts, adaptation, and vulnerability, Part A: Global and sectoral aspects, in: *Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, The Intergovernmental Panel on Climate Change, 2014, pp. 485-533.

[20] B. Timbal, D. Abbs, J. Bhend, F. Chiew, and J. Church et al., Murray basin cluster report, climate change in Australia projections for Australia's natural resource management regions: Cluster reports, in: Ekström M., Whetton P., Gerbing C. et al. (Eds.): *CSIRO and Bureau of Meteorology*, 2015.

[21] CSIRO, Adapting agriculture to climate change — Preparing Australian agriculture, forestry and fisheries for the future, in: Stokes C. & Howden M. (Eds.), *CSIRO Publishing: Commonwealth Scientific and Industrial Research Organization*, 2010.

[22] T. G. Measham, B. L. Preston, T. F. Smith, B. Cassandra and R. Gorddard et al., *Adapting to climate change through local municipal planning: barriers and challenges*, *Mitig Adapt Strateg Glob Change* 16 (2011) 889-909, doi: 10.1007/s11027-011-9301-2.

[23] I. Gray and G. Lawrence, *A Future for Regional Australia: Escaping Global Misfortune*, Cambridge: Cambridge University Press, 2001.

[24] M. Alston, Who is down on the farm? Social aspects of Australian agriculture in the 21st century, *Agriculture and Human Values* 21 (2004) 37-46.

[25] C. Cocklin, J. Dibden and N. Mautner, *From market to multifunctionality? Land stewardship in Australia*, *Geographical Journal* 172 (2006) (3) 197-205.

[26] G. A. Wilson, *From productivism to post-productivism and back again? Exploring the (un)changed natural and mental landscapes of European agriculture*, *Transactions of the Institute of British Geographers* 26 (2001) (1) 77-102. doi: 10.1111/1475-5661.00007.

[27] G. A. Wilson, From weak to strong multifunctionality: Conceptualizing farm-level multifunctional transitional pathways, *Journal of Rural Studies* 24 (2008) 367-383.

[28] H. Renting, W. A. H. Rossing, J. C. J. Groot, J. D. van der Ploeg and C. Laurent et al., Exploring multifunctional agriculture: A review of conceptual approaches and prospects for an integrative transitional framework, *Journal of Environmental Management* 90 (2009) S112-S123.

[29] G. Calvo, M. Fonte, M. Ishii-Eiteman, J. Jiggins, L. Roger and C. Plencovich, *Towards Multifunctional Agriculture for Social, Environmental and Economic Sustainability*: UNESCO-SCOPE-UNEP, 2009.

[30] J. Holmes, Impulses towards a multifunctional transition in rural australia: interpreting regional dynamics in landscapes, lifestyles and livelihoods, *Landscape Research* 33(2008) (2) 211-223.

[31] N. Barr, *Victoria's Small Farms*, Epsom: Department of Natural Resources and Environment, 2002.

[32] J. Holmes, Impulses towards a multifunctional transition in rural Australia: Gaps in the research agenda, *Journal of Rural Studies* 22 (2006) (2) 142-160, doi: https://doi.org/10.1016/j.jrurstud.2005.08.006.

[33] R. Carey, K. Larsen, J. Sheridan, and S. Candy, Melbourne's food future: Planning a resilient city foodbowl, The University of Melbourne, 2016, available online at: http://www.ecoinnovationlab.com/.

[34] ABS, Australian Demographic Statistics, CAT. No. 3101.0, accessed on 10/11/2017.

[35] ABS, Agricultural Commodities Australia 2015-2016, Cat. No. 7121.0, 2016a, accessed on 16/09/2017, available online at: http://www.abs.gov.au/AUSSTATA/abs@.nsf/DetailsPage/7121.02015-16?OpenDocument.

[36] ABS, Counts of Australian Businesses 2011 to 2016, Cat. No. 8165.0, 2016b, accessed on 3/09/2017, available online at: http://www.abs.gov.au/ausstats/abs@.nsf/mf/8165.0.

[37] VRO, Geomorphology of Victoria, 2015, accessed on 06/10/2016, available online at: http://www.data.vic.gov.au/data/dataset/geomorphology-of-victoria.

[38] NASA and USGS, *Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global*, USA: NASA, USGS, 2014.

[39] CSIRO and BoM, *Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report*, Australia, 2015, pp. 53-76.

[40] R. Knutti and J. Sedlácek, *Robustness and uncertainties in the new CMIP5 climate model projections*, *Nature*

Climate Change 3 (2012) 369-373, doi: 10.1038/nclimate1716.

[41] BoM, Climate statistics for Australian locations, 2017, accessed on 4/12/2017, available online at: http://www.bom.gov.au/climate/data/.