# FOOD INDUSTRY SITE SELECTION USING GEOSPATIAL TECHNOLOGY APPROACH

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A thesis submitted in fulfilment of the
requirement for the award of the degree of
Doctor of Philosophy (Remote Sensing)

Faculty of Geoinformation and Real Estate
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JANUARY 2016

“To my beloved parents and husband”

## ACKNOWLEDGEMENT

Verily praises are indeed due to Allah (SWT), the author of all good things. I will never be able to thank Allah (SWT) for helping me in all my life and especially in this research.

Firstly, I would like to express my special appreciation and thanks to my supervisor Prof. Sr. Dr. Mazlan Hashim, who have been a tremendous mentor for me. I would like to thank you for encouraging my research and for allowing me to grow as a research scientist. At the same time, I also appreciate Universiti Teknologi Malaysia for providing the International Doctorate Fellowship (IDF) award.

Finally, I would like to thank my family. I am really grateful to my beloved father, mother and husband who always supported me kindly with best encouragement. I beseech Allah to reward you all most abundantly.

# ABSTRACT

Food security has been an ongoing concern of governments and international organizations. One of the main issues in food security in Developing and Sanctioned Countries (DSCs) is establishment of food industries and related distributions in appropriate places. In this respect, geospatial technology offers the most up-to-date Land Cover (LC) information to improve site selection for assisting food security in the study area. Currently food security issues are not comprehensively addressed, especially in DSCs. In this research, ASTER L1B and LANDSAT satellite data were used to derive various LC biophysical parameters including build-up area, water body, forest, citrus, and rice fields in Qaemshahr city, Iran using different satellite-derived indices. A Product Level Fusion (PLF) approach was implemented to merge the outputs of the indices to prepare an improved LC map. The suitability of the proposed approach for LC mapping was evaluated in comparison with Support Vector Machine (SVM) and Artificial Neural Network (ANN) classification techniques. For implementing site selection, the outcomes of satellite-derived indices, as well as the city, village, road, railway, river, aqueduct, fault, casting, abattoir, cemetery, waste accumulation, wastewater treatment, educational centre, medical centre, military centre, asphalt factory, cement factory, and slope layers were obtained using Global Positioning System (GPS), on-screen digitizing, and image processing were used as input data. The Fuzzy Overlay and Weighted Linear Combination (WLC) methods were adopted to perform site selection process. The outcomes were then classified and analyzed based on the accessibility to main roads, cities and raw food materials. Finally, the existing industrial zones in the study area were evaluated for establishing food industries based on site selection results of this study. The results indicated higher performance of PLF method to provide up-to-date LC information with an overall accuracy and Kappa coefficient values of 95.95% and 0.95, respectively. The site selection result obtained using WLC method with the accuracy of 90% was superior, thus it was selected for further analyses. Based on the achieved results, the study has proven the applicability of current satellite data and geospatial technology for food industry site selection to resolve food security issues. In conclusion, site selection using geospatial technology provides a great potential for a reliable decision-making in food industry planning, as a significant issue in agro-based food security, especially in sanctioned countries.

# ABSTRAK

Keselamatan makanan sentiasa menjadi kebimbangan kerajaan dan organisasi antarabangsa. Satu daripada isu utama di negara-negara membangun dan yang menerima sekatan Developing and Sanctioned Countries (DSCs) ialah penentuan industri makanan dan taburan tempat-tempat sesuai yang berkaitan. Sehubungan ini, teknologi geospatial menawarkan informasi litupan tanah (LC) paling terkini bagi memperbaiki pemilihan tapak untuk membantu keselamatan makanan dalam kawasan kajian. Ketika ini pemilihan tapak belum lagi dikaji dengan komprehensif, terutamanya di DSCs. Di dalam kajian ini, data satelit ASTER L1B dan LANDSAT digunakan bagi memperolehi pelbagai parameter biofizikal LC termasuk kawasan membangun, bahagian air, hutan, sitrus dan sawah padi di bandar Qaemshahr, Iran menggunakan indeks-indeks terbitan satelit yang berbeza. Kaedah pelakuran tahap produk (PLF) telah dilaksanakan untuk menggabung output indeks-indeks bagi menyediakan peta LC yang lebih baik. Kesesuaian kaedah dicadangkan bagi pemetaan LC telah dinilai berbanding dengan teknik klasifikasi mesin vektor sokongan (SVM) dan rangkaian neural tiruan (ANN). Untuk melaksanakan pemilihan tapak, hasil daripada indeks-indeks terbitan satelit dan data bandar, kampung, jalan raya, landasan keretapi, sungai, saluran air, gelinciran, penuangan, pembantian, kubur, pengumpulan sisa, rawatan kumbahan air, pusat pendidikan, pusat perubatan, pusat ketenteraan, kilang asfalt, dan lapisan cerun diperolehi menggunakan sistem penentududukan sejagat (GPS), pendigitan pada-skrin dan pemprosesan imej digunakan sebagai data input. Kaedah tindihan kabur dan kombinasi linear diberatkan (WLC) telah digunakan untuk proses pemilihan tapak. Hasil ini kemudian telah dikelaskan dan dianalisa berdasarkan akses kepada jalan utama, bandar-bandar dan bahan-bahan makanan mentah. Akhir sekali, zon-zon industri sedia ada dalam kawasan kajian dinilai bagi menentukan industri makanan berdasarkan keputusan pemilihan tapak dalam kajian ini. Hasil menunjukkan prestasi yang lebih tinggi bagi kaedah PLF untuk memberikan informasi LC terkini dengan nilai-nilai ketepatan keseluruhan dan pekali kappa masing-masiang adalah 95.95% dan 0.95. Keputusan pemilihan tapak yang diperolehi melalui kaedah WLC dengan ketepatan 90% adalah lebih baik, maka ianya telah dipilih untuk analisa lanjutan. Berdasarkan keputusan yang diperolehi, kajian ini membuktikan kebolehgunaan data satelit semasa dan teknologi geospatial bagi pemilihan tapak industri makanan untuk menyelesaikan isu keselamatan makanan. Kesimpulannya, pemilihan tapak menggunakan teknologi geospatial menyediakan potensi besar bagi membuat keputusan yang boleh diterima dalam perancangan industri makanan dan sebagai satu isu signifikan dalam keselamatan makanan berasaskan pertanian khususnya di negara-negara yang dikenakan sekatan.

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| | | |
|---|---|---|
| AHP | - | Analytical Hierarchy Process |
| ALOS | - | Advanced Land Observing Satellite |
| ANNs | - | Artificial Neural Networks |
| ASTER | - | Advanced Spaceborne Thermal Emission and Reflection Radiometer |
| DEA | - | Data Envelopment Analysis |
| DEM | - | Digital Elevation Model |
| DN | - | Digital Number |
| DT | - | Decision Tree |
| E-FCM | - | Evolutionary Fuzzy Cognitive Map |
| ETM+ | - | Enhanced Thematic Mapper+ |
| EVI | - | Enhanced Vegetation Index |
| FAO | - | Food and Agriculture Organization of the United Nations |
| FLAASH | - | Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes |
| GDSS | - | Geographic Decision Support System |
| GCP | - | Ground Control Points |
| GIS | - | Geographical Information Systems |
| ICEO | - | Iran Construction Engineering Organization |
| IDOE | - | Iran Department of Environment |
| IMOJA | - | Iran Ministry of Jihad-e-Agriculture |
| IJDI | - | Iran Jahad Daneshgahi Institute |
| IFDO | - | Iran Food and Drug Organization |
| IFOV | - | Instantaneous Field of View |
| IIPO | - | Iran Industrial Parks Organization |
| IRRI | - | International Rice Research Institute |
| IMO | - | Iran Meteorological Organization |
| IMIMT | - | Iran Ministry of Industry Mine and Trade |
| INGO | - | Iran National Geography Organization |
| IRS | - | Indian Remote Sensing Satellite |
| ISC | - | Iran Statistic Centre |
| ISODATA | - | Iterative Self-Organizing Data Analysis |

| | | |
|---|---|---|
| K-NN | - | K-Nearest Neighbour |
| Landsat MSS | - | Landsat Multispectral Scanner System |
| Landsat TM | - | Landsat Thematic Mapper |
| MADM | - | Multi-Attribute Decision Making |
| MCDA | - | Multi-Criteria Decision Analysis |
| MCDM | - | Multi-Criteria Decision Making |
| MCE | - | Multi-Criteria Evaluation |
| MLC | - | Maximum Likelihood Classification |
| MODIS | - | Moderate Resolution Imaging Spectroradiometer |
| MSW | - | Municipal Solid Waste |
| NDBI | - | Normalized Build-up Index |
| NDBaI | - | Normalized Bareness Index |
| NDVI | - | Normalized Difference Vegetation Index |
| OWA | - | Ordered Weighted Averaging |
| RF | - | Random Forest |
| SAVI | - | Soil-Adjusted Vegetation Index |
| SAW | - | Simple Additive Weighting |
| SeaWiFS | - | Sea-viewing Wide Field-of-view Sensor |
| SMCE | - | spatial Multi-criteria Evaluation |
| SMCDA | - | Spatial Multi-Criteria Decision Analysis |
| SPOT | - | Système Pour l'Observation de la Terre |
| SRM | - | Structural Risk Minimization |
| TOPSIS | - | Technique for Order of Preference by Similarity to Ideal Solution |
| SVMs | - | Support Vector Machines |
| WLC | - | Weighted Linear Combination |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background of the Study

Food security has been an ongoing concern of governments and international organizations and is one of the most pressing concerns in the society for the coming decades (United Nations, 2010; Rockson *et al.*, 2013). Innovations should contribute to food security through its three components: availability, access and consumption (Teng *et al.*, 2015). Food industry is one of the key factors in assessing food security, while one of the main issues in food industry is appropriate site selection in developing or sanctioned countries (Ahmadi *et al.*, 2004; Ziari and Ashrafi, 2008; Agahi and Abdi, 2009). To develop a food industry, it is necessary to consider the potential areas in case of accessibility, delivery, and environmental factors (Pan *et al.*, 2012; Teng *et al.*, 2015). Providing up-to-date land cover information is one of the requirements in identification of the potential sites (Van Haaren and Fthenakis, 2011; Donevska *et al.*, 2012). In this respect, geospatial technology is considered as a reliable source to provide the required data (Rahman *et al.*, 2012; Salim, 2012). Accordingly, in this research, geospatial technologies namely remote sensing and GIS are used to provide up-to-date land cover information for improved site selection in a developing and sanctioned country.

However, progress has not been as flat as favorable, in attempt to obtain food security the world has seen many crises in food security and people constantly have to fight hunger (Assembly, 2000). Some of the main causes of crisis in food are increasing population and urbanization, rising petroleum prices, biofuels, rising food

prices, natural disasters, and food losses (United Nations, 1974; Ma *et al.*, 2004; Searchinger *et al.*, 2008; Thornton *et al.*, 2009; Cudjoe *et al.*, 2010). It has been estimated that lost or wasted food is a third of total food production in the world (Kelly *et al.*, 2013). Therefore, appropriately development of food industries can support reducing wasted food that it shows the importance of the present research.

The Food and Agriculture Organization of the United Nations-FAO (1996) uses the following description for food security: "Food security exists all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life". It has deteriorated since 1995 and reductions in child malnutrition are proceeding too slowly to meet the Millennium Development Goal (MDG) target of halving hunger by 2015 (Tirado *et al.*, 2010). This conjuncture is prone to create tensions in food markets that could lead to world food price rises as in April 2008 when the price of rice has more than doubled in only seven months (Bouvet and Le Toan, 2011). Recent studies advise that the world will need 70 to 100% more food by 2050 (World Bank, 2007; Davies *et al.*, 2009). Asia had about 60 % of the world's hungry during the period of 2011 to 2013. Therefore, eradication of hunger and malnutrition in Asia must be a top priority by 2025. It can be achieved if the rates of hunger and stunting drop annually at 4% and 9%, respectively (Teng *et al.*, 2015).

Food conversion and complementary industry is known as the industry that convert the raw materials from food sources such as agriculture, cultivated, livestock, poultry, and fish to comestible products with higher shelf-life time. The processing operations include sorting, physical and chemical changes, packaging, storage, transportation, and distribution (Lambert *et al.*, 2006b). Establishment in a suitable places is a key element in success and survival of industrial centers (Dezyani *et al.*, 2009). Locational analysis has grown to maturity over the last decades, evolving from its earliest roots to its current widespread use (Walsh, 2008).

Finding a suitable location for food industry is a complex process and many criteria must be considered (Lambert *et al.*, 2006a). In many of developing countries, the required data are collected via traditional methods which are tedious and time

consuming, or the old existing data are used (Mohamed and Plante, 2002). Site selection operation can involve the advantages of geospatial technology namely remote sensing and geographical information system. Remote sensing has a great potential to extract the earth surface features such as roads, rivers, and vegetation, as well as providing a detailed land cover/use map from satellite images (Hu and Wang, 2013; Wasige *et al.*, 2013; Weeks *et al.*, 2013). Geographical information system allows the analyst to efficiently utilize data from various sources to produce detailed models to identify potential places (Abramovich, 2012).

This study is implemented in Qaemshahr city in Iran. One of the most important economic sectors in Iran is agriculture conversion industries, which provides 80% of food requests, one-fourth of gross domestic products (GDP), and one-third of the occupations (Hosseinzadeh, 2012). According to the Iran Jahad Daneshgahi Institute-IJDI (2000), food industry in Iran in term of added value is about eight times more than the electrical industry and three times greater in comparison with the rubber and plastic industry. Food industry investment in Iran is about 2.4 billion U.S dollars, which involve about 16 percent of the total industries investment. Based on the report presented by Iran Ministry of Industry Mine and Trade-IMIMT (2013), about 270,000 employments are recorded in food industry in Iran. If consider the employments that do not have license from the IMIMT, total number of employments in food industry would be about 700,000.

Nevertheless, there have been many unusual policy changes and/or external shocks to the economy in Iran; this has resulted in the occurrence of a multitude of structural breaks in macroeconomic variables (Heidari *et al.*, 2012). According to the fact that Iran is an oil-exporting country, decreasing oil price in recent year led the Iranian economy to a negative balance. In addition, due to the financial system sanction, transferring money for some kinds of trades such as food and industrial raw materials is almost impossible. Therefore, more attempts to reach self-sufficient in different aspects, especially in covering the country’s food requirement is essential (Baradaran-Seyed and Majdzadeh, 2013).

In this study, GIS and remote sensing technologies were employed to identify potential areas to plan food industry in study area and provide an up-to-date geodatabase to assist food security. One of the primary materials in food industry site selection is availability of an up-to-date land cover map. Improving the accuracy of land cover maps is very significant because these thematic maps are primary sources in many applications such as site selection, management of natural resources, urban planning, etc. To provide a high accuracy land cover map, this study proposes an innovative approach, called Product Level Fusion (PLF). To perform land cover mapping using this approach, different main land cover types existing in the study area were extracted individually using various satellite-derived indexes including Normalized Difference Water Index (NDWI) for water body extraction, Normalized Difference Build-up Index (NDBI) for built-up area extraction, Normalized Difference Vegetation Index (NDVI) for broadleaf forests and citrus trees extraction, and Enhanced Vegetation Index (EVI) for the extraction of rice fields and other vegetation. All the obtained maps were then integrated to produce a complete land cover map of the study area.

The suitability of the proposed approach for land cover mapping was evaluated in comparison to: (1) Support Vector Machine (SVM) and (2) Artificial Neural Network (ANN) as two most common and high potential classification techniques. The provided land cover map, the extracted features using remote sensing, the ancillary information obtained from various organizations, and the ground observation data collected using in-situ GPS surveys; all were imported into ArcGIS environment for further processing to identify the suitable places for food industry. In doing so, Weighted Linear Combination and fuzzy logic methods were employed. Subsequently, the achieved potential areas were analyzed and classified to different suitability levels based on accessibility to main roads and cities as well as raw food materials (rice and citrus). Finally, a comparative analysis was performed based on the achieved results and the current industrial zones in the study area.

## 1.2 Problem Statement

Food industry is one of the key factors to improve the security level of population food requirements (Soccol *et al.,* 2013). In developing or sanctioned countries where the required data are hardly available, one of the main issues in food industry is appropriate site selection (Ahmadi et al., 2004; Ziari and Ashrafi, 2008; Agahi and Abdi, 2009). In food industry site selection, the main challenge is providing the complementary and up-to-date land cover information (Mohamed and Plante, 2002; Gbanie *et al.*, 2012). This study proposes integration of remote sensing technology with GIS modeling to prepare the required input data in GIS-based site selection for improved decision-making. Indeed, the scientists constantly attempt to improve the techniques to map land cover types and resolve the problems associated with the current mapping techniques (Deng *et al.*, 2011; Adam *et al.*, 2012; Paneque-Gálvez *et al.*, 2012; Gong *et al.*, 2013). In this respect, an innovative approach based on product level image fusion is proposed in this study to improve the accuracy of the generated land cover map. In Qaemshahr city, as a pole of rice and citrus in Iran, there is not available any updated geodatabase for locating the food-related industries. Therefore, another main attempt of this study is providing a high accuracy and up to date geodatabase for establishing the future food-related industries in the study area. The outcomes of the study will support the region and country to facilitate facing the food security problems engendered due to the economic sanctions against Iran.

## 1.3 Research Aim and Objectives

This study aims at investigating the applicability of geospatial technologies, namely remote sensing and GIS to identify the suitable sites for food industry to assist food security issues.

1. To improve the accuracy of land cover mapping using an innovative image fusion approach,
2. To produce land cover map of the study area using support vector machine and artificial neural network techniques,
3. To identify the potential areas for food industry based on the defined criteria,
4. To analyze and classify the potential areas to different suitability levels based on proximity to raw food materials, and main roads and cities, and
5. To carry out comparative analysis of the outcome potential areas and the existing industrial zones.

## 1.4 Research Questions

The research questions which would be answered after reaching the aim and objectives of the study are as follows:

1. What is the accuracy level of land cover maps produced using SVM and ANN methods?
2. Is the proposed image fusion approach able to improve the accuracy of land cover mapping?
3. How is the performance of the applied site selection methods?
4. Where are the most suitable sites within the selected sites for food industries?
5. How is the suitability of the existing industrial zones for establishing food industries?

## 1.5 Scope of Research

In the study, two high performance image classification techniques including support vector machine (SVM) and artificial neural network (ANN) were used to classify the ASTER satellite imagery to generate up-to-date land cover maps of Qaemshahr city in Iran. The accuracy of the produced land cover maps was then assessed based on some ground truth GPS data collected through field observation. The processing procedures were performed using ENVI 4.8 and ArcGIS 10 softwares.

Further, the study proposed an innovative image fusion approach based on integration of the products of different satellite-derived indexes to map land cover types in the study area. ASTER imagery, and shortwave infrared and blue bands of Landsat TM data were used to extract different land cover types existing in the study area, including the water bodies using Normalized Difference Water Index (NDWI), built-up areas using Normalized Difference Built-up Index (NDBI), forest and citrus trees using Normalized Difference Vegetation Index (NDVI), and paddy rice and other vegetation using Enhanced Vegetation Index (EVI). In addition, Lines of Communication (LOC) – Roads technique and onscreen digitizing were used to extract roads and railways, respectively. Accuracy assessment analysis was performed based on some ground truth GPS data collected through field observation. ENVI 4.8, ERDAS Imagine 2011, and ArcGIS 10 softwares were used for this purpose.

To identify the potential areas for establishing food industry in the study area, the Weighted Linear Combination and fuzzy overlay models were employed. Based on the criteria considered for site selection in this study and site selection algorithms available in ArcGIS software, the Weighted Linear Combination (WLC) and fuzzy overlay models were selected (Jiang and Eastman, 2000; Reisi and Soffianian, 2011). Several criteria and factors were considered in the process and the required information were collected through remote sensing data, GIS data, organizational data, and GPS survey. The processing procedures were performed using ArcGIS 10

Extensions including: Analysis Tools, Spatial Analyst Tools, Data Management Tools, Conversion Tools, and etc.

The potential areas identified in this study for establishing food industries were analyzed and classified to different suitability levels based on proximity to raw food materials, as well as main roads and cities. Rice and citrus as the main raw food-based materials in the study area were considered to analyze the potential areas to find more suitable sites based on accessibility to raw materials. The processing procedures were performed in ArcGIS 10 software environment.

Finally, the suitability of two industrial zones existing in the study area including the Rostamkola and Sangtab was evaluated for establishing food industries, based on the potential sites for food industries identified in this study. The processing procedures were performed in ArcGIS 10 software.

## 1.6 Significance of Research

Food security is a critical issue in developing countries. Approximately 3 billion people, around half of the world's population, are dependent on rice for survival (Pishgar-Komleh *et al.*, 2011). Rice is the second most consuming food in Iran. Around 44% of the country's rice is produced in Mazandaran province (Bansouleh, 2009). Based on IJID (2013) report, Qaemshahr is one of the most fertile cities in this estate which is covered by 37 thousand hectares of agricultural land: 15,600 hectares belonging to paddy rice fields and 18,800 hectares belonging to citrus groves. Therefore, Qaemshahr is one of the country's pole for rice and citrus production (Golafshani *et al.*, 2012). Nevertheless, according to the IMIMT (2013), there is not enough conversion and complementary food industries in this region, because of less attention of previous policy makers to this region. Proximity to primary and raw agricultural materials and easy accessibility through suitable transportation systems (roads and rail ways), makes Qaemshahr as a potential land for establishment of food industries. All these mentions indicate significance of the researches and studies related to food security in the study area.

Identifying the suitable sites for food industries is the first issue in principles of designing food industry in food science and technology field (Dezyani *et al.*, 2009). Since the traditional methods are time consuming, expensive, and may not yield desired results (Vasiljević *et al.*, 2012), this study attempts to utilize geospatial technologies for selection of potential sites in the study area. Construction of the industrial units in potential sites, not only improve the flow of materials and services to the customers, but also puts the company in a favorable situation (Badri *et al.*, 2012). Since there is not any database available in the study area providing the suitable sites for establishing food industries and there is not any specialized zone for food industries in the study area, this study utilizes advanced technologies to prepare an up-to-date model providing the optimum sites for future food industry plans. In addition, the study further attempt to classify the selected potential sites to different suitability levels based on the proximity to raw food materials, main roads, and cities. The provided model will be useful for the policy makers in the region as well as the manufacturers and investors.

According to previous studies, in spite of the advantages of geospatial technologies and however they are widely used in different scientific disciplines such as civil, geology and mining, architecture, agriculture, etc., they are not much considered in food science issues. Maybe this is because usually food science researches are involved with chemistry, microbiology, and other related researches. This study linked food science with the geospatial technologies through using GIS and remote sensing techniques in developing food industry based on the specified food industry criteria.

Another significance of this study is involving remote sensing technology with GIS-based site selection for a proper decision making to assist food security. The study demonstrates great advantage of remote sensing data to provide the information required in site selection process. Remote sensing satellite images and different image processing techniques are employed to precisely extract and provide some of the required information to be input in GIS-base site selection to identify the potential sites for food industries.

The study proposed a product level fusion approach based on integration of different satellite-derived indexes for improved land cover mapping as a primary input in site selection process. The findings of this study will be beneficial for few groups including local organizations such as research center of agriculture, environment organization, industrial parks organization, food and medicine organization, manufacturers and investors, as well as the researchers and scientific groups.

## 1.7 Thesis Outlines

This thesis is organiezed in five chapters:

- **Chapter 1** introduces the study, and involves: background of study, problem statement, aim and objectives of study, research questions, scope of study, and significance of study.

- **Chapter 2** is a review of existing literature and describes the fundamental part of the research which provides appropriate knowledge including the theories and applications employed in this study.

- **Chapter 3** addresses each of the objectives outlined in Chapter 1 by adopting the appropriate research methods.

- **Chapter 4** presents the results and analyses achieved consequent to the implementation of the methods adopted in this study. The results and relevant analyses are illustrated and elaborated in various forms such as tables and diagrams in this chapter.

- **Chapter 5** delivers the conclusions of the study and remarks some useful suggestions and recommendations about the future researches related to this study/ or to further this study.

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