# Food Security Mapping in Pakistan

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By

**Rubina Kiran**
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**APPROVAL SHEET**

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## Dedication

This dissertation is dedicated to my Late Parents.

# DECLARATION

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# ABSTRACT

This study has performed the Small Area Estimation analysis of food insecurity at district level in Pakistan through a combination of Pakistan Household Integrated Expenditure Survey (HIES 2015-16) and Pakistan Social and Living Standard Measurement Survey (PSLM 2014-15) datasets. Secondly, district level food insecurity incidence as well as food insecurity density mapping is done based on the estimates of SAE. Thirdly, the spatially varying predictor variables of food insecurity across districts of Pakistan are mapped, through Parametric and Semi Parametric Geographically Weighted Regression (GWR) estimates.

According to the SAE District Food Insecurity Incidence estimates, the 20 highly food insecure districts are found in Baluchistan province, with Washuk as the most food insecure district having almost 93% food insecure households. While, the least food insecure district is Abbottabad from KPK with 44.27% food insecure households. The SAE District Food Insecurity Density estimates turned the situation upside down. As, Karachi city from Sindh province, which is the second least food insecure with respect to food insecurity incidence estimates, became the most food insecure in terms of food insecure people (6.4 million). Washuk district from Baluchistan, which was the most food insecure district according to the food insecurity incidence, is the 13$^{th}$ least food insecure district with only 0.17 million food insecure people. Similarly, the top 20 districts with most food insecure people are from Punjab. Additionally, most of the districts from Baluchistan, which were under category of 20 most food insecure districts, are now under category of 20 least food insecure districts.

The Parametric and Semi Parametric GWR Analysis provided strong evidence of the spatially varying relationship of the factors affecting the food insecurity in Pakistan at district level. The Semi Parametric GWR Analysis short listed the variables taken as local via applying Geographical Variability Test. Some of the variables, which were considered as Local, now became Global variables. The Semi Parametric GWR Analysis had explanatory power higher than Parametric GWR Analysis. It was observed that the education related variables have significant negative relationship with the food insecurity, showing that districts with high education are less food insecure. Furthermore, the housing related variables such as average number of rooms per household and own residence are also significant determinants of food insecurity in different districts, with negative sign. Additionally, the health and sanitation related variables such as access to piped water and flush toilet connected with sewerage also proved to be significant in various districts with negative sign as expected.

For targeted policy interventions, the policy makers must consider the food insecurity density in addition to the food insecurity incidence. As, there are many districts with low food insecurity incidence and a lot of people being food insecure. The evidence of spatially varying determinants of food insecurity across districts, highlight the requirement of targeting the district specific factors for food insecurity reduction in Pakistan. It will help in optimal utilization of resources in the district specific fields of action, leading to the positive impact on geographically disaggregated food security situation in Pakistan. The analysis implies that food insecurity reduction efforts require to he targeted in Pakistan at district level. A comparatively inflexible national level approach for food insecurity reduction might not be much successful.

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# Abbreviation List

| | |
|---|---|
| AIC | Akaike Information Criterion |
| BIC | Bayesian Information Criterion |
| CPI | Consumer Price Index |
| FAO | Food and Agriculture Organization |
| FATA | Federally Administered Tribal Areas |
| FCNS | Food Consumption and Nutrition Survey |
| FCS | Food Consumption Score |
| FGT | Foster–Greer–Thorbecke |
| FIVM | Food Insecurity and Vulnerability Mapping |
| GIS | Geographic Information System |
| GLS | Generalized Least Square |
| GWR | Geographically Weighted Regression |
| HCI | Head Count Index |
| HIES | Household Integrated Expenditure Survey |
| HLM | Household Level Method |
| ICA | Integrated Context Analysis |
| KPK | Khyber Pakhtunkhwa |
| Lasso | Least Absolute Shrinkage and Selection Operator |
| LSMS | Living Standard Measurement Survey |
| MDG | Millennium Development Goals |
| MPI | Multi-dimensional Poverty Index |
| OLS | Ordinary Least Square |
| PCA | Principal Component Analysis |
| PGI | Poverty Gap Index |
| PSLM | Pakistan Social and Living Standard Measurement Survey |
| PSUs | Primary Sampling Units |
| PUPs | Per Unit Price |
| SAE | Small Area Estimation |
| SDPI | Sustainable Development Policy Institute |
| SPGI | Squared Poverty Gap Index |
| SSUs | Secondary Sample Unit |
| UN | United Nations |
| VIF | Varianec Inflation Factor |
| WB | World Bank |
| WFP | World Food Program |
| ZHC | Zero Hunger Challenge |

# CHAPTER 1

# INTRODUCTION

Food is the prime requisite which is rudimentary amongst human requirements and an elementary human right as well (Ingram, 2011; Maxwell, 1996). In a country, favorable food security state is indispensable for poverty alleviation, improving health status for efficient productivity and moving on sustainable development path (FAO., 2010).

## 1.1 Food Security

The concept and definition of food security has undertaken numerous changes starting from the introduction of its idea in early 1940s. In 1970s, the food security concept was developed from food-supply perspective to ensure that every person located around have sufficient food. The notion of entitlement promoted the significance of consumption and accessibility (Sen, 1982). Sen revealed in her renowned work, that the food related issues are inclined by the food production and the agricultural activities, and by the social and economic structures as well. Following her views, scarcity and institutional failures causing suboptimal food distribution, are main factors triggering food insecurity.

Sen defined starvation as the inadequate access to the food in spite of food availability for the one who can afford (Sen, 1982). The examples are the Ethiopian famine 1972–1974 which led to starvation, even with insignificant losses of food production. In 1973, Food and Agriculture Organization (FAO) survey showed that the most of the affected countries such as Niger, Mali, and Mauritania were fronting issue of suboptimal distribution regardless of having sufficient grains (Baro & Deubel, 2006). Sen accentuated the ability of the individuals to access food rather than availability issues (Webb & Braun, 1994).

Presently, the multidimensional conception of food security adopted from World Food Summit 1996 and as defined by Food and Agriculture Organization (FAO) is the situation "when all the people, at all the times have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs for an active and healthy life" (FAO., 2009, 2014; R. E. A. Khan et al., 2012).

FAO explains four key aspects of food and the nutrition security comprising availability, access, utilization, and the stability. It plugs in the dietary requirements of the consumed food items with sanitation and health facilities for a healthy and active life. Conventionally, the food and nutrition security embrace mother's knowledge regarding cooking, feeding, cleanliness as well as ensuring the safe drinking water etc. The food security necessitates adequate caloric intake while, nutrition security goes further with the adequate intake of the essential nutrients for a disease resistant body.

Conversely, the consequences of food insecurity are severe health issues containing child malnourishment, diseases and obesity along with poverty (Hammond, 2011). However, achievement of the nutritional and food security is the one from sustainable development goals.

According to the declaration in World Food Summit 1996, the food security framework encompasses availability, access, utilization, and the stability aspects. Of which, the first three elements determine food security physically, while fourth one has the time dimension. The presence of all four elements guarantees food security. For instance, easy access of food is not ensured by its availability. Also, proper utilization of food is not determined by access to the food only. Finally, lacking food stability disturbs other aspects of the food security structure. The World Food Program states, "Availability is the amount of food that is present in country or area through all forms of domestic production, imports, food stocks and food aid" (WFP, 2009).

The WFP has conceptualized food accessibility in terms of "A household's ability to access sufficient amount of food regularly through a combination of purchases, barter, borrowings, food assistance or gifts"(WFP, 2009). The World Food Summit has explained accessibility from three scopes as, "Physical, economics and social access". Firstly, physical access is defined as a condition when the food is produced in some of the areas, and it can be made available easily country wide to cover up the food deficient areas. Secondly, economic access means that the people could buy enough food. Finally, the social aspect of food insecurity is defined as; when people are not permitted to do so, because of gender or the community specific norms, irrespective of economic and the physical accessibility of the food (Riely et al., 1999).

The World Food Summit expresses utilization in terms of "safe and nutritious food which meets their dietary needs". It depicts that the access to and the availability of safe and nutritious food is mandatory for performing healthy physical activities. The additional factors contributing toward the proper food utilization include availability of the sanitation facilities and the safe drinking water along with proper understanding of preparing and storing healthy food.

The World Food Summit denotes stability as a state, which exists "at all times" in terms of food availability, access, and absorption. A chronic food insecurity situation exists when the food requirements are not achieved over an elongated period. While, the transitory food insecurity is the temporary prevalence of the food insecurity situation (Maxwell & Frankenberger, 1995).

## 1.2 Food Insecurity Mapping

The Food security maps expose the spatial variability of the relevant indicators amid entities in the geographically disaggregated strata. Food security maps can also be helpful in spatially targeting the low-income households with food insecurity incidence. As, it

might be possible otherwise that households with high incomes enjoy the benefits of welfare programs formulated for supporting the poor, while, the low income households remain underprivileged of such benefits (Henninger, 1998; Hentschel et al., 2000; *Mapping poverty* 2004).

## I.3 Food Insecurity Situation in General and Specifically in Pakistan

Food insecurity issue is amassed in developing countries. The UN Millennium Goals include meeting the food security targets via plummeting the figure of the people experiencing hunger to half, till 2015. Generally, it is projected that global production of the livestock and cereal will rise by 90% and 56% respectively, till 2050. While, the expected growth of demand by developing countries is 93% for the cereal and 85% for meat, of the total world demand growth, up to 2050 (Rosegrant et al., 2002). By 2050, the overall share of the malnourished children in the developing countries would drop from 31% to 14%. But, in the case of the Sub-Saharan Africa, situation is expected to worsen through an upsurge in number of the malnourished children. As far as, the South Asia's condition is concerned, more than $1/4^{th}$ of the children under the age of five will become malnourished, by 2050. All these facts indicate that the MDG to meet the food security state does not appear to be achievable in near future, as planned.

Additionally, the projections point out that world's population will touch the figure of 9 billion, and natural as well as human resources will become overburdened, by 2050. It seems like, extremely difficult to meet food security challenges all around the globe. Despite of the decline in the global hunger, as reported by FAO. (2014), the number of people being food insecure reached 900 million, worldwide (FAO., 2013).

As far as Pakistan is concerned, some areas are relishing a better food security state, while others are suffering from hunger and are facing serious threats of the food insecurity. Pakistan is not confronted with the issue of food availability, as it is an agricultural

country and is also able to export the food, as well. However, the main problem is hindrance in easy access to the food and its absorption, which is subjective to various factors, ranging from sanitation and health facilities to mother's education (Iram & Butt, 2004). In Pakistan, the patterns of food security incidence have not been detected as invariant (SDPI, 2009). The food security risk index 2013[1] has revealed that Pakistan falls under the high-risk category. It stood 27th amongst the 48 countries selected for the analysis. Global food insecurity index 2014[2] has ranked Pakistan 75th among 107 countries under discussion. Consequently, all these figures highlight the grim concentration of the food insecurity phenomenon in Pakistan (Aziz et al., 2016).

On the other hand, the limitations to food access are still the core restriction in attaining household food security. Almost, two-thirds of the Pakistani households lack the ability to afford nutritious diet, while, making current food expenditures (Planning Commission of Pakistan, 2016). Therefore, every four Pakistanis out of ten, are breathing in the state of multidimensional poverty (G. o. P., 2016).

The food and nutrition security are being emphasized as one of the prime challenges, Pakistan is confronting with. The government of Pakistan initiated a National Zero Hunger Program, in alignment with the United Nations Zero Hunger Challenge (ZHC), a universal program. National Zero Hunger Program has further been reinforced in Pakistan with endorsement of Vision 2025, keeping food and the nutrition security on the top priority in the development programs of government, for the period 2015-2025.

## 1.4 Problem Statement

Food insecurity problem can only be addressed with, first emphasizing and then refining the regional, national and household food security status in any country (Park et al.,

[1] https://reliefweb.int/map/world/world-food-security-risk-index-2013
[2] https://www.nature.org/content/dam/tnc/nature/en/documents/latin-america/Food.pdf

1993). The aggregate indicators often mislead because they may be unsuccessful to uncover the enormous dissimilarities among different areas or regions. Thus, for identifying the most vulnerable areas, food insecurity maps may have a considerable contribution through concentrating the areas lagging in development. Therefore, such maps may provide guidance to the policy makers to select fruitful intervention strategies out of multiple policy options. The household surveys devices limited levels of disaggregation e.g., *HIES – within province and urban/rural*. Contrarily, being larger source of data, census collects insufficient data related to welfare variables.

The main aim of this study is production of accurate and easy to calculate, disaggregated food insecurity estimates in Pakistan. As, mapping of such deductions helps to display the facts associated with the spatial distribution of the food insecurity accompanied by its area specific determining factors. In addition, to check whether the outcomes of food-insecure districts vary significantly when utilizing the food insecurity incidence and food insecurity density methodologies? If confirmed, policymakers may need to incorporate both approaches to develop effective targeted interventions.

## 1.5 Rationale

The optimal deployment of policy interventions and aid entail a thorough and more accurate information regarding the targeted areas (Farrow et al., 2005). As, the household surveys are representative of some regions, the analysis grounded on such datasets does not indicate the targeted or vulnerable areas specifically (Datt & Jolliffe, 1999).

Some of the food security estimates constructed from smaller datasets, at district level, are available (SDPI, 2009; WFP, 2017). ICA of the vulnerability to natural hazards and the food insecurity in Pakistan, conducted by WFP (WFP, 2017) provided information beneficial from policy viewpoint. Nevertheless, there exist certain limitations highlighted in the report itself, which didn't make Integrated Context Analysis (ICA) the most

valuable. Firstly, 33 districts were excluded from the analysis based on Multi-dimensional Poverty Index (MPI), due to the data constraint. Secondly, food insecurity is not directly associated with MPI, rather, some indicators of MPI are concerned with utilization and access aspects of food security. Thirdly, the population estimates are constructed from projected values and growth rates from 1991 census. Additionally, there is small sample problem, which is not confronted in case of using population census or PSLM datasets. In the light of the information presented above and in literature review, it is evident that:

1. SAE method, through combining the survey and census datasets, provides valid geographically disaggregated estimates of food poverty or the food security as compared to the estimations from survey data having smaller coverage (Hentschel et al., 2000). SAE allows for the reliable estimation of the targeted areas at the desired disaggregated levels (Kristjanson et al., 2005). But, in case of Pakistan, study based on such technique has not been performed yet.
2. The spatial correlation of factors determining food security status has remained an unexplored research domain in food security related studies in Pakistan.
3. The estimates of food insecurity density are significant for successful targeted interventions, accompanied by the food insecurity incidence estimates (Minot & Baulch, 2005). As, there may be a lot of food insecure people residing in an area with low food insecurity incidence. However, this dimension has also not been deliberated in the food security mapping studies in Pakistan.

This study aims at filling the above stated food insecurity related research gaps.

## 1.6 Research Questions

This study seeks to investigate the answers to the following research questions, guided by the rationale:

1. Do the improved results obtained from the application of SAE by combining larger and smaller datasets outperform the outcomes of existing studies?
2. What is the spatial correlation among factors influencing food security status in Pakistan, and how does this correlation impact food security in the region?
3. Do the outcomes of food-insecure districts vary significantly when utilizing the food insecurity incidence and food insecurity density methodologies? If confirmed, policymakers may need to incorporate both approaches to develop effective targeted interventions.

## 1.7 Research Contributions

The visualization of food insecurity estimates supports the efficient planning in comparison with tabulated analysis. Because the spatial analysis quantifies more clearly the patterns of the targeted areas. In addition, spatially variable determining factors of the food poverty can also be highlighted for suggesting required policy interventions for different localities, accordingly (Farrow et al., 2005).

To cover up the literature gaps identified in the section 3, this study has made following contributions based on the PSLM 2014-15 and HIES 2015-16 datasets:

a) Estimation and Mapping of *Food Insecurity Incidence at District Level in Pakistan*, applying SAE technique.
b) Estimation and Mapping of *Food Insecurity Density at District Level in Pakistan.*
c) Map Visualisation of the *District Specific Significant Variables of Food Insecurity in Pakistan* through *Geographically Weighted Regression (GWR)* estimation.
d) Emphasizing the policy significance of the food insecurity density approach for devising district-specific targeted interventions

## 1.8 Structure of the Thesis

Chapter 1 highlight the significance of the present study and provide its justification.

Chapter 2 provides the literature review relevant to the research topic. Both the international and the national studies are reviewed. The citations have been made accordingly all over the thesis, this chapter discusses only main results of the relevant empirical studies. In addition to the international case studies, reports of Food and Agriculture Organization (FAO), Sustainable Development and Policy Institute (SDPI) and World Bank (WB) have been deliberated. The Facts and figures highlighting national and the global food insecurity situation, as well as research gaps reported in

Chapter 3 is based on model and methodology employed in this study. The general procedural steps of Household Level Method of SAE have been discussed. The detailed procedural steps including the consumption modelling, simulation and bootstrap, validation and mapping are explained. In addition, the second technique of GWR is explained in detail along with the mapping technique of GWR estimation results. In addition, it encompasses the detailed information regarding the data sources; HIES 2015-16 and PSLM 2014-15. The data extraction and treatment comprising the selection of variables, variable definition, and location codes, as well as merging of the two data sets are also discussed in this chapter.

Chapter 4 provides the SAE estimation results, mapping and analysis. The chapter contains the detailed analysis with tables and maps of food insecurity incidence at national, provincial and district level. In addition, the detailed analysis of food insecurity density estimates at district level is also presented in the form of table and map visualization.

Chapter 5 and 6 includes the GWR estimation results and analysis. These chapters provides detailed discussion regarding the district specific significant variables.

Subsequently, the map visualization of the parameter estimates, and relevant t-values of the district specific significant variables have also been provided in these chapters separately for Parametric and Semi-Parametric GWR.

Finally, Chapter 7 concludes the findings of this study have. The policy suggestions are put forward in the light of the conclusions drawn. The detailed definition of the variables selected, based on the two datasets, as well as the software and packages used for the analysis are given in the appendices.

# CHAPTER 2

# LITERATURE REVIEW

Food security is a multi-dimensional notion, encompassing the availability, access, sufficient level of consumption, and above all proper utilization features surrounded by a healthy environment (Hussein, 2002). Owing to the complex nature, the measurement of food security necessitates an index of the relevant indicators (Frankenberger & Coyle, 1993). The alternate indicator variables, commonly used for assessment of food security as described in existing relevant literature include livestock, land, agricultural production, income from different sources, diverse daily food consumption, local food prices, health assessment of the children underage of five, and coping strategies.

The food security studies, and the relevant policies have gone under major change processes over time with respect to unit and scope of the analysis, and the perception of food security. Ranging from state to the household level, from availability to the sustainability, subjective perceptions have been complementing the objectively measurable indicators of the food security (Devereux & Maxwell, 2001). Consequently, through a combination of qualitative as well as quantitative indicators, results of food security studies have turn out to be more valid and precise. For instance, nowadays the food security assessments investigate local populations and then rank vulnerability status of the communities along with individual households. (Woodson, 1997).

A household's capacity of captivating and recuperating from shocks can be analyzed from livelihood perspective (Ellis & Mdoe, 2003). Greater are the share of the resources allocated for food and the health services attainment, greater is the household susceptibility to food and the nutritional insecurity.

## 2.1 Food Insecurity and the Vulnerability Mapping (FIVM)

The Food insecurity and the vulnerability mapping (FIVM) systems were developed at the 1996 World Food Summit through gathering the representatives from 185 countries to observe the global and national forces for attaining the objective of food security. The FIVM is supported by the Geographic Information System (GIS). GIS is a valuable rapid assessment tool to identify the crisis magnitude as well as locality in addition to the relief associated requirements of resources (Kaiser et al., 2003).

Moreover, the poverty and food security maps at small geographical levels are the most beneficial for the policymakers and the researchers. The household surveys or census separately do not attend this purpose. As, the income information from census data does not prove to be a close substitute for average income or the poverty rates at smaller geographical units. Therefore, it entails optimal use of census data which is not utilized optimally in most of the developing countries. In addition, the evidences based on dis-aggregated geographical levels supports in targeting the resources successfully, to the poor (Baker & Grosh, 1994). The World Bank's Living Standard Measurement Surveys (LSMS) permits the disaggregation of the poverty rates or the average incomes only at urban - rural level. Conversely, the census data faces the issue regarding inadequate information about income or expenditure. Nevertheless, census data incapacitates the small sample complications. Accordingly, it became essential for the policy makers to derive alternate indicators of welfare. However, such indicators did not prove to be a good proxy for the income or consumption like indicators of welfare (Grosh & Glinskaya, 1997).

This stimulated the apprehension to combine the required information existing in household surveys with that of comprehensive census data for originating the consumption-based estimates of poverty at smaller geographical units. Hentschel et al.

(2000) estimated the household consumption patterns, through a combination of household survey and the census data in case of Ecuador.

Hentschel et al. (2000) devised a process for the derivation of household probability to confront the poverty in census and then employing it for analyses at disaggregated geographical units of interest via merging survey and the census data. The application of this methodology leads to poverty estimation at any disaggregated geographical level. The improved methodology comprises first stage regression features of disturbances (Elbers et al., 2000).

Moreover, there exist analytical variances in poverty and income estimation results attained from census and the household survey datasets. In case of South Africa, employing South Africa October Household Survey (OHS, 1995) and allied Income and Expenditure Survey (IES) in fusion with Population Census (1996), substitute imputed estimates of income for all households included in the census were computed that are consistent with survey estimates (Alderman et al., 2002). Imputed values of consumption not available in census, serve as an income proxy that is available. As, the consumption is generally collected in household surveys more accurately as compared with income. Therefore, consumption is considered more valid as a welfare measure (Deaton, 1997).

Poverty mapping assists in equitable distribution of grants. As, the number of individuals for significant allocation cannot be evaluated directly. In general, lacking capacity on the part of the central governments in information collection and the lack of incentives on the part of the local governments for its transmission works as a hindrance (Alderman, 2001). Due to the systematic bias, the census income may underestimate the poverty in some areas, while overestimate in others.

The information in census gathered on income does not serve as a good substitute for the mean expenditures at varying geographical levels. The poverty mapping aims at

disaggregating the welfare-based information at smaller geographical levels i.e., districts or municipalities. It supports the decentralization process of government services via prioritizing the allocation of government resource.

The beneficial information in the census data is not properly utilized in most of the developing countries. It necessitates the easy access of researchers and policy makers to census data for productive efforts.

Poverty mapping guides in rational distribution of resources as well as targeting the affected directly using improved maps based on census data employing the welfare indicators related to income or consumption. If, the objective is the estimation of compensation for price change effects on access ability of the households, welfare measure based on consumption is more appropriate. The process encompasses reflection of the actual consumption at further disaggregated level through merging consumption-based predictions with the relevant indicators present in both the household survey and census datasets. Afterwards, estimated parameters are applied to the census data for calculation of census households' probability being in poverty. It generates unbiased predictions having smaller standard errors up to certain disaggregation level beyond which the standard errors rise exceptionally.

National level food security does not guarantee food security at geographically disaggregated levels i.e., districts or households. The geographic and socio-economic factors are of great significance in formulating relevant policies (Khan et al., 2012).

## 2.2 Case Studies on Poverty and Food Security Mapping

This section provides review of poverty and the food security related case studies for Bangladesh Kenya, Mexico, Malawi, Ecuador, Sri Lanka, Vietnam, and Nigeria, highlighting the developments in the poverty and the food security mapping as under:

1. Small area estimation for analysis of rural poverty and the food security

2. Measures of the physical accessibility and distance for poverty mapping
3. Environmental information for poverty assessments in wide area
4. Spatial relationships related to poverty and the food security analysis.

The studies discussed here have turned up with special effects through considering the location as well as geographical impacts (Hyman et al., 2005). However, such variables are not used widely in the existing literature related to the poverty and food security mapping except the studies mentioned below.

### 2.2.1 Bangladesh

In Bangladesh, the poor households residing in urban areas, experience reduced food accessibility as they grow in numbers. It compelled coping of food insecurity in addition to poverty alleviation. As, poverty may be rooted contrarily in varying targeted areas, the combatting policies would also differ across geographical units. It pointed toward mapping poverty at the lowest geographical units along with the distinct factors triggering the concerned problem (Kam et al., 2005).

HIES (2000) was used for Bangladesh to derive poverty estimates but limitation including small sample size and the geographical coverage hindered the estimation at further disaggregated levels. Therefore, SAE approach (Ghosh & Rao, 1994) was used which uses the estimates from household survey to the population census for avoiding the issue of statistical bias. Furthermore, SAE approach allowed for disaggregation at the lowest geographical units. The sample survey 2000-01 by the International Rice Research Institute for Bangladesh was utilized, as it encompassed more determinants of household income, as compared with the HIES. Bangladesh Census data 2001 was utilized to disaggregate at sub-district level. Consequently, a model was developed including the explanatory variables common to the census and survey datasets. The predictor variables considered were workers' educational status, agriculture and non-

agriculture workers per household, highest education of household head and members, trade income, religion, electricity, ownership of pucca house and agricultural land.

To serve the purpose of the study, poverty incidence was measured by Head Count Index (HCI), severity using the Squared Poverty Gap Index (SPGI), and intensity was indicated by the Poverty Gap Index (PGI) (Foster et al., 1984). The poverty line was estimated employing Cost of the basic needs' technique (Ravallion & Scn, 1996; Roy et al., 1992). At first, the food poverty line was made by costing the food items in the consumption bundle through market prices for the period concerned. Consequently, the total poverty line was obtained through a combination of non-food expenditures with food expenditures.

For comparison, the upper limit threshold was 2112 kilocalories, while lower limit threshold was 1800 kilocalories. The estimates revealed that about 45% of the Bangladeshi rural households were suffering from poverty, while 18% were living under extreme poverty. Gini index was also estimated to represent the income disparities in Bangladesh among the no-poor and poor households.

Moreover, geographically weighted regression (GWR) technique (Brunsdon et al., 2002) was applied, in order to discover the spatial variation in nature of relationship existing between the poverty estimates and selected predictor variables. As, such differences entail geographically varying policy interventions. The results indicated geographically significant variations in the relation of predictor variables (high lands and claycy soil, irrigation, travelling time, livestock and land and ownership) with poverty incidence. Therefore, varying targeted interventions were suggested across the selected geographical units, considering the income inequalities in better-off regions too.

### 2.2.2 Ecuador

The spatial analysis of food poverty was done at district level in Ecuador (Farrow et al., 2005) using SAE technique. The food consumption and food poverty estimate for 990 districts were obtained through combining Living Standards Measurement Survey (1998) and the Ecuadorian population census (2001) datasets. The FGT indicators for poverty: poverty headcount ratio, severity and gap (Foster et al., 1984) were obtained for the maximum and minimum bounds of food poverty.

The selected food poverty determinants were labor market structure, market access, social capital and agricultural productivity related with climate, management, tenure system and soil. In addition, the access to water, type of the agriculture workers (salaried / non-salaried) was also included.

The results pointed toward specific spatial units where the food poverty is concentrated. The GWR indicated geographically varying factors that are accountable for food poverty. The Geographical Analysis Machine (Openshaw et al., 1987) was employed in order to highlight districts below the food poverty line. The results identified significant inverse relationship between access to water, market access and food poverty. Furthermore, the districts having large number of agriculture workers found suffering from lesser food poverty.

The indication of indicators of food poverty that are spatially variable implied diverse policy interventions for reducing food poverty at district level Recommendations were put forward regarding land tenure reforms, transport and infrastructural improvements and investments leading to rural development for food poverty reduction.

### 2.2.3 Kenya

Spatial analysis technique was used for estimating poverty incidence at community level in Kenya (Kristjanson et al., 2005). Poverty incidence was considered

as dependent variable. On the other hand, the selected independent variables were livestock density, pasture potential, road density, educational access, security access, agriculture potential, soil fertility and distance to major town.

At sub district level, poverty maps were formulated for analyzing the poverty incidence as well as factors responsible for poverty in the geographical units concerned. For the deep geographical coverage, information regarding food and non-food expenditures from Kenya welfare monitoring survey (1997) and Kenya population census were merged employing SAE.

The results came up with the fact that the poverty incidence was differing (11% to 93%) across sub locations in Kajiado district. The estimates of log linear Poisson regression (McCullagh & Nelder, 1989) showed that the pasture potential and the livestock density were significant and strong predictors of poverty. Additional factors affecting the poverty level were major town distance, access to security and education, road density, soil fertility and agricultural potential. Subsequently, discussion with stakeholders emphasized that quality of and access to the education and health well predict poverty levels. Assets (natural, human, physical and financial) were correlated with poverty levels in sub locations of the Kajiado district. Additionally, other household related factors such as household size and household head's education etc. were also affecting the poverty and household welfare.

### 2.2.4 Malawi

The analysis for Malawi (Benson et al., 2005) is related to the food insecurity along with poverty incidence at spatially disaggregated levels. SAE technique was employed to compute the poverty indicator. The poverty mapping was done by combining living standard measurement survey and the national census. The model based on the common explanatory variables from both the datasets. It allowed for the

disaggregation of the geographical units to the lower levels and thus discovering the targeted areas. In this regard, the analyses of spatial regression for global model and for local models was carried out with varying assumptions. The spatial regressions assume the spatial stationarity in relation of the poverty head count and predictor variables. On the other hand, GWR assumes spatially varying relation between dependent and predictor variables.

The estimation results of the spatial regressions indicated that rainfall is related to the lower levels of poverty because of high yields. The other economic activities, average maize yield, and crop diversity also significantly determine the poverty level. Additionally, access to services proved to be insignificant. However, the dependency ratio and the maximum educational attainment determine prevalence of poverty significantly.

On the other hand, the GWR models results exposed the spatially variable relation between poverty level and its determining factors. Thus, emphasizing the need of policies based on targeted interventions at sub-district level.

The estimation results from two models are opposing to certain extent. As, variables which came up to be insignificant in spatial regression model were significant in results from GWR in case of some sub-locations. The direct relationship between the poverty and agriculture indicated ineffectiveness of agriculture in reducing food insecurity. The time taken in reaching the nearest hospital was most significant at district level, pointing toward the importance of accessing services. However, the access to the regional level or sub-district services was not much significant. There was spatially varying relation between the education and poverty across rural Malawi. In some areas, there was positive association showing no welfare from educated people. On the other hand, in other areas

negative relation was found. This entailed need for investigating additional factors to make the educational attainment useful in poverty reduction.

### 2.2.5 Mexico

Targeted programs for poverty alleviation i.e. cash transfers and the provision of health as well as educational facilities are the efficient and useful means to target the poverty (Henninger & Snel, 2002; Skoufias et al., 2001). Contribution of the agricultural research to reduce poverty in Mexico has not benefitted all poor. Therefore, their identification is required for targeting them (Bellon et al., 2005). In addition, the agricultural technology requirements to target the crop breeding vary across the region. This necessitated poverty mapping at disaggregated level. SAE technique was applied for this purpose, for combining data from the National Survey of Household Incomes and Expenditures 2000 and the General Population and Housing National Census 2000. The selected predictor variables were Dwelling type, Household size, No. of members in a household older than 15 with different educational status.

According to the results of model developed for predicting rural household expenditures except potable water, all the variables were significant. The education, lacking potable water and poor housing were related inversely to variance of the per capita expenditures. Though, proportion of household with telephone facility caused an increase in the variance.

The results identified poor in specific regions who were living in different conditions. The forecasted per capita expenditures of rural household indicated spatial variability at municipality level, with extreme poverty concentration in rural areas of southern Mexico. Nevertheless, approximately, forty thousand communities were living below the food poverty line on rural community level. Moreover, at municipality level, about thousand municipalities were below the food poverty line. The commercial farming areas were not

found experiencing rural poverty. The extremely poor rural communities were found in the areas with heavy rainfall, erodible soil, sloping lands and the poor access to the services. To target research for the poor, above mentioned factors need to be taken under consideration for useful results.

### 2.2.6 Nigeria

Almost one fourth of the West-African malnourished population lives in Nigeria. Un-targeted policy interventions have worsened the rural poverty and food insecurity levels there. For improving the situation and reducing the undernourishment, it requires to formulate and implement the effective targeted programs at geographically disaggregated levels (Legg et al., 2005). The determining factors of food security and poverty are geographically variant. Considering this fact might help to improve the performance of the targeted intervention policies.

SAE technique devised by World Bank (2002) was used to map poverty and the food insecurity. For this purpose, datasets included were the Rural Livelihoods Survey and Food Consumption and Nutrition Survey (2001) (FCNS). The selected explanatory variables were rainfall (annual), tree and grass cover (%), bare Soil (%), and fertility of soil, population density, number of households, and the market travel times.

The results highlighted three major areas with severe rural poverty based on livelihood indicators. Additionally, the iodine deficiency was mostly present in the south-west, extreme north, and center of Nigeria. Also, the areas with Vitamin A deficiency were found in north-east and south-west. The strong negative correlation between livelihood and the vitamin A deficiency indicated the nutritional levels associated with the income levels. However, iodine deficiency was weakly correlated with the livelihood showing the regional variability in dietary habits. The strong correlation among development indicators such as piped water, distances to health and educational facilities was found.

On the other hand, weak or no-correlation was found between the distance to main electricity source and public toilets with other variables.

### 2.2.7 Sri Lanka

A study was conducted to estimate the spatially disaggregated poverty and the food security at sub-district level in Sri Lanka (Amarasinghe et al., 2005). The sub-district level poverty maps are formulated using SAE and principal component analysis (PCA) techniques. The variables selected for the explanation of nutritional poverty incidence were availability of and access to the irrigation water, availability of and access to land, infrastructure facilities and the employment.

The food poverty line threshold is defined as cost of the food items to attain the required minimum levels of nutrition. In Sri Lanka, a household living below the food poverty line and spending more than half of expenditures on food is considered as both the poor and food insecure. The poverty maps constructed to locate the poor households, indicated that the poverty was varying geographically across the sub-districts. Thus, it might be helpful in formulating the targeted interventions as well as equitable disbursement of financial aid for poverty alleviation. It will result in significant reduction in food poverty and the household food insecurity.

Subsequently, spatial clustering was performed. The clusters with poor households' concentration were found in the four rural districts with the agriculture as main source of income. Low poverty clusters were found near urban areas, pointing that poor households from agriculture areas do not have sufficient economic opportunities to improve their condition.

The significant variability in poverty incidence was explained by the spatial autocorrelation across sub-districts. The Rural areas suffering from water scarcity showed

the geographical link of the irrigated areas and big agricultural land holdings, with low groups of poor households. Furthermore, the areas with larger proportion of the small land holdings have direct association with poor households' cluster in the districts. A better access to the irrigational infrastructures can contribute to significant reduction in poverty.

The estimation results described that the availability along with the access to water and land significantly determine the rural poverty spatial clusters. Further disaggregated spatial analysis provided a clearer picture of the poverty incidence. Nevertheless, the study faced the constraint of reliable data regarding the accessibility to markets, resources, and services. The study paved the way for future research on identification of the poor and reasons behind their poverty.

### 2.2.8 Vietnam

The density and incidence of poverty were mapped employing SAE in case of Vietnam (Minot & Baulch, 2005) using the Population census (1999) and household survey (1997-98) data. For estimation of the per capita consumption expenditures, a total of 39 predictor variables, common in both the household survey and population census data were selected. They represented household characteristics including household size and its composition, the education of household head and his spouse, housing size and type, household head's occupation, ethnicity, access to the basic services and ownership of consumer durables. The threshold poverty line was defined as the food expenditures for acquiring 2100Kcal per day per person along with the other expenditures.

A separate analysis is done on the rural and urban level data. The estimation results of the per capita expenditures discovered that the rural households were characterized with more children, females and elder are poorer. On the other hand, these characteristics are insignificant, except for the large proportion of children, for urban household.

Furthermore, the household head occupation and education proved to be the significant determinants of the per capita expenditures in case of both the rural and urban households. The dwelling type (temporary or permanent material), the living area along with access to the basic services (electrification, tap water, and well water) were found as significant factors determining the per capita expenditures of household. The electrification was insignificant for per capita expenditures of urban households but significant for the rural. Access to the well water was significant in case of rural households. Conversely, tap water was significant for the urban households. Moreover, the sanitation facilities and the durable goods' ownership (television and radio) came up significant for rural as well as the urban households.

Additionally, poverty incidence and poverty density are also estimated in case of Vietnam. The poverty incidence was defined as the proportion of households having per capita expenditures less than the poverty line. However, poverty density was obtained as a product of poverty incidence and total population of area under consideration. The importance of density mapping was highlighted by the fact that a large number of poor were located in the areas with low poverty incidence, in Vietnam. It was an indication of a trade-off existing between the targeting policy interventions based on poor people and the poor areas. In case of targeted interventions concerned with areas having highest poverty incidence, a lot of poor will be deprived of the benefits of such efforts.

## 2.3 Studies on Food Security in Pakistan

Food security incorporates climatic changes and the disasters along with food availability, economic access and the utilization aspects. Therefore, varying factors determining food security can be found at disaggregation units starting from national to the individual.

### 2.3.1 National Level Studies

Different studies at national level, have addressed food insecurity issue in Pakistan. Mahmood et al. (1991) have analyzed the factors responsible for malnourishment and the poverty in Pakistan. They have discovered that the high prices, larger household size, heavy dependency ratio, lower standards of education, etc. are the significant factors. Likewise, Ahmed et al. (1995) found that the food demand is over-burdened with high population growth rates, varying income distributions and the increased urbanization. Whereas, the food supply is reduced as a result of costly irrigation, lack of technology and debt burdens.

### 2.3.2 Provincial Level Studies

It is required to investigate in detail, food insecurity incidence, extent and severity at further disaggregation level (Ibok et al., 2014; Wolfe & Frongillo, 2001). At provincial level, Asghar and Muhammad (2013) investigated into socioeconomic determinants of household food security, in case of Pakistan. Sindh was found as most food insecure province in Pakistan. Likewise, Sultana and Kiani (2011) highlighted the need of easy food availability and access along with the improved educational standards. Whereas, analyzing the effects of household level socioeconomic characteristics on food security, it was found that the household size and household head education significantly affect the food security in rural areas of Punjab (Bashir et al., 2013; Bashir et al., 2012). Furthermore, empirically analyzing food security, Iram and Butt (2004) underlined the importance of considering the factors which directly or indirectly affect the household food security.

### 2.3.3 District Level Studies

Khan et al. (2012) analyzed the determinants of dimensions of food security such as availability, the access and utilization of food in case of 120 rural districts of Pakistan.

The estimations explored that nearly 67% of districts were experiencing the food insecurity issue, of these 40 were suffering from extreme situation. The reduced production of the selected food items hindered food availability. Whereas adult literacy and electricity facility were significant determinants of food access. Whereas, safe drinking water availability, number of hospitals as well as child immunization affected the food utilization significantly.

The Food security assessment by World Food Program (WFP) and the Sustainable Development Policy Institute (SDPI) in 2009 for Pakistan (SDPI, 2009) portrayed the food insecurity situation in Pakistan at district level. Food security assessment comprised the primary as well as secondary data. The report specified the severity of the situation, as the food insecurity had increased in the year 2009 compared with that in 2003. The percentage of the food insecure districts escalated from 45% to 61%. Access to the sufficient food was an issue for 48.6% of population. Inter and intra differentials of provincial food security were evident in the report. As, FATA was at the top with 67.7% food insecure people, followed by Baluchistan with 61.2% and KPK with 56.2%. Whereas, the least food insecure people (23.6%) belonged to Islamabad, the capital city. At district level, Dera Bugti leads with 82.4% food insecure population. Conversely, Islamabad was found as the most food secure district. Mostly, food insecure districts were found in Baluchistan. This figure doubled from 2003 to 2009. On the other hand, mostly the food secure districts were found in Punjab. While analyzing the physical availability of the food, it was indicated that, irrespective of 6% rise in districts producing surplus wheat, overall, the districts producing surplus food reduced by 10% during the period 2003-09. Therefore, mostly the districts fulfilled their food demand through imports or from other districts. The price differences at regional level along with the price

surge resulting from the artificial shortages, caused the issue of financial access to the food.

Major determining factors of food access were Food Consumption Score (FCS), dependency ratio, income of the household, expenditures on food, living environment, food prices and the strategies adopted in order to cope with food insecurity. The percentage of food secure districts having adequate food access came down (13.3 % to 7.6%) during 2003-09. It was an indication of the problem aggravation. Moreover, out of 55 districts, 25 districts only from Baluchistan, were experiencing extremely deteriorated condition of access to food in 2009. In Southern Punjab, this situation was further alarming with 4 of 5 districts falling in the same category. These figures necessitated the policy makers' concerns to provide adequate access to the food. The expansion in poverty led to increase the share of the household food expenditure in total expenditures during 2005-09 by 6%. Consequently, the reduced education and health expenditures aggravated the food insecurity severity further. To cope with the food inadequacy, the affected households mostly moved toward the cheap and less nutritional food or limited their meal size. Lastly, the food absorption was analyzed at household level by the food security assessment including the sanitation facility, safe drinking water availability and the female literacy rate. The analysis pointed out that, in 2009, the percentage of districts having sound condition of food absorption reduced to 7.6%. More than 50% of households were lacking toilet facility and access to the safe drinking water in 25% of Pakistani districts. In the similar manner, 23% of the districts had female literacy rate less than 10%. Overall, the report concluded that at individual level the food security situation has worsened in Pakistan during 2003-09.

The Integrated Context Analysis (ICA) of the vulnerability to the food insecurity and the natural hazards in Pakistan by WFP (WFP, 2017) mainly focused on the ranking of

districts in terms of exposure to the food security along with natural calamities. The study was done for suggesting medium and the long-term policies. For this purpose, a multi-dimensional poverty index (MPI) was estimated based on the various PSLM rounds (2004-05 to 2014-15) MPI was used as a proxy of vulnerability to the food insecurity of all provinces except FATA. The alternate prevalence rates of food security as estimated by WFP for the period 2014-17 were used due to the data constraints regarding FATA. On the other hand, national data of natural hazards at district level was utilized. While global data was utilized for rest of the variables. MPI was based on 15 variables under three broad categories: health, education and living standard.

Based on the results, ICA segmented 7 agencies of FATA and 123 districts into the five ICA categories. The category-I declared 42 districts as highly vulnerable to the food insecurity as well as natural hazards. The category-II mentioned 20 districts as moderately vulnerable to the food insecurity and highly vulnerable to the natural calamities. The category-III declared 19 districts characterized with high vulnerability to the food insecurity with lower levels of the natural disasters. The category-IV included 28 districts with lesser vulnerability to the food insecurity along with higher level of the natural hazards. The final category-V encompassed 21 districts which were less vulnerable to the natural disasters as well as food insecurity.

### 2.3.2 Household Level Studies

Schichting and Ahmadi-Esfahani (2004a) examined the relation of household income and food security. The results indicated that the demand for nutrients is not solely determined by income. On the other hand, while analyzing the rural households' food security in Sindh, Shaikh (2007) indicated that factors related to women such as time allocation and age along with food prices and income of household affect the household food security significantly.

Whereas, Hazarika and Khasnobis (2005) investigated the relationship of children food security and women's power to bargain in intra- household decisions. The OLS regression was used to estimate the effect of mother related predictor variables including education, working for wage, parental age differences, first marriage age. The results revealed that food security is linked positively with women status in household.

Mahmood et al. (2014) analyzed the factors determining food security using a sample comprising 120 rural households from Faisalabad They explored that 63.3% of rural households were facing problem of required food availability, about 50% were satisfied with the quality of available food, and almost 63% of the sample lacked the food access of any kind Bashir et al. (2012) indicated that around 42 million persons face deprivation of the proper food access and overall, 23% households are suffering from food insecurity. Further household level studies are discussed in next subsection.

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### 2.3.5 Studies on Variables Determining Different Aspects of Food Security

While determining the food security level, physical and economic access to food, as well as fair distribution of food are important to consider (Timmer, 2000). In case of Pakistan, only 1/3$^{rd}$ rural districts have access to the secure food. Consequently, 67% are experiencing food insecurity including 46% as extremely food insecure (Khan et al., 2012). A study indicated that Pakistan secured 19$^{th}$ position among 26 developing countries, while measuring the food security based on affordability, availability, and quality aspects. According to the National Nutrition Survey Pakistan (GoP, 2011) the food insecurity is an attention seeking problem for Pakistan. This survey showed that with 72 % food insecure households, Sindh stands first followed by the Baluchistan and Punjab. The problem of hunger is inflated as a result of poverty, food prices up-surge, the energy deficits, economic setbacks, political chaos and terrorism.

The food security level demands adequate availability, easy access to sufficient resources for acquiring dietary and nutritious requirements by the households, as well as apt utilization of food. It encompasses health dimensions including safe drinking water, basic knowledge of nutrients, sanitation, and treatment of disease, child care, food storage facility and food storage (Arif & Khalid, 2007). The key aspect representing food security in developing world is accessibility. At houschold level, household income along with the socio economic variables determine food accessibility. Accordingly, more than half of districts are experiencing food insecurity in Pakistan (Schichting & Ahmadi-Esfahani, 2004b).

The physical access to food is affected mainly by production of the basic food items used for fulfilling the dietary needs. The factors affecting thc food absorption include immunization of children, availability of hospitals and safe drinking water. The low adult literacy and electrification problem affect the food access negatively (Khan et al., 2012). The socio-economic factors leading to affect the food security status include infrastructure facilities, purchasing power, access to the education and health services, discrimination based on caste and gender, and the access to the public utilities, e.g., safe drinking water, sanitation, electrification and landlessness (GoP, 2011).

A lot of diversified variables have been employed in studies to analyze food security household level. Some of these are income of household, prices of food, women age and the time allocation (Shaikh, 2007). Others used the technology adaption variables such as fertilizer use and the high yielding seeds, irrigation facilities, farm size, ownership of oxen, household head type, education of the household head and other activities (Van der Veen & Gebrehiwot, 2011). Furthermore, status of women in household as represented by the education, mother's age, work for wage and parental age differences were considered as the important variables (Guha-Khasnobis & Hazarika, 2006). On the other

hand, the demographic and health allied factors, mobility and access to food, food expenditures, food aid and nutrition programs, food environment quality, substitute food sources significantly affect the household food security (Sharkey et al., 2011).

Subsequently, some factors upsetting micro level food security in Pakistan were analyzed in a study. Those factors were residence place, ratio of the dependents, the social capital, educational and employment status of household head (Sultana & Kiani, 2011).

Aziz et al. (2016) found that in Pakistan, 67% households are food insecure with Sindh as the most food insecure. The factors found responsible for such condition are; large household size, high dependency ratio, lacking basic facility of housing, reliance on a single income source and low education level of household head.

Khan et al. (2012) proposed models for the food access and absorption. The food access is taken as food per capita per day and the impact of selected independent variables was analyzed for Pakistan. The predictor variables were income, adult literacy, electrified house, male and female going school, marginal farmer ratio and the district locality. Other factors considered in different studies affecting food accessibility are the price index of food, employment rate, CPI food, landless labor, length of roads and household size (Haile et al., 2005; Najafi, 2003). On the other hand, factors affecting food absorption were immunization, access to the safe drinking water, female literacy rate, hospitals availability in district and the location of district. Additional variables included were the number of beds, doctors, nurses, present in hospitals and the health units.

In light of the indicators referred or used by the studies as discussed in this section, this study selected the variables related to the household level and geographical characteristics which were commonly available in PSLM and HIES survey data for attaining the objectives of the study.

### 2.3.6 Studies on Role of Government in Addressing Food Insecurity Issue

Some studies have focused on the role of government in handling the food insecurity issue. Khan and Shah (2011) stated several serious strategic measures and policy initiatives taken by the Government of Pakistan to address the food insecurity related issues. Such measures include enhancement of food production and imports, programs leading to improve nutritional levels, strategies combating poverty and social safety net provisions. Ahmad (2009) has stressed upon the need of liberal financial support to the small farmers for per unit production enhancement, availability of certified seeds and fertilizers at subsidized rates, prevention of wheat smuggling and post-harvest losses as well as adequate supply of irrigation water. A study (Hussain & Akram, 2008) has emphasized upon curing departmental miss-management, easy financial support to the small farmers, control input and out prices, curing land diseases, as well as focus on research and development programs for curing food insecurity.

### 2.3.7 Areas Needing Investigation

Effective implementation of policy interventions and aid requires a comprehensive and precise understanding of the specific areas in focus. However, relying solely on household surveys, which represent only certain regions, may not provide a clear indication of the exact targeted or vulnerable areas (Datt & Jolliffe, 1999).

Some food security estimates, based on smaller datasets at the district level, have been made available (SDPI, 2009; WFP, 2017). A Vulnerability and Food Insecurity Integrated Context Analysis (ICA) was conducted by WFP (2017), providing valuable information from a policy perspective under certain limitations. Such as, exclusion of many districts due to data constraints, population estimates based on very old census data and small sample problem, which is not encountered when using population census or PSLM (Pakistan Social and Living Standards Measurement) datasets.

Based on the comprehensive literature review, it is evident that the SAE method, which combines survey and census datasets, offers geographically disaggregated estimates of food poverty or food security with greater accuracy compared to estimations from survey data with limited coverage (Hentschel et al., 2000). SAE enables reliable estimation of targeted areas at specific disaggregated levels (Kristjanson et al., 2005). However, such a technique has not been applied in studies related to Pakistan's food security yet. Research related to the spatial correlation of factors influencing food security status remains largely unexplored in Pakistan. Successful targeted interventions in food insecurity require significant estimates of food insecurity density, along with food insecurity incidence estimates (Minot & Baulch, 2005). It is crucial to consider that an area with low food insecurity incidence might still have a substantial number of food-insecure individuals. Unfortunately, this dimension has not been adequately addressed in food security mapping studies in Pakistan. The objective of this study is to address the aforementioned research gaps concerning food insecurity.

# CHAPTER 3

# METHODOLOGY

## 3.1 Conceptual Framework

Food security is a complex concept that involves ensuring that all people have physical, social, and economic access to sufficient, safe, and nutritious food to meet their dietary needs and preferences for an active and healthy life. It encompasses various elements, and a theoretical framework can help illustrate its components and interactions.

### 3.1.1 Theoretical Framework of Food Security

Food security encompasses following aspects which explain the brief concept of food security:

*Availability:* Refers to the sufficient production and availability of food within a region or country. This dimension focuses on the physical presence of food in the market and the capacity of food systems to produce, import, and distribute enough food to meet the demand of the population. Factors such as agricultural productivity, transportation, storage, and trade play a crucial role here.

*Access:* Involves the ability of individuals and households to obtain adequate food through purchase, production, or exchange. Access to food refers to the ability of individuals and households to obtain food through purchase, production, or transfer. It involves not only economic factors but also social and cultural aspects that may influence people's ability to access food.

*Utilization:* Focuses on the proper use of food and nutrients to ensure adequate nutrition and health. Food utilization refers to the intake of nutrients and calories from the food consumed, as well as the health outcomes resulting from that consumption. Proper

utilization depends on factors such as food safety, nutrition knowledge, healthcare, and sanitation.

*Stability:* Addresses the consistency of food availability and access over time, avoiding sudden disruptions and price shocks. Food security is not just about having enough food in the present but also ensuring that this access to food is sustained over time. Stability relates to the ability of individuals and communities to cope with shocks and stresses such as natural disasters, economic fluctuations, or political disruptions.

*Governance and Policy:* Encompasses the political and economic factors that influence food security, including policies, regulations, and institutional frameworks.

*Sustainability:* Involves the long-term capacity to maintain food security without compromising future generations' ability to do the same.

Fig.3.1 represent this theoretical framework:

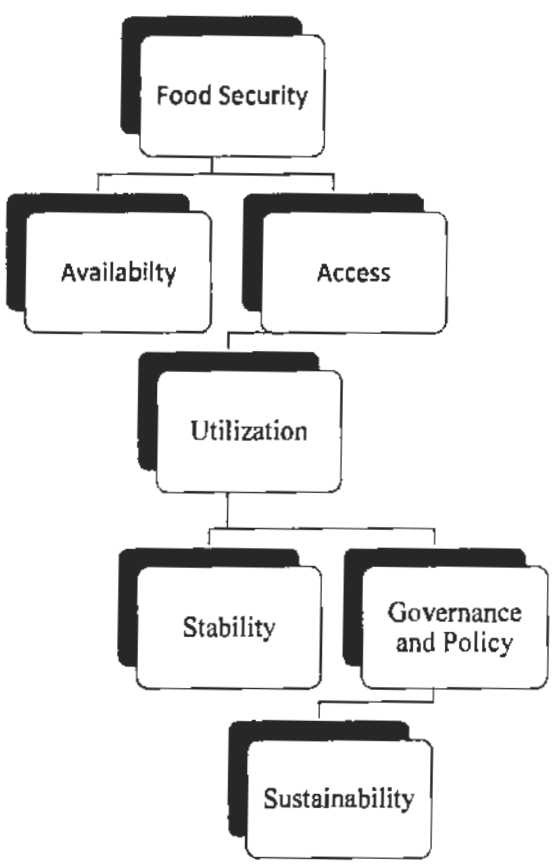


**Figure 3.1** Theoretical Framework of Food Security

### 3.1.2 Theoretical Framework for Access Aspect of Food Security

The access aspect of food security focuses on the ability of individuals and households to obtain adequate food to meet their dietary needs and preferences. It involves various dimensions that influence people's ability to access food. Below is a detailed theoretical framework for the access aspect of food security:

*Income and Purchasing Power:* One of the primary determinants of food access is the level of income and purchasing power of individuals and households. Higher income enables people to afford an adequate and diverse diet, whereas low income can lead to food insecurity.

*Employment and Livelihood Opportunities:* Access to stable and decent employment opportunities is crucial for individuals to generate income and secure access to food. Livelihood opportunities, such as farming or entrepreneurship, can also influence food access.

*Food Prices and Inflation:* The cost of food, influenced by factors like production, transportation, and trade, directly impacts people's ability to purchase food. Price stability and inflation rates play a role in ensuring consistent access.

*Social Safety Nets:* Government-led social safety net programs, such as food subsidies, cash transfers, and food assistance programs, can help vulnerable populations access food during times of economic hardship.

*Market Access and Infrastructure:* The availability and accessibility of markets, as well as transportation and storage infrastructure, determine how easily food reaches consumers, especially in remote or underserved areas.

*Geographic and Spatial Factors:* Food access can be influenced by geographic and spatial factors, including proximity to food sources, urban-rural divide, and environmental conditions affecting agriculture and food production.

*Education and Information:* Education about nutrition and agricultural practices empowers individuals to make informed choices, while information dissemination about food availability and prices aids in decision-making.

*Social and Cultural Factors:* Social norms, cultural practices, and traditions can shape food preferences, distribution patterns, and gender roles related to food access.

*Political Stability and Conflict:* Political stability is essential for the smooth functioning of food supply chains and access to food. Conflict or instability can disrupt food access, leading to food crises.

*Food Waste and Loss:* Reduction of food waste and post-harvest losses is crucial to ensuring that food reaches consumers rather than being wasted along the supply chain.

*Climate Change and Natural Disasters:* Environmental factors, including climate change and natural disasters, can affect food production and access, leading to food shortages and increased vulnerability. Fig.3.2 illustrates the detailed theoretical framework for the access aspect of food security:

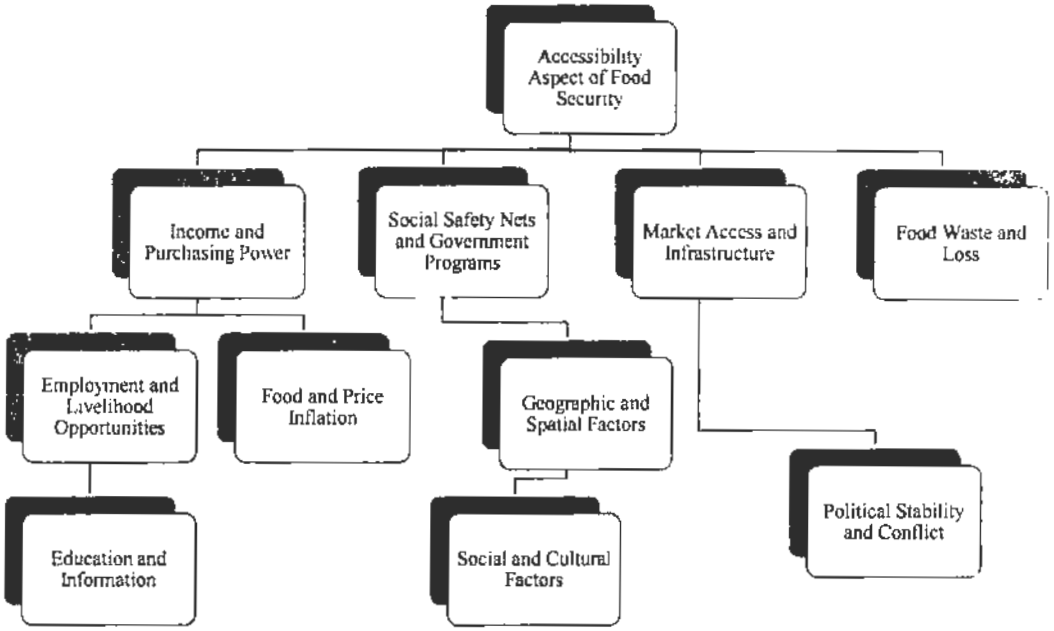


**Figure 3.2** Theoretical Framework of Access Aspect of Food Security

This theoretical framework is comprehensive and provides a detailed understanding of the various factors that contribute to the access aspect of food security. In practice, these elements are interconnected and may vary across different regions and contexts. Addressing each of these dimensions is essential to improving food access for vulnerable populations and achieving sustainable food security

### 3.1.3 Relationship of Selected Variables with Accessibility Aspect of Food Security

The broad categories of variables selected after screening process that are common to both the HIES and PSLM datasets can have various relationships with the access aspect of food security in Pakistan. How each variable might influence food access in the context of Pakistan is explained below:

*Age:* Age can influence access to food in several ways. Young children and the elderly are more vulnerable to food insecurity as they may have specific dietary needs and limited ability to earn income. In Pakistan, younger age groups and the elderly might face challenges in accessing adequate food, particularly in low-income households.

*Dependency Ratio:* The dependency ratio, which compares the number of dependents (children and elderly) to the working-age population, can affect food access. A higher dependency ratio may lead to increased pressure on working members to provide for the entire household's food needs, potentially impacting food security.

*Education:* Education plays a significant role in improving food access. Higher education levels can lead to better employment opportunities and income, which, in turn, enhances the ability to purchase food. Additionally, education can increase awareness about proper nutrition and food utilization.

*Clean Water and Piped Water:* Access to clean water is crucial for food security as it affects food preparation, hygiene, and sanitation. Inadequate access to clean water can lead to foodborne illnesses, affecting health and food utilization. Availability of piped water can

facilitate food preparation and reduce the time burden of water collection, positively impacting food access.

*Marital Status:* Marital status can influence access to food, especially for single-headed households or households with fewer income-earning members. Single parents or individuals may face additional challenges in providing adequate food for their families.

*Ownership and No. of Rooms:* Household ownership and the number of rooms can indicate the economic status of the household. Higher levels of ownership and more rooms might suggest better economic conditions, which could positively affect food access.

*Toilet Facility:* Access to proper sanitation and toilet facilities is essential for maintaining health and reducing the risk of food contamination. Improved toilet facilities contribute to better food security outcomes.

It's important to note that these variables do not act in isolation; instead, they interact with each other and with other socio-economic and environmental factors to influence food access. In Pakistan, like in any other country, the government's policies and interventions, along with social safety nets, play a significant role in mitigating the impact of these variables on food security.

To develop a comprehensive understanding of the relationships between these variables and food security in Pakistan, it is necessary to conduct detailed research and analyses using appropriate data sources and methodologies. Food security is a multidimensional issue, and addressing it effectively requires a holistic approach that takes into account the various factors affecting access to food.

Household income and expenditure surveys are commonly used to gather information about the spatial distribution of food insecurity. These surveys usually involve small sample sizes, which limits the estimation of food insecurity some regions within a country. Census data

are typically available at smaller geographic unit level, but they mainly provide information about household characteristics and rarely include inquiries about income or expenditure.

Household income, along with other socioeconomic variables, plays a crucial role in determining household accessibility. In our model, we have chosen to incorporate the household's socioeconomic variables instead of household income. The PSLM District-level survey focused on gathering data related to essential social indicators, while the provincial-level survey, HIES, not only collected information on social indicators but also included data on income and consumption. In this study the income is not considered as independent variable as only the variable common to both the datasets are considered. Also, the consumption expenditures are taken as proxy of income to represent welfare indicator. Additionally, consumption expenditures are deflated using Paasche price index to neutralize the price difference faced by different households. The Paasche index is used to deflate the households total food expenditures. For this purpose the households total food expenditures are divided by the corresponding Paasche Index. The "current period" is substituted by "household under consideration", whose purchases are utilized for weighting the prices faced by the household, relative to base prices.

## 3.2 Food Security Mapping and Small Area Estimation (SAE)

Food security or poverty mapping permits for disaggregation of the related measures to smaller geographical units. The notion of mapping comprises the measurement of the food insecurity or poverty incidence in a specific area of interest. Methods of mapping vary from the participatory profiles to econometric methodologies. Food security and poverty mapping techniques diverge in terms of analytical tools and impact, policy outline etc. for implementation in affected areas of the developing world. Mapping requires the census data for direct micro level analysis or through extrapolation. Mostly, the analysis is performed

on national level. However, the subnational areas need to be focused in research for coping the food insecurity. Widely used methods for food security or poverty mapping are: Small Area Estimation (SAE), The Combination of the Qualitative Information and the Secondary Data, the Multivariate Weighted Basic Need Index, the Direct Measurement of the Household-Survey Data, Extrapolation of the Participatory Approaches, and the Direct Measurement from Census Data (Davis, 2003). Others include method of constructing SAE from regression models and the simulation methods for interpolation from comprehensive to the general data sets (Hyman et al., 2005).

SAE is the process of estimating the welfare related indicators for the geographically disaggregated levels through a combination of census and the survey data. Basically, it is the application of the predicted model parameters to similar variables available in census data, with the assumption that the relationship is true for both the population and the sample (Ghosh & Rao, 1994). SAE has been applied in many countries for getting disaggregated poverty estimates. Minot (2000) has applied SAE method for finding out the district level averages in case of Vietnam. David Bigman et al. (2000) combined household survey and the census of Burkina Faso. (Bigman & Srinivasan, 2002) applied SAE for serving the same tenacity in case of India. For China, Bigman and Hunag (2000) utilized agriculture census for achieving this goal. Bigman and Loevinsohn (1999) applied SAE method for directing the agricultural R and D for the sake of reducing poverty in Kenya. Godilano et al. (2000) pooled the small area poverty incidence and the flood risks for investigating the aptness of rice production in case of Bangladesh, applying SAE technique. The SAE comprises two key techniques: Using census data on the household units (*Mapping poverty* 2004) and the Community level averages on the Household level units. This study applied the later technique i.e. using Census Data on the Household Units (*Mapping poverty* 2004). The rationale for picking this methodology is given next to the detailed procedure section.

The Household Level Method (HLM) was designed by Hentschel et al. (2000) and Elbers et al. (2000) and presented by Deichmann (1999) and (*Mapping poverty* 2004). The HLM necessitates two data sets as under:

1. Census Data
2. Household Survey for nearly the same period of census.

This method has been used widely in studies for different countries. In Nicaragua, the population census 1995 and the LSMS 1990 were combined through this technique. In case of Ecuador, the Population Census 1990 data was combined with Survey data for the year 1994. In China, the agriculture census for the year 1997 was utilized in place of population census. Likewise, for Brazil, due to the non-availability of census data, the large household survey data was used.

### 3.2.1. General Procedural Steps

1. The household welfare model presented in the equation (1) is estimated. Per Adult Equivalent Food Consumption Expenditures is taken as the welfare indicator. For this purpose the household survey data is used.

$$lnC = \alpha + \beta 1X + \beta 2V + \varepsilon \qquad (1)$$

C= Food consumption expenditures (per adult equivalent), as food security proxy

X= matrix of household level characteristics

V= matrix of the geographical characteristics

2. The estimated parameters from equation (1) are utilized to find out the probability of every household experiencing food insecurity in the census data.

3. The results thus obtained for the households are aggregated at the district level by averaging the probabilities for concerned geographical units. The predicted value lnC for each household in the area concerned is given by:

$$\beta 1 * X \qquad (2)$$

While, estimated value of indicator used as a benchmark for the determination of the probability of household being food insecure:

$$Fij = 1 \; if \; lnCij < lnZ; \qquad (3)$$

$$Fij = 0 \; if \; otherwise$$

The Expected Food Security Status of the household i (Fi*):

$$E(Fi \therefore Xi, \beta, \sigma) = \varphi \left[\frac{lnZ - X'i\beta}{\sigma}\right] \qquad (4)$$

Where, $\varphi$ = Cumulative standard normal distribution

The equation (4) provides the probability of a food insecure household. While the $\beta\hat{}$ and $\sigma\hat{}$ are attained from the model of the benchmark indicator

$$Fi^* = E(Fi \therefore Xi, \beta\hat{}, \sigma\hat{}) = \varphi \left[\frac{lnZ - X'i\beta\hat{}}{\sigma\hat{}}\right] \qquad (5)$$

Regional Food Insecurity (F):

$$F = \frac{1}{N}\sum_{i=1}^{N} Fi \qquad (6)$$

Here, N= no of household in a district

Expected Regional Food Insecurity:

$$E(F \therefore X, \beta, \sigma) = \frac{1}{N}\sum_{i=1}^{N} E(Fi \therefore Xi, \beta, \sigma) \qquad (7)$$

Food insecurity incidence is then estimated as an average probability of a food insecure household:

$$F^* = E(F \mid X, \hat{\beta}, \hat{\sigma}) = \frac{1}{N}\sum_{i=1}^{N} \varphi\left[\frac{lnZ - X'i\hat{\beta}}{\hat{\sigma}}\right] \quad (8)$$

F* can be computed considering different levels of food insecurity.

### 3.2.2. Detailed Procedural Steps

The methodology of food security mapping comprises of the following steps:

#### *3.2.2.1 Modelling Consumption*

After data preparation and variable selection, the next step involved in SAE methodology is to model the consumption using the selected variables. In order to specify the best model the following models are estimated:

- **Beta model**

Beta model is the estimated OLS model which has significant coefficients of multicollinearity free predictor variables and highest adjusted-$R^2$. General form of the beta model is represented in the equation (9) (Elbers et al., 2003).

$$ln(y_{ch}) = X_{ch}\beta + u_{ch} \quad (9)$$

Where,

$ln(y_{ch})$ = log per adult equivalent food expenditures of household $h$ in cluster $c$

$X_{ch}$ = vector of predictor variables for household $h$ in cluster $c$

$u_{ch}$ = is the error term decomposable into two sub-components as described in equation (10)

$$\hat{u}_{ch} = \hat{u}_{c.} + (\hat{u}_{ch} - \hat{u}_{c.}) = \hat{\eta}_c + \hat{e}_{ch} \quad (10)$$

Here,

$\hat{u}_{c.}$ = weighted average of $\hat{u}_{ch}$ for a specific cluster $c$

$\hat{\eta}_c$ = location or cluster effect

$\hat{e}_{ch}$ = household specific effect

The error term in described in equation (10) is obtained from running the OLS regression in equation (9). The error term ($\hat{u}_{ch}$) is then used to model the household-specific ($\hat{e}_{ch}$) and location-specific ($\hat{\eta}_c$) effects.

- The beta model is developed using only those *Xs* from household survey which are predictive for consumption. The following steps are considered for choosing the best predictors.
    - The VIF is defined as "the ratio of the variance of $\hat{\beta}j$ when fitting the full model divided by the variance of $\hat{\beta}j$ if fit on its own" (James et al., 2017). The minimum possible value which VIF can take is 1, indicating 'no collinearity'. As a rule of thumb, the values of VIF exceeding 5 or 10 is an indication of considerable collinearity problem. The formula for computing VIF for each candidate variable is described in equation (11).

$$VIF(\hat{\beta}_j) = \frac{1}{1 - R^2_{X_j | X_{-j}}} \qquad (11)$$

Here, $R^2_{X_j | X_{-j}}$ is obtained from regressing $X_j$ on the rest of the predictive variables. In case, if the value of $R^2_{X_j | X_{-j}}$ approaches 1, the value of VIF will be greater indicating the presence of collinearity (James et al., 2017).

- Step-wise variable selection methods utilize a threshold in order to determine the variables to be included in the model. One can choose between forward and backward selection process. In forward selection we start with adding variables to the model and testing there significance. On the other hand, in backward selection we start with all possible candidate

variables and drop them one by one through testing at each step. In this study, the following stepwise selection criteria are used:

In Forward Selection with p-value, a threshold p-value=0.05 is set and forward selection criterion is applied to select the variables. When a variable is added to the model, if its p-value is less than 0.05, the variable is retained in the model. Otherwise the variable is discarded. Subsequently, the existing variables' significance is re-checked after just adding the variable in the new model. The process is repeated until all the variables included in the model satisfy the selection criterion.

- In case of backward selection, a threshold p-value=0.05 is taken and variable are dropped on the basis of p-value. Initially, the model is estimated considering all candidate variables. The variable with the smallest t-value in absolute terms is found. Its p-value is compared with the threshold level. If the p-value is greater than the threshold level. The variable under consideration is dropped. And the process is repeated with a set of new potential variables until all the variables satisfy the criteria.

As explained by James et al. (2017), Least Absolute Shrinkage and Selection Operator (Lasso) is a shrinkage estimator. The lasso coefficients minimize the function described in equation (12).

$$(y - X\beta)'(y - X\beta) + \lambda \sum_{j=1}^{k} |\beta_j| \qquad (12)$$

Where, $(y - X\beta)'(y - X\beta)$ is the OLS quadratic function, $\lambda$ is the tuning parameter and $\sum_{j=1}^{k} |\beta_j|$ is the Lasso penalty. The basic idea behind this technique is that Lasso includes a penalty for increasing the number of

variables to the model under consideration. The process is done through shrinking the impact of the specific variables until the coefficient of such variables become zero. The value of the tuning parameter $\lambda$ determine the number of variables staying in the model.

Moreover, the value of the tuning parameter $\lambda$ is selected through k-fold cross-validation. In this process the sample is divided into "k" segments and one segment is separated. Lasso is run on the rest of the "k-1" segments. The model is used to predict the values from the "separated segment" and mean square error is estimated. Subsequently, the cross-validation error is computed for each value of tuning parameter in the chosen range of $\lambda$ values. The optimal value of $\lambda$, having minimum cross-validation error is selected for Lasso process.

- As model adjustment criterion either Adjusted $R^2$, Akaike Information Criterion (AIC) or Bayesian Information Criterion (BIC) are used in place of p-values as threshold. It reduces the chance of over-fitting the model through imposing a penalty on the newly added variables. In the BIC measure, the main objective is to minimize the *BIC* value. *BIC* can be described as in equation (13).

$$BIC = \ln(n)\, k - 2\ln(\hat{L}) \qquad (13)$$

Here, $\hat{L}$ = maximized value of the likelihood function of the model

$n$ = no of observations

$k$ = no of estimated parameters by the model

For a given value of $\hat{L}$, as the value of k decreases, it tend to reduce *BIC*. The second measure of goodness of fit of the model is the adjusted $R^2$. The main objective is to maximize the value of adjusted $R^2$. The formula for adjusted $R^2$ is defined as under:

$$\bar{R}^2 = 1 - \frac{n-1}{n-k}(1 - R^2) \qquad (14)$$

Similarly, $n$ is the no of observations and $k$ represents the no of estimated parameters. Also, for the given value of $\bar{R}^2$, the value of *BIC* reduces with the decrease in value of $k$.

- **Model adjustment from Stepwise Selected variables: Backward Stepwise**

  Firstly, the model is run including all 'k' variables and the value of either Adjusted-$R^2$ or BIC is noted. Secondly, each of the 'k' variables are dropped one by one (drop the lowest impact variable first) from the model and goodness of fit of the 'k-1' regressions is recorded. If the model fit is not affected by dropping a certain variable, that variable is excluded from the model. The process is repeated with a new group of 'k-1' variables until the remaining variables have impact on the model's goodness of fit.

- **Model adjustment from Stepwise Selected variables: Forward Stepwise**

  This process initiates with running 'k' models i.e. for each candidate variable and the value of goodness of fit (Adjusted-$R^2$ or BIC) is noted. Then, the variables having largest on the goodness of fit of model is included in set of selected variables. Subsequently, a regression is

estimated on the basis of new set of selected variables, including rest of the 'k-1' variables one by one and goodness of fit is noted. The process is repeated until no variable out of the remaining variables has impact on goodness of the fit of model.

- **Model adjustment from Lasso variables: Backward Stepwise**

  Firstly, the model is run including all 'k' variables and the value of either Adjusted-$R^2$ or BIC is noted. Secondly, each of the 'k' variables are dropped one by one (drop the lowest impact variable first) from the model and goodness of fit of the 'k-1' regressions is recorded. If the model fit is not affected by dropping a certain variable, that variable is excluded from the model. The process is repeated with a new group of 'k-1' variables until the remaining variables have impact on the model's goodness of fit.

- **Model adjustment from Lasso variables: Forward Stepwise**

  This process initiates with running 'k' models i.e. for each candidate variable and the value of goodness of fit (Adjusted-$R^2$ or BIC) is noted. Then, the variables having largest on the goodness of fit of model is included in set of selected variables. Subsequently, a regression is estimated on the basis of new set of selected variables, including rest of the 'k-1' variables one by one and goodness of fit is noted. The process is repeated until no variable out of the remaining variables has impact on goodness of the fit of model.

- **Model Comparison and Selection of 'Robust' Set**

  After getting the variables through the above stated process, the models are compared and the robust set of variable is finally selected.

- **Alpha Model**

The next step after getting the variables for Beta model, is to model the household specific effect. To serve this purpose, the Alpha model is estimated. Initially, the OLS regression based on Beta model is run and the residuals are obtained along with $\hat{y}_{ch}$. Subsequently, residuals $e_{ch}$ are modelled through the group of comparable variables (not already included in Beta Model) and the interaction of the comparable variables with interacted variables $\hat{y}_{ch}$ and $\hat{y}^2{}_{ch}$. Finally the best model is selected to predict residuals. Highly collinear variables are dropped applying VIF test. Then variables are selected through model adjustment and backward selection based on BIC.

- **GLS Model**

After the Beta and Alpha Models are prepared, GLS model is estimated. In case of OLS, regression coefficients are estimated with the assumption of the same errors distribution for all of the households. On the other hand, the GLS takes into account the different errors distributions across areas or households, which supports our assumption. Moreover the GLS estimators are more efficient as compared with the OLS estimators. In addition, GLS provides the estimates of distributions of estimated coefficients and errors as well. The GLS model is described in the equation (15).

$$C = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \tilde{\eta} + \tilde{e} \qquad (15)$$

Here $x_1$ and $x_2$ are the variables selected from Beta model.

The insignificant variables are dropped from the model until all variables included are significant with high value of adjusted- $R^2$.

### *3.2.2.2 Simulation and Bootstrap*

The next step after modelling consumption from HIES data, is to simulate the consumption on the PSLM data. For this purpose parametric and bootstrap techniques are employed.

- **Parametric Approach for Consumption Simulation**

Poverty or food security is nonlinearly related to the welfare, as a result the SAE methods based on linear characteristics are not valid (Molina & Rao, 2010). As the expenditure variances of rich households tend to be greater than those in poor households. Elbers et al. (2003) suggest the Monte Carlo simulation technique for obtaining multiple vectors of the welfare estimates using the model estimated from survey data. The Monte Carlo simulation is used for obtaining the number of simulations sufficient to obtain the reliable welfare levels from PSLM.

The typical simulation follows sampling of the estimates from model parameters' posterior distribution. The OLS assumptions and normality of the model are relied upon as:

$$\hat{\beta}_{GLS}^{HIES} \sim N\left(\beta^{HIES}, var(\beta^{HIES})\right)$$

$$\tilde{\varepsilon} \sim N(0, \hat{\sigma}^2)$$

$$\hat{\sigma}^2 \sim \frac{\hat{\sigma}(T-K)}{\chi^2_{T-K}}$$

The regression estimates for food consumption expenditures as defined in equation (16) are obtained with the normality assumption defined in preceding lines.

$$\ln \tilde{y}_{ch} = X_{ch}^{PSLM} \bar{\beta}_{GLS} + \tilde{\eta}_c + \tilde{e}_{ch} \qquad (16)$$

The randomly drawn parameters from the estimated distributions are applied to estimate food consumption expenditures for each household in PSLM and the simulation is repeated 100 times. Subsequently, the food insecurity headcount rates

are computed on the basis of simulated household food expenditures for all rounds. Then, average food insecurity rates are computed at district level.

- **Bootstrap Technique for Consumption Simulation**

As explained by Efron and Tibshirani (1993), in bootstrap technique, a set of B independent bootstrap samples $x^{*1}, x^{*2}, x^{*3}, \ldots, x^{*B}$ is selected. Each bootstrap sample consist of n sample points drawn with replacement out of the parent dataset $x = (x_1, x_2, x_3, \ldots, x_n)$. The bootstrap replications are estimated for each bootstrap sample statistic of interest.

$$\hat{\theta} = g(x): \hat{\theta}_b^* = g(x^{*b}), b = 1, \ldots..B.$$

Subsequently, the bootstrap standard error of $\theta$ i.e., se($\theta$) is estimated through sample standard deviation of B replications. The sample standard deviation is described as under:

$$\widehat{s.e.}(\hat{\theta}) = \sqrt{\frac{1}{B-1}\sum_{b=1}^{B}(\hat{\theta}_b^* - \overline{\theta^*})^2}$$

$$\overline{\theta^*} = B^{-1}\sum_{b=1}^{B}\hat{\theta}_b^*$$

$\widehat{s.e.}(\hat{\theta})$ is known as nonparametric bootstrap estimate, as it is based on the nonparametric estimate of the population $F$ i.e. $\hat{F}$.

As an alternative, the bootstrap technique can be applied for simulating consumption. In this technique the bootstrapped samples from the survey data are used to get the required parameters for simulating PSLM vectors. The bootstrapped samples of the HIES data are obtained from each simulation. A GLS model is run for each simulation sample and a set of beta coefficients and errors is obtained for each simulation. The simulation is repeated 100 times. The food insecurity headcount

rates are computed for each round based on the simulated household food expenditures. Finally, food insecurity rates are averaged at district level.

#### *3.2.2.3 Validation*

The best simulation is selected by comparing the results with estimate from HIES data. The estimates are aggregated at provincial level and district level (one at a time). The food insecurity rates at the relevant aggregation level are compared. The absolute differences and squared differences between simulated food insecurity rate and the rates computed from HIES are observed. Finally, the simulation with the minimum squared difference is selected.

#### *3.2.2.4 Mapping Food Insecurity*

Finally, after validation phase, the food insecurity rates as well as food insecurity density estimates are mapped at national, provincial and district level. For this purpose, in addition to the result files, shapefiles with coordinates of Pakistan are used. Stata packages 'shp2dta' for converting shapefile into data file and 'spmap' for creating maps are used to convert shapefiles into data files and create maps. For map creation the indicators file to be mapped is merged with the database converted from shapefiles.

### 3.2.3 Rationale for Choosing the Methodology

Regardless of the computational as well as econometric challenges comprising spatial autocorrelation and the heteroscedasticity, non-normality and the large volume of the census data (Elbers et al., 2000) this methodology still has a potential superiority over the other techniques reported as under:

1. The process is straightforward and can be easily understand.
2. The reliability of estimates could be tested using the built in programs of the World Bank.

3. The size of the standard error is dependent upon the level of disaggregation and power of the predictor variables to predict the dependent variable. Whereas, the disaggregation level depends upon the map objectives and properties based on which the household sample is being selected. There exists a swap between the standard error size and policy requirements.
4. Finally, it is the only technique which allows for comprehensive examination of the statistical properties.

## 3.3 Geographically Weighted Regression Modelling (GWR)

Normally, the regression models which are employed for the estimation of the linkage between food security and its predictor variables work with the assumption of spatial stationarity (SDPI, 2009; WFP, 2017). However, such relations might be spatially non-stationary. Thus, indicating the significance of a specific determinant of food security in some geographical units while insignificant in others. Moreover, direction of such relation may also be varying geographically (Kam et al., 2005). All these facts highlight the significance of taking the spatial non-stationarity under consideration for the sake of food security mapping at district level in Pakistan. In case of spatial non-and is found, the recommendations would be based on geographically varying policy interventions. Geographically Weighted Regression (GWR) method (Fotheringham et al., 2003) has been employed and proved to be useful in different studies such as population density and housing (Mennis, 2006), food security and poverty mapping in Bangladesh (Kam et al., 2005), poverty in US (Partridge & Rickman, 2005), poverty mapping in rural Malawi (Benson et al., 2005) as well as urban poverty (Longley & Tobón, 2004). The application of GWR technique through spatial data analysis provided more accurate as well as solution-oriented results in the fields mentioned above.

Specifically, in this study the employment of SAE technique assumes that the spatial process accounting for the food insecurity headcount levels is invariant across the districts of Pakistan. In other words, there is spatial stationarity in the analyzed relationship. However, the assumption of spatial stationarity might not be true for all the units of analysis (Fotheringham & Brunsdon, 2002). Global models ignore the spatial non-stationarity, in the relation of food insecurity incidence and its potential determinants.

Therefore, GWR offers a technique to assess the extent to which the spatial variation exists between the food insecurity and its potential determinants. Local models are estimated for each district of Pakistan. Which, highlight the spatially varying significant determinants of food insecurity for each unit of analysis.

### 3.3.1 Conventional Gaussian GWR

Generally, in GWR, the vector of regression coefficients and intercept is estimated as disaggregated geographical location function, represented by the following equation:

$$y_i = \beta_0(x_i, y_i) + \sum_k \beta_k(x_i, y_i) X_{ik} + \varepsilon_i \qquad (17)$$

Here, $i$ is the location with coordinates $(x_i, y_i)$ at which βs are estimated.

Subsequently, the GWR model is standardized for a location indicated by a regression point through applying weights to the data points following the distance decay continuous function or fixed size discrete window (Fotheringham et al., 2003). There is a choice between the adaptive or fixed decay function. The adaptive decay function, provides varying shape of the function in accordance with density of the data points which are closest in neigbour of the data point concerned. This endorses the estimation of local parameters based on adequate regression data points in data wise low density areas.

### 3.3.2 Geographical Variability Test

In this test (Tomoki, 2016), the fitted model with the assumption of all variables spatially varying, is compared with the model assuming kth variable coefficient spatially fixed. If the AIC criterion shows that the fitted model is performing better than the model with kth fixed coefficient. This implies that kth coefficient is spatially non-stationary and the kth variable is considered as a local term in Semi-Parametric Gaussian GWR Model. Otherwise, the kth coefficient variable is taken as global term in Semi-Parametric Gaussian GWR Model. The same practice is repeated for all the independent variables.

### 3.3.3 Semi-Parametric Gaussian GWR

In case of the conventional Gaussian GWR model if the geographical variability test identifies some variables with spatially invariant coefficients, then the semi-parametric Gaussian GWR model (Tomoki, 2016) can be applied. Semi-Parametric GWR model has a matrix of global terms which have spatially invariant relationship with the dependent variable and identified through geographical variability test. The model can be described as follows:

$$y_i = \beta_0(x_i, y_i) + \sum_k \beta_k(x_i, y_i) X_{ik} + \sum_l \gamma_l Z_{l,i} + \varepsilon_i \qquad (18)$$

Where, $\gamma_l$ is the fixed coefficient of the $l$th explanatory variable $Z_{l,i}$. In this sense, the semi-parametric GWR model is a mix of geographically local terms and the global terms.

### 3.3.4 Rationale for Methodology

The interpretation of GWR results is easier to some extent. As, the GWR method does not include the spatial lag variables for controlling spatial autocorrelation. However, spatial dependency is considered as a segment of local regression analysis ( Fotheringham et al., 2000).

Moreover, the outcome of GWR process is based on a huge information including coefficient estimates and corresponding t-values for respective independent variable, goodness of fit (R2) for each local regression residual values etc. this deluge information obtained from GWR analysis can be best portrayed through maps. GWR 4.0 software (Charlton et al., 2006) is employed for the estimation of local parameters employing the same independent variables used in the globel model.

### 3.3.5 Mapping GWR Estimates

Finally, the GWR estimates including geographically varying significant determinants coefficients as well as corresponding t-values are mapped. For this purpose, in addition to the result files, shapefiles with coordinates of Pakistan are used. Stata packages 'shp2dta' for converting shapefile into data file and 'spmap' for creating maps. For map creation the indicators file to be mapped is merged with the database converted from shapefiles.

## 3.4 Data

For this study two data sets closer in time, HIES 2015-16 and census 2017 were required. However, due to non-availability of the census 2017 data set, it is replaced with PSLM 2014-15. HIES provides data on consumption and multiple well-being indicators for poverty estimation. But the direct estimates from the HIES data are not representative at district level but at province level. On the other hand, PSLM covers welfare indicators that are representative at district level. But it does not provides consumption information and it is not helpful in direct estimation of poverty. The small area estimates (SAE) make the direct estimates from the HIES more precise. Also, the estimates are predicted for the areas which are not included in the sample.

This section includes the brief introduction of the data sets used in this study, data manipulation as required as well as the basic variable selection for the analysis.

### 3.4.1 Brief Introduction of the Data Sets

In this section a brief introduction of the two data sets used in analysis is given.

*Pakistan Social and Living Standards Measurement Survey (PSLM) 2014-15:* PSLM 2014-15 is the sixth round based on the indicators at district level. It provides district level social indicators estimates and the improvement as stated in MDGs. It comprises intermediary along with the output measures to assess the performance of the social sector. Also, in order to assess population welfare a large number of outcome measures are included in the PSLM 2014-15. The data obtained from PSLM Survey helps government to formulate the development plans as well as policies for poverty reduction. The district level indicators are generated for the sectors including education, health, water and sanitation, household assets, and satisfaction to service delivery.

The PSLM 2014-15 universe comprises of all provinces, rural and urban areas of Pakistan, except for military restricted areas and FATA. Pakistan Bureau of Statistics has designed its personal sampling frame at urban and rural level. Every town or city is disaggregated in enumeration block based on 200 to 250 households. These enumeration blocks are named Primary Sampling Units (PSUs). A sample of 16 households form each rural and urban PSU is considered as Secondary Sample Unit (SSUs). Overall 5428 PSUs consisting of 81992 households i.e. SSUs were selected. From Baluchistan 82 PSUs, 7 PSUs from Sindh and 13 PSUs from KPK were excluded due to law and order situation. Finally, 5326 PSUs and 78635 SSUs were covered during the survey.

*Household Integrated Economic Survey (HIES) 2015-16:* HIES 2015-16 data comprises of 24238 households. Information regarding household income, saving, consumption expenditures, consumption patterns and liabilities is gathered for rural /urban households at national and provincial level.

The HIES 2015-16 universe comprises of all provinces, rural and urban areas of Pakistan, except for military restricted areas and FATA. Pakistan Bureau of Statistics has designed its personal sampling frame at urban and rural level. Every town or city is disaggregated in enumeration block based on 200 to 250 households. These enumeration blocks are named Primary Sampling Units (PSUs). A sample of 12 households from each urban PSU and 16 households form each rural PSU is considered as Secondary Sample Unit (SSUs). Overall 1668 PSUs consisting of 26688 households i.e. SSUs were selected. However, some areas were excluded due to law and order situation. Finally, 1605 PSUs and 24238 SSUs were covered during the enumeration.

### 3.4.2 Data Preparation

In order to map food insecurity the first step is data manipulation and preparation. It is important to prepare the data in order to find out the variables that are common between the HIES and PSLM. It allows the prediction of consumption from PSLM. For a valid food insecurity mapping, identical definition of the selected variables is required from the two data sets. If the data is not prepared cautiously, it has serious implications on variable selection for the model and statistical matching issue in imputation process. The HIES and PSLM must have common variables in the sense that questions indicating those variables must be defined similarly in both the data sets. Additionally, such variables are required to have similar distributions. Moreover, these common variables must have sufficient correlation with the welfare measure i.e. consumption. Finally, a cluster variable is required to merge the HIES and PSLM data at a certain level.

#### 3.4.2.1 Location Code

Every element of the hierarchical location code indicates unique geographical level. The basic geographical variables at household level include province, region (rural/ urban), PSU and district. The location codes consistency is ensured between the HIES

and PSLM datasets. The location codes work as a unique identifier to match the numerous administrative units. It helps to obtain the results at administrative level of interest through truncation of location code. So, truncating the household code from right side by 7 digits gives district level data.

### 3.4.2.2 Variable Definition

The consumption variable is predicted on the basis of the variables common in the PSLM and HIES survey datasets. It highlights the importance of identifying and coding the variables in the similar manner, which are common in both the datasets. Due to comparatively smaller questionnaire, the identification started from PSLM. The categories of common variables are characteristics of household head, household characteristics, dwelling characteristics, assets of household and agriculture. But the study focused only those common variables that are correlated with the selected welfare measure i.e. consumption. Moreover the variables with large number of missing values as well as changing significantly over the time are not considered.

1. At first, a list of similar questions and common variables is generated.
2. Then common variables are generated in both the data sets.
3. As a result the household level data base is generated from HIES and PSLM.

### 3.4.2.3 Statistical Properties of Variables

The variables capturing the similar characteristics are considered as candidate variables for the regression model. In order to compare the statistical properties of the common variables in both the datasets, the weighted means of the variables of interest are compared. For this purpose the variables with weighted means falling under a certain defined range have been selected.

According to Zhao (2006), there are different ways to compare the statistical properties of the variables concerned based on the type of variables. In case of categorical variables,

chi-square frequency distributions can be compared. While for continuous variables Kolmogorov-Smirnov test can be used as test of distributions. On the other hand, for census variables, the mean of census variable is analyzed whether it falls under the confidence interval of the same variable from the survey data. In addition means and standard deviation of the comparable variables can also be compared.

In this study, in order to compare the candidate variables, the first step is to exclude the binary variables related to less than 10% of the households or more than 90% of the households. Secondly, variables containing a large number of missing values are eliminated. Finally, the ratios of weighted means and the standard deviations of relevant variables from HIES and PSLM are compared. The variables, for which ratios of means and standard deviations of the variables between HIES and PSLM fell within the range 0.95 and 1.05, are kept for further screening.

#### 3.4.2.4 Variables at Cluster Level

In order to include cluster level effects, variables are included at different administrative level and not at the household level. For this purpose population means of the variables at cluster level are included as candidate variables.

### 3.4.3 Construction of Household Food Consumption Aggregates

The construction of the household food consumption aggregates involve a number of procedural step (Deaton & Zaidi, 2002) explained as follows:

#### 3.4.3.1 Data Cleaning Process

The data from HIES 205-16, requires some manipulations before estimation process. In case of some households, either quantity or value is missing for some of the food items. Initially, these are replaced with zeros.

The four consumption categories are added to get the total quantity of a food item. Per Unit Price (PUPs) is taken as the ratio of value and the total quantity consumed of a food

item by the individuals in a household. PUP is not same as original prices. As, the quality choice and actual prices affect the unit prices. However, problems are faced that the unit prices cannot be calculated for the households who did not report their expenditures and the measurement error. These problems cannot be completely avoided (Deaton, 1997). Missing prices are substituted with average prices. The outliers are omitted using upper and lower bounds (meanPUP±3sdPUP). The revised PUPs are then multiplied with the quantities, for adjusted total expenditures.

### 3.4.3.2 Calculation of Household Total Food Expenditure

The data is segregated into food and non-food items. Since, the consumption expenditure data in HIES is recorded on fortnightly basis for some food items and on monthly basis for others. So, the data is converted on monthly basis for all food items. Additionally, the quantity of food items is converted into same unit (kg). The adjusted food expenditure on food items are add by household to get the total food expenditures by each household.

### 3.4.3.3 Calculation of Paasche Index

The Paasche Index is defined as:

$$P_p^h = \frac{p^h . q^h}{p^0 . q^h} = \sum_i^n w_i \left(\frac{p_i^h}{p_i^0}\right)$$

Here, the "current period" is substituted by "household under consideration", whose purchases are utilized for weighting the prices faced by the household, relative to base prices.

At first the budget share of each food item $w_i$ is calculated as the proportion of total consumption of food item $i$ out of the total food expenditure by the household. Secondly, the log price ratio is obtained by dividing the median of per unit price by Primary Sampling Units (PSUs) by the median of per unit prices by food items and taking log. Thirdly, the budget share of each food item is multiplied by the log price ratio. Finally,

the Paasche Index is obtained by taking the antilog of the product and summing the Paasche index by household.

#### 3.4.3.4 Deflation of Monthly Household Total Food Expenditures

The Paasche index is used to deflate the households total food expenditures. For this purpose the households total food expenditures are divided by the corresponding Paasche Index.

#### 3.4.3.5 Per Adult Equivalent Monthly Household Total Food Expenditures

Per adult equivalent monthly household total food expenditures are obtained by dividing the deflated monthly food expenditure by the number of adult equivalents per households. For this purpose, the household per adult equivalents are calculated using the Nutrition Based Adult Equivalent Scales issued by the Nutrition Cell of Planning Commission (CRPRID, 2002).

Adult Equivalent Scales are defined as:

$$A_{ij} = S_i\,(a_j, s_i)$$

Where, $A_{ij}$ is the *jth* individual's and the *ith* commodity's scale value, the *jth* individual's categorization is based on age $a_j$ and sex $s_i$ (Buse & Salathe, 1978).

### 3.4.4 Calculation of Threshold Food Expenditure

The threshold food expenditures are defined here, as the monthly subsistence per adult equivalent food expenditures for meeting the caloric requirements. The national food basket, with the minimum indispensable common food items developed in 2011 by the Nutrition Section of Planning Division is used as a reference to calculate the monthly subsistence per adult equivalent food expenditures to get the officially indorsed minimum per day 2350 Kcal. The basket consisted of monthly consumption of wheat (10kg), rice

(2.3 kg/), pulses (1 kg), milk (4.5 ltr), meat (1.3kg), fats and oils (1.25 kg), sweetener (1.5 kg), and fruits and vegetables (10.5 kg) (Malik et al., 2015).

Per day quantities are converted into values on the basis of prices of 2015-16 (G. o. P, 2016). It was found that an adult requires Rs. 2275.67 to purchase food providing 2350Kcal per day. Thus, monthly subsistence per adult equivalent food expenditures of Rs. 2275.67 are taken as the threshold food expenditures.

# CHAPTER 4

# SAE ANALYSIS; MAPPING AND DISCUSSION

The one of the objectives of this study was to produce the accurate food security incidence and density estimates district level in Pakistan employing SAE technique. As, the mapping such findings would help in displaying the facts related to the spatial distribution of food security as well as effective policy interventions. This chapter displays the food insecurity incidence and density estimates and respective maps. The results are discussed in detail, comparing the results with the existing relevant literature.

## 4.1 Food Insecurity Incidence in Pakistan

In this section the estimates of national, provincial and district level food insecurity incidence in Pakistan is discussed in detail. As well as the respective maps of the three levels of food insecurity incidence are displayed.

### 4.1.1 National Food Insecurity Incidence

The food insecurity incidence in Pakistan is measured as the food insecurity headcount. The threshold level for food insecurity is taken as the expenditures required to meet per adult equivalent monthly caloric requirement. The expenditures to meet per adult equivalent monthly caloric requirement are calculated as Rs. 2275.67. The overall food insecurity situation in Pakistan has not gone better. As, according to the estimates the food insecurity incidence in Pakistan is 67.84 % which is close to the food insecurity as reported by the National Nutrition Survey Pakistan (2011, 2018) (Government of Pakistan & UNICEF, 2019). The estimated figure highlights the fact that about $2/3^{rd}$ of the households in Pakistan are experiencing food insecurity. As they fail to make the threshold subsistence food expenditures.

### 4.1.2 Provincial Food Insecurity Incidence

Table.4.1 reports the estimated food insecurity incidence at provincial level in Pakistan. The provinces are ranked with Baluchistan at the top having about 87% food insecure households, followed by Sindh and Punjab. KPK is the least food insecure with 63.16 % households experiencing food insecurity.

**Table.4.1 Provincial Food Insecurity Incidence in Pakistan**

| Ranking | Province | Food Insecurity Incidence (PSLM) (%) | Food Insecurity Incidence (HIES) (%) |
|---|---|---|---|
| 1 | Baluchistan | 87.13 | 89.45 |
| 2 | Sindh | 68.84 | 71.72 |
| 3 | Punjab | 67.46 | 65.35 |
| 4 | KPK | 63.16 | 63.43 |

Source: Authors own estimations

The reason that HIES overestimates for Baluchistan and Sindh but underestimates for Punjab can be explained by the sub table 4.1(a) in appendix. Baluchistan is characterized with thin Population and so data is more volatile. Therefore, sometimes results are over estimated other time underestimated. Additionally, reason for such differences in results can be explained by dubiousness of data quality in respect of Baluchistan (Anwar & Qureshi, 2002; Arif, 2006; Malik, 2005; Saboor et al., 2004). On the other hand, Punjab is characterized with large population therefore less volatile data.

Figure.4.1 represents the map of food insecurity incidence in Pakistan at provincial level. The red zone is Baluchistan with maximum food insecure households. Whereas, the blue zones representing comparatively the lower levels of food insecurity, are Punjab and KPK respectively. Grey zone represents FATA with no data.

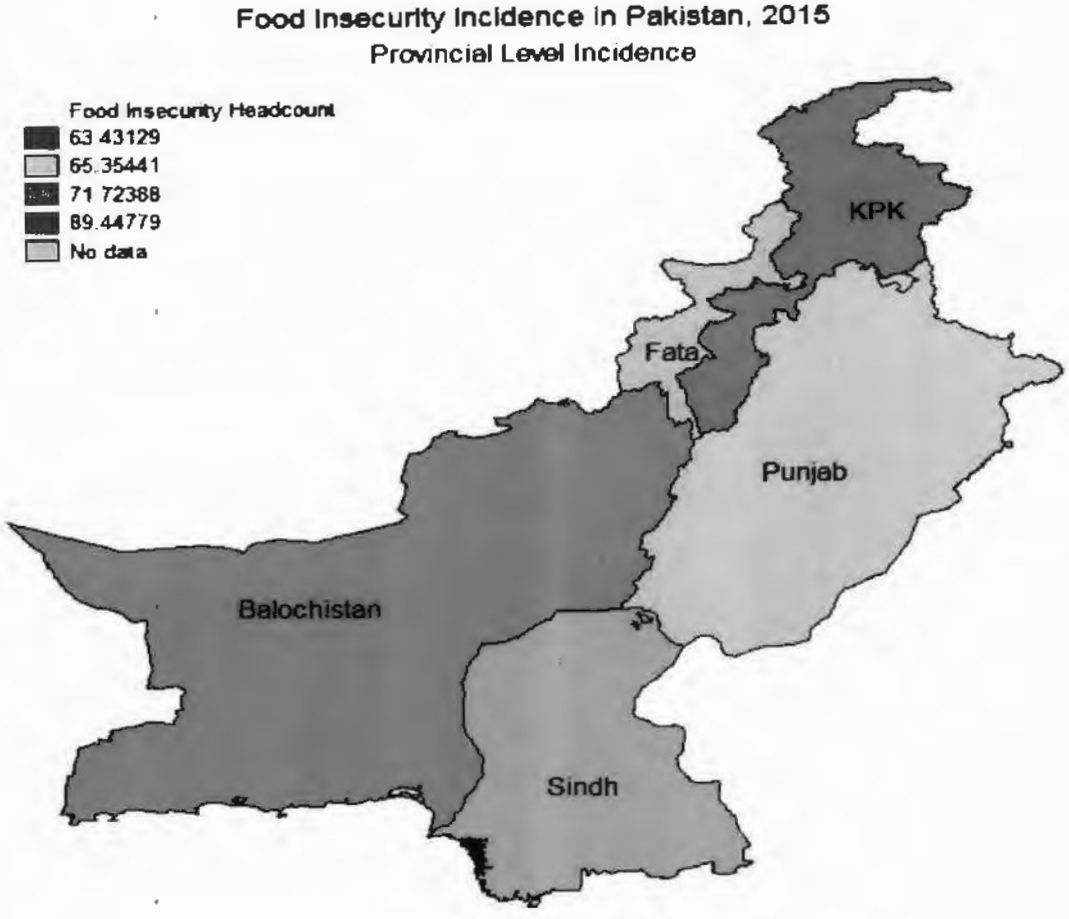


**Figure 4.1** Provincial Food Insecurity Incidence

As compared with the result of SDPI (2009) report, the food insecurity situation has deteriorated in all the provinces. Baluchistan is still the most food insecure and KPK is the least food insecure province. This result is supported by the existing literature (Asghar & Muhammad, 2013; Hameed et al., 2021; Ishaq et al., 2018) on food insecurity situation in Pakistan.

Baluchistan province in Pakistan grapples with considerable food insecurity due to a combination of factors that contribute to its unique socio-economic and environmental challenges. There are several key reasons that make Baluchistan more susceptible to food insecurity when compared to other provinces in the country. Firstly, Baluchistan experiences higher poverty rates compared to other regions in Pakistan. This pervasive poverty, coupled with unemployment, significantly reduces the purchasing power of its residents, making it challenging for them to access sufficient and nutritious food.

Additionally, the province has been grappling with security challenges and ethnic conflicts, which disrupt economic activities, including agriculture and trade. This instability can severely disrupt food supply chains and exacerbate food insecurity in the region.

Furthermore, access to crucial social services such as healthcare, education, and food assistance programs may be limited, especially in remote and underserved areas of Baluchistan. This lack of safety nets leaves vulnerable populations more susceptible to food insecurity during times of economic hardship or shocks. Moreover, social and gender inequalities further worsen the food insecurity situation in Baluchistan. Women and marginalized groups encounter greater challenges in accessing food and resources, making them more vulnerable to food insecurity.

In conclusion, Baluchistan's food insecurity is a complex issue influenced by poverty, unemployment, security challenges, limited access to social services, and gender inequalities. Addressing these challenges will be crucial in improving the overall food security situation in the province.

### 4.1.3 District Food Insecurity Incidence

The main objective of this study was to estimate food insecurity at the geographically disaggregated level i.e., district level. Table.4.2 indicates the district level food insecurity incidence in Pakistan. The districts are ranked from most food insecure to the least food insecure district. Washuk district of Baluchistan is found to be the most food insecure district with almost 93% food insecure households failing to spend subsistence monthly per adult equivalent food expenditures. The ranking describes that first 20 most food insecure districts belong to Baluchistan province including Killa Abdullah, Khuzdar, Awaran, Ziarat, Jhal Magsi, Nasirabad, Gwadar, Jaffarabad, Dera Bugti, Kharan, Harnai, Kohlu, Chagai, Kachhi, Mastung, Nushki, Sibi and Barkhan. All these districts have food

insecurity incidence falling between 85%- 93%, a figure double as compared with SDPI (2009) report. All of these 20 districts from Baluchistan come under the category of high vulnerability to food insecurity (WFP, 2017). On the other hand, there were only 10 districts with the worst food insecurity situation from Baluchistan according to SDPI (2009).

On the other hand, according to the results, the least food insecure district is Abbottabad district of KPK with 44.27% food insecure households, a figure similar to SDPI (2009) report. Additionally, the 5 least food insecure districts are Haripur, Mansehra, Chitral, Karachi City and Abbottabad. Of these, 4 districts belong to KPK province and fall under the category of low vulnerability to food insecurity according to WFP (2017). The food insecurity incidence of these districts ranges from 53% to 44%.

Similarly, the Figure.4.2 denotes the map of food insecurity incidence at district level in Pakistan. The red zones depict the most food insecure districts with more than 90% of households being food insecure. All the 6 red zone districts are from Baluchistan province. Subsequently, the orange zones represent the districts having food insecurity headcount ranging between 80-89%. In total, 29 districts fall in this zone. Most of the orange zone districts are found in Baluchistan followed by Sindh province. None of the districts from KPK and Punjab fall under this category, except for Rajanpur district from Punjab.

The off-white regions highlight the districts with food insecurity incidence falling between 65-79%. Overall, 49 districts are in this zone. The only district from Baluchistan province coming under this region is Killa Saifullah. All other districts in this range are from other three provinces. Of which, 10 are from KPK, 17 from Sindh and 21 from Punjab. The light blue areas show the districts with food insecurity incidence in between 50-64%. In this area 28 districts are included from overall Pakistan. None of the districts

**Table.4.2. District Food Insecurity Incidence In Pakistan**

| Ranking | District | Province | Food Insecurity Incidence | Ranking | District | Province | Food Insecurity Incidence | Ranking | District | Province | Food Insecurity Incidenc |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Washuk | B | 93.44% | 39 | Naushahro Feroze | S | 78.05% | 77 | Swat | KPK | 66.38% |
| 2 | Killa Abdullah | B | 92.19% | 40 | Tando Muhammad Khan | S | 77.82% | 78 | Gujranwala | P | 66.28% |
| 3 | Khuzdar | B | 91.50% | 41 | Dadu | S | 77.72% | 79 | Dera Ismail Khan | KPK | 65.80% |
| 4 | Awaran | B | 90.92% | 42 | Badin | S | 77.13% | 80 | Mandi Bahauddin | P | 65.75% |
| 5 | Ziarat | B | 90.92% | 43 | Rahim Yar Khan | P | 77.10% | 81 | Peshawar | KPK | 65.63% |
| 6 | Jhal Magsi | B | 90.91% | 44 | Muzaffargarh | P | 76.79% | 82 | Nankana Sahib | P | 65.49% |
| 7 | Nasirabad | B | 89.81% | 45 | Matiari | S | 76.59% | 83 | Kohistan | KPK | 65.16% |
| 8 | Gwadar | B | 89.75% | 46 | Sanghar | S | 76.27% | 84 | Sialkot | P | 65.11% |
| 9 | Jaffarabad | B | 89.51% | 47 | Shaheed Benazirabad | S | 76.08% | 85 | Sahiwal | P | 64.94% |
| 10 | Dera Bugti | B | 89.45% | 48 | Sujawal | S | 76.01% | 86 | Shangla | KPK | 64.92% |
| 11 | Kharan | B | 89.28% | 49 | Larkana | S | 75.48% | 87 | Sargodha | P | 64.82% |
| 12 | Harnai | B | 89.22% | 50 | Jamshoro | S | 75.16% | 88 | Nowshera | KPK | 64.42% |
| 13 | Kohlu | B | 89.18% | 51 | Umerkot | S | 74.22% | 89 | Faisalabad | P | 64.16% |
| 14 | Chagai | B | 87.69% | 52 | Thatta | S | 74.00% | 90 | Lower Dir | KPK | 64.10% |
| 15 | Kachhi | B | 87.58% | 53 | Kasur | P | 73.92% | 91 | Bannu | KPK | 64.07% |
| 16 | Mastung | B | 87.27% | 54 | Buner | KPK | 73.64% | 92 | Toba Tek Singh | P | 63.61% |
| 17 | Nushki | B | 87.00% | 55 | Mirpur Khas | S | 73.48% | 93 | Narowal | P | 63.40% |
| 18 | Sibi | B | 86.46% | 56 | Tank | KPK | 73.26% | 94 | Khushab | P | 63.25% |
| 19 | Barkhan | B | 85.90% | 57 | Bahawalpur | P | 73.21% | 95 | Mianwali | P | 63.18% |
| 20 | Zhob | B | 85.46% | 58 | Bhakkar | P | 72.74% | 96 | Lahore | P | 62.17% |
| 21 | Pishin | B | 85.28% | 59 | Upper Dir | KPK | 72.03% | 97 | Lakki Marwat | KPK | 61.75% |
| 22 | Kashmore | S | 84.94% | 60 | Bahawalnagar | P | 71.98% | 98 | Batagram | KPK | 60.69% |
| 23 | Ghotki | S | 83.89% | 61 | Layyah | P | 71.60% | 99 | Hangu | KPK | 60.57% |
| 24 | Kalat | B | 83.82% | 62 | Lodhran | P | 70.94% | 100 | Kohat | KPK | 59.69% |
| 25 | Jacobabad | S | 83.72% | 63 | Tharparkar | S | 70.77% | 101 | Swabi | KPK | 59.60% |
| 26 | Las Bela | B | 83.64% | 64 | Chiniot | P | 70.65% | 102 | Malakand PA | KPK | 59.43% |
| 27 | Musakhel | B | 83.59% | 65 | Khanewal | P | 70.26% | 103 | Gujrat | P | 59.26% |
| 28 | Quetta | B | 82.85% | 66 | Multan | P | 69.75% | 104 | Karak | KPK | 58.62% |
| 29 | Shikarpur | S | 82.63% | 67 | Sheikhupura | P | 69.63% | 105 | Attock | P | 57.09% |
| 30 | Khairpur | S | 81.55% | 68 | Vehari | P | 69.56% | 106 | Jhelum | P | 56.13% |
| 31 | Sukkur | S | 81.24% | 69 | Charsadda | KPK | 69.55% | 107 | Rawalpindi | P | 55.28% |
| 32 | Qambar Shahdadkot | S | 81.12% | 70 | Okara | P | 69.40% | 108 | Islamabad | FCT | 54.07% |
| 33 | Loralai | B | 80.60% | 71 | Hyderabad | S | 68.99% | 109 | Chakwal | P | 53.66% |
| 34 | Rajanpur | P | 80.34% | 72 | Jhang | P | 68.67% | 110 | Haripur | KPK | 53.45% |
| 35 | Sheerani | B | 80.31% | 73 | Pakpattan | P | 68.45% | 111 | Mansehra | KPK | 53.20% |
| 36 | Killa Saifullah | B | 78.82% | 74 | Hafizabad | P | 67.62% | 112 | Chitral | KPK | 51.06% |
| 37 | Dera Ghazi Khan | P | 78.52% | 75 | Mardan | KPK | 67.03% | 113 | Karachi City | S | 49.85% |
| 38 | Tando Allah Yar | S | 78.32% | 76 | Tor Ghar | KPK | 66.43% | 114 | Abbottabad | KPK | 44.27% |

Source: Author's own estimations

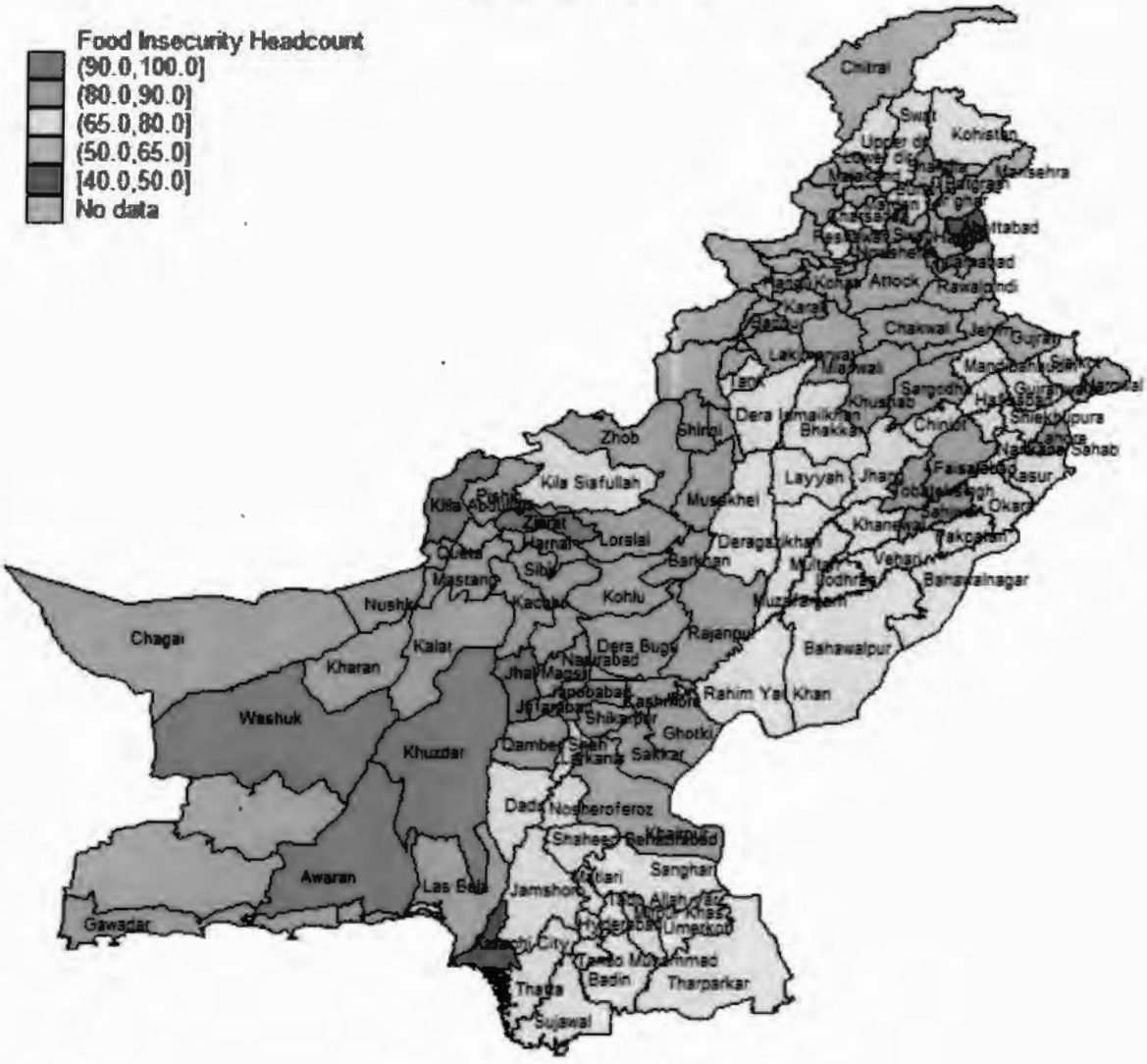


**Figure 4.2** District Food Insecurity Incidence

is based on model and methodology employed in this study. The general procedural steps of Household Level Method of SAE have been discussed. The detailed procedural steps including the consumption modelling, simulation and bootstrap, validation and mapping are explained. In addition, the second technique of GWR is explained in detail along with the mapping technique of GWR estimation results.

## 4.2 District Food Insecurity Density

Another important objective of this study was to estimate the food insecurity density at district level in Pakistan. As, there may be a lot of food insecure people in districts with low food insecurity incidence in Pakistan. The estimation of food insecurity density might also be helpful in successfully targeting the affected areas (Minot & Baulch, 2005). This section provides detailed analysis of the district food insecurity density estimates in Pakistan.

The Table.4.3 displays the district food insecurity density estimates in Pakistan. The situation turns upside down in case of Karachi. As, the Karachi city from Sindh province, which is the second least food insecure with respect to food insecurity incidence estimates, comes up with the highest number of food insecure people (6.4 million), according the district food insecurity density estimates in Pakistan. WFP (2017)indicated Karachi under the category of low vulnerability to food insecurity. Similarly, the top 20 districts with most food insecure people are from Punjab, except for Karachi and Peshawar. However, according to the food insecurity incidence estimates, the 20 most food insecure districts were from Baluchistan. First 10 districts with most food insecure population include Karachi City, Lahore, Rahim Yar Khan, Faisalabad, Muzaffargarh, Multan, Gujranwala, Bahawalpur, Rawalpindi, and Sheikhupura respectively. The food insecurity density of these districts ranges from 6.43 to 2.24 million.

Subsequently, Washuk district from Baluchistan, which was the most food insecure district according to the food insecurity incidence, is the 13$^{th}$ least food insecure district with only 0.17 million food insecure people. Washuk is reported as highly vulnerable to food insecurity in ICA (WFP, 2017).

**Table.4.3 District Food Insecurity Density In Pakistan**

| Ranking | District | Population | Food Insecurity Density | Food Insecurity Density (In Million) | Ranking | District | Population | Food Insecurity Density | Food Insecurity Density (In Million) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Karachi City | 12906861 | 6433680 | 6.43 | 58 | Swabi | 1114258 | 664146 | 0.66 |
| 2 | Lahore | 8843249 | 5498182 | 5.50 | 59 | Khushab | 1028518 | 650506 | 0.65 |
| 3 | Rahim Yar Khan | 5348066 | 4123502 | 4.12 | 60 | Islamabad | 1193019 | 645086 | 0.65 |
| 4 | Faisalabad | 5889614 | 3778838 | 3.78 | 61 | Umerkot | 864589 | 641715 | 0.64 |
| 5 | Muzaffargarh | 3887101 | 2985013 | 2.99 | 62 | Nowshera | 971351 | 625709 | 0.63 |
| 6 | Multan | 3754034 | 2618497 | 2.62 | 63 | Hafizabad | 918667 | 621222 | 0.62 |
| 7 | Gujranwala | 3929469 | 2604291 | 2.60 | 64 | Upper Dir | 857602 | 617731 | 0.62 |
| 8 | Bahawalpur | 3319128 | 2429825 | 2.43 | 65 | Bannu | 929833 | 595731 | 0.60 |
| 9 | Rawalpindi | 4361061 | 2410982 | 2.41 | 66 | Manschra | 1056086 | 561787 | 0.56 |
| 10 | Sheikhupura | 3212433 | 2236909 | 2.24 | 67 | Tando Allah Yar | 716487 | 561188 | 0.56 |
| 11 | Sialkot | 3355016 | 2184294 | 2.18 | 68 | Jhelum | 978516 | 549257 | 0.55 |
| 12 | Dera Ghazi Khan | 2564761 | 2013945 | 2.01 | 69 | Buner | 724949 | 533834 | 0.53 |
| 13 | Kasur | 2701741 | 1997085 | 2.00 | 70 | Jamshoro | 709168 | 532978 | 0.53 |
| 14 | Khairpur | 2279620 | 1858990 | 1.86 | 71 | Jaffarabad | 593865 | 531593 | 0.53 |
| 15 | Peshawar | 2765210 | 1814715 | 1.81 | 72 | Matiari | 690761 | 529044 | 0.53 |
| 16 | Bahawalnagar | 2518799 | 1812968 | 1.81 | 73 | Chakwal | 966607 | 518650 | 0.52 |
| 17 | Vehari | 2571864 | 1789098 | 1.79 | 74 | Khuzdar | 559213 | 511657 | 0.51 |
| 18 | Okara | 2540204 | 1762955 | 1.76 | 75 | Tando M. Khan | 643086 | 500448 | 0.50 |
| 19 | Sargodha | 2663323 | 1726443 | 1.73 | 76 | Kohat | 814850 | 486392 | 0.49 |
| 20 | Khanewal | 2421789 | 1701495 | 1.70 | 77 | Thatta | 648226 | 479713 | 0.48 |
| 21 | Hyderabad | 2400748 | 1656183 | 1.66 | 78 | Abbottabad | 998542 | 442028 | 0.44 |
| 22 | Jhang | 2231870 | 1532541 | 1.53 | 79 | Sujawal | 532241 | 404568 | 0.40 |
| 23 | Gujrat | 2402434 | 1423574 | 1.42 | 80 | Haripur | 732266 | 391374 | 0.39 |
| 24 | Ghotki | 1685820 | 1414198 | 1.41 | 81 | Lakki Marwat | 616959 | 380996 | 0.38 |
| 25 | Dadu | 1690461 | 1313818 | 1.31 | 82 | Kohistan | 575178 | 374808 | 0.37 |
| 26 | Mardan | 1918591 | 1286074 | 1.29 | 83 | Karak | 596761 | 349838 | 0.35 |
| 27 | Quetta | 1514926 | 1255116 | 1.26 | 84 | Shangla | 498621 | 323728 | 0.32 |
| 28 | Swat | 1821357 | 1209028 | 1.21 | 85 | Malakand PA | 525037 | 312050 | 0.31 |
| 29 | Rajanpur | 1501935 | 1206728 | 1.21 | 86 | Pishin | 359049 | 306195 | 0.31 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 30 | Sanghar | 1541806 | 1175994 | 1.18 | 87 | Nasirabad | 318533 | 286075 | 0.29 |
| 31 | Sahiwal | 1802312 | 1170454 | 1.17 | 88 | Awaran | 304883 | 277202 | 0.28 |
| 32 | Layyah | 1595306 | 1142308 | 1.14 | 89 | Las Bela | 327661 | 274069 | 0.27 |
| 33 | Larkana | 1461160 | 1102877 | 1.10 | 90 | Batagram | 444162 | 269557 | 0.27 |
| 34 | Badin | 1364759 | 1052703 | 1.05 | 91 | Tank | 356403 | 261095 | 0.26 |
| 35 | Qambar Shahdadkot | 1288521 | 1045238 | 1.05 | 92 | Gwadar | 288714 | 259125 | 0.26 |
| 36 | Toba Tek Singh | 1624319 | 1033310 | 1.03 | 93 | Loralai | 300845 | 242481 | 0.24 |
| 37 | Lodhran | 1444935 | 1025010 | 1.03 | 94 | Chitral | 414672 | 211728 | 0.21 |
| 38 | Tharparkar | 1420785 | 1005471 | 1.01 | 95 | Kalat | 248541 | 208338 | 0.21 |
| 39 | Pakpattan | 1466192 | 1003585 | 1.00 | 96 | Killa Saifullah | 251189 | 197978 | 0.20 |
| 40 | Bhakkar | 1369981 | 996559 | 1.00 | 97 | Tor Ghar | 293427 | 194934 | 0.19 |
| 41 | Narowal | 1569602 | 995061 | 1.00 | 98 | Zhob | 227634 | 194539 | 0.19 |
| 42 | Sukkur | 1218131 | 989569 | 0.99 | 99 | Dera Bugti | 212289 | 189894 | 0.19 |
| 43 | Shikarpur | 1194674 | 987170 | 0.99 | 100 | Hangu | 285553 | 172949 | 0.17 |
| 44 | Naushahro Feroze | 1260697 | 983933 | 0.98 | 101 | Kachhi | 196555 | 172149 | 0.17 |
| 45 | Shaheed Benazirabad | 1287249 | 979342 | 0.98 | 102 | Washuk | 178031 | 166347 | 0.17 |
| 46 | Mirpur Khas | 1275710 | 937335 | 0.94 | 103 | Jhal Magsi | 172028 | 156392 | 0.16 |
| 47 | Kashmore | 1052990 | 894390 | 0.89 | 104 | Chagai | 135244 | 118593 | 0.12 |
| 48 | Jacobabad | 1050980 | 879888 | 0.88 | 105 | Mastung | 133200 | 116240 | 0.12 |
| 49 | Charsadda | 1178430 | 819543 | 0.82 | 106 | Nushki | 132152 | 114978 | 0.11 |
| 50 | Mandi Bahauddin | 1213458 | 797902 | 0.80 | 107 | Sibi | 124664 | 107789 | 0.11 |
| 51 | Dera Ismail Khan | 1158701 | 762444 | 0.76 | 108 | Kharan | 116378 | 103900 | 0.10 |
| 52 | Chiniot | 1059590 | 748623 | 0.75 | 109 | Harnai | 114534 | 102190 | 0.10 |
| 53 | Killa Abdullah | 794245 | 732203 | 0.73 | 110 | Ziarat | 107710 | 97929 | 0.10 |
| 54 | Attock | 1260429 | 719579 | 0.72 | 111 | Kohlu | 96315 | 85895 | 0.09 |
| 55 | Nankana Sahib | 1086237 | 711405 | 0.71 | 112 | Barkhan | 88261 | 75820 | 0.08 |
| 56 | Lower Dir | 1091554 | 699695 | 0.70 | 113 | Musakhel | 73948 | 61815 | 0.06 |
| 57 | Mianwali | 1068581 | 675104 | 0.68 | 114 | Sherani | 64647 | 51918 | 0.05 |

Source: Author's own estimation

Additionally, most of the districts from Baluchistan including Zhob, Dera Bugti, Kachhi, Jhal Magsi, Chagai, Mastung, Nushki, Sibi, Kharan, Harnai, Ziarat, Kohlu and Barkhan, which were under the category of 20 most food insecure districts with more than 80% food insecure households, are now under the category of 20 least food insecure districts with less than 0.20 million food insecure people. All of these 20 districts from Baluchistan come under the category of high vulnerability to food insecurity (WFP, 2017). On the other hand, there were only 10 districts with the worst food insecurity situation from Baluchistan according to SDPI (2009). Furthermore, Sheerani from Baluchistan is the least food insecure district with only 0.05 million food insecure people. While according to the food insecurity incidence estimates Sheerani was ranked 35$^{th}$ position with more than 80% food insecure households. According to the WFP (2017) Sheerani fall under the category of highly vulnerable areas to food insecurity in Pakistan.

Similar analysis is depicted in Figure.4.3 which clearly highlights district food insecurity density situation in Pakistan. The red zone represents the most food insecure district with more than 6 million food insecure people. The only district in this zone is Karachi from Sindh province. As, represented by orange zone, the second most food insecure district with about 5.50 million food insecure people is Lahore from Punjab province. Rahim Yar Khan from Punjab, as shown by yellow zone. Furthermore, the districts having food insecure people within the range 2.00-3.78 million are found in Sindh and Punjab, as depicted with green zones. Most of the districts with less than 1 million food insecure people are found in Baluchistan and KPK province respectively, highlighted as dark blue zones. Province wise district food insecurity density analysis reveals that all districts of Baluchistan except for Killa Abdullah have less than 0.7 million food insecure people.

**Table 4.4 Comparison of Results with FSA Pakistan 2009 and ICA Pakistan 2017 District Food Insecurity Estimates**

| District | Food Insecurity Incidence | Food Insecurity Incidence (FSA 2009) | *Food Insecurity Vulnerability Incidence (ICA 2017) | District | Food Insecurity Incidence | Food Insecurity Incidence (FSA 2009) | *Food Insecurity Vulnerability Incidence (ICA 2017) | District | Food Insecurity Incidence | Food Insecurity Incidence (FSA 2009) | *Food Insecurity Vulnerability Incidence (ICA 2017) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Washuk (B) | 93.44% | No Estimates | 41.70% | 39. Naushahro Feroze (S) | 78.05% | 39.30% | 27.22% | 77. Swat (KP) | 66.38% | 54.20% | 25.60% |
| 2. Killa Abdullah (B) | 92.19% | 64.30% | 43.70% | 40. Tando Muhammad Khan (S) | 77.82% | 34.30% | 39.76% | 78. Gujranwala (P) | 66.28% | 37% | 8.35% |
| 3. Khuzdar (B) | 91.50% | 63.90% | 35.21% | 41. Dadu (S) | 77.72% | 49.20% | 28.92% | 79. Dera Ismail Khan (KP) | 65.80% | 56% | 33.14% |
| 4. Awaran (B) | 90.92% | 67.20% | 45.43% | 42. Badin (S) | 77.13% | 40.00% | 39.29% | 80. Mandi Bahauddin (P) | 65.75% | 31.60% | 16.15% |
| 5. Ziarat (B) | 90.92% | 57.90% | 42.79% | 43. Rahim Yar Khan (P) | 77.10% | 39.00% | 30.68% | 81. Peshawar (KP) | 65.63% | 49.30% | 15.02% |
| 6. Jhal Magsi (B) | 90.91% | 52.10% | 44.78% | 44. Muzaffargarh (P) | 76.79% | 49.90% | 34.99% | 82. Nankana Sahib (P) | 65.49% | No Estimates | 15.58% |
| 7. Nasirabad (B) | 89.81% | 41.40% | 41.09% | 45. Matiari (S) | 76.59% | 33.50% | 30.67% | 83. Kohistan (KP) | 65.16% | 73.50% | 61.40% |
| 8. Gwadar (B) | 89.75% | 53.60% | 29.70% | 46. Sanghar (S) | 76.27% | 25.00% | 31.21% | 84. Sialkot (P) | 65.11% | 29.20% | 11.08% |
| 9. Jaffarabad (B) | 89.51% | 41.60% | 37.22% | 47. Shaheed Benazirabad (S) | 76.08% | 57.50% | 33.61% | 85. Sahiwal (P) | 64.94% | 33.80% | 20.06% |
| 10. Dera Bugti (B) | 89.45% | 82.40% | 52.21% | 48. Sujawal (S) | 76.01% | No Estimates | 43.69% | 86. Shangla (KP) | 64.92% | 60.90% | No Estimates |
| 11. Kharan (B) | 89.28% | 60.60% | 50.10% | 49. Larkana (S) | 75.48% | 37.30% | 25.23% | 87. Sargodha (P) | 64.82% | 39.90% | 20.24% |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12. Harnai (B) | 89.22% | No Estimates | 46.52% | 50. Jamshoro (S) | 75.16% | 36.00% | 32.94% | 88. Nowshera (KP) | 64.42% | 47.50% | 17.33% |
| 13. Kohlu (B) | 89.18% | No Estimates | 53.56% | 51. Umerkot (S) | 74.22% | 59.40% | 41.82% | 89. Faisalabad (P) | 64.16% | 31.90% | 10.68% |
| 14. Chagai (B) | 87.69% | No Estimates | 21.62% | 52. Thatta (S) | 74.00% | 39.10% | 39.67% | 90. Lower Dir (KP) | 64.10% | 64.50% | 24.79% |
| 15. Kachhi (B) | 87.58% | No Estimates | 45.80% | 53. Kasur (P) | 73.92% | 40.20% | 16.49% | 91. Bannu (KP) | 64.07% | 52.10% | 29.31% |
| 16. Mastung (B) | 87.27% | 65% | 31% | 54. Buner (KP) | 73.64% | 60.60% | 31.03% | 92. Toba Tek Singh (P) | 63.61% | 29.90% | 16.27% |
| 17. Nushki (B) | 87.00% | 69.60% | 33.79% | 55. Mirpur Khas (S) | 73.48% | 38.60% | 35.17% | 93. Narowal (P) | 63.40% | 43.50% | 19.32% |
| 18. Sibi (B) | 86.46% | 56.00% | 36.38% | 56. Tank (KP) | 73.26% | 60% | 35% | 94. Khushab (P) | 63.25% | 48.30% | 21.35% |
| 19. Barkhan (B) | 85.90% | 62.20% | 47.50% | 57. Bahawalpur (P) | 73.21% | 43.60% | 27.86% | 95. Mianwali (P) | 63.18% | 44% | 24.75% |
| 20. Zhob (B) | 85.46% | 67.00% | 50 94% | 58. Bhakkar (P) | 72.74% | 40.80% | 30.54% | 96. Lahore (P) | 62.17% | 29.10% | 3.87% |
| 21. Pishin (B) | 85.28% | 58.20% | 33.94% | 59. Upper Dir (KP) | 72.03% | 75.60% | 39.59% | 97. Lakki Marwat (KP) | 61.75% | 66.30% | 32.84% |
| 22.Kashmore (S) | 84.94% | No Estimates | 35.68% | 60. Bahawalnagar (P) | 71.98% | 33.30% | 24.81% | 98. Batagram (KP) | 60.69% | 50.40% | 33.32% |
| 23. Ghotki (S) | 83.89% | No Estimates | 31.75% | 61. Layyah (P) | 71.60% | 37.40% | 24.51% | 99. Hangu (KP) | 60.57% | 54.20% | 25.63% |
| 24. Kalat (B) | 83.82% | 64.20% | 38.53% | 62. Lodhran (P) | 70.94% | 39.00% | 28.48% | 100. Kohat (KP) | 59.69% | 52.60% | 21.60% |
| 25. Jacobabad (S) | 83.72% | 38.70% | 36.54% | 63. Tharparkar (S) | 70.77% | 53.40% | 44.17% | 101. Swabi (KP) | 59.60% | 53% | 20.96% |
| 26. Las Bela (B) | 83.64% | 49.80% | 39.92% | 64. Chiniot (P) | 70.65% | No Estimates | 19.92% | 102. Malakand PA (KP) | 59.43% | 61% | 20.41% |
| 27. Musakhel (B) | 83.59% | 78.50% | 47.16% | 65. Khanewal (P) | 70.26% | 39.20% | 24.45% | 103. Gujrat (P) | 59.26% | 38% | 8.58% |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 28. Quetta (B) | 82.85% | 40.90% | 15.13% | 66. Multan (P) | 69.75% | 44.60% | 21.36% | 104. Karak (KP) | 58.62% | 63.70% | 27.26% |
| 29. Shikarpur (S) | 82.63% | 32.40% | 30.22% | 67. Sheikhupura (P) | 69.63% | 35.80% | 13.62% | 105. Attock (P) | 57.09% | 41.90% | 10.52% |
| 30. Khairpur (S) | 81.55% | 50.40% | 26.88% | 68. Vehari (P) | 69.56% | 35.40% | 21.96% | 106. Jhelum (P) | 56.13% | 34.30% | 6.34% |
| 31. Sukkur (S) | 81.24% | 66.90% | 21.95% | 69. Charsadda (KP) | 69.55% | 54.70% | 24.28% | 107. Rawalpindi (P) | 55.28% | 28.60% | 5.08% |
| 32. Qamber Shahdadkot (S) | 81.12% | 44.10% | 32.66% | 70. Okara (P) | 69.40% | 36.10% | 23.59% | 108. Islamabad (FCT) | 54.07% | 23.60% | 0.87% |
| 33. Loralai (B) | 80.60% | 68.80% | 43.60% | 71. Hyderabad (S) | 68.99% | 46.60% | 14.87% | 109. Chakwal (P) | 53.66% | 41.70% | 7.67% |
| 34. Rajanpur (P) | 80.34% | 55.30% | 39.78% | 72. Jhang (P) | 68.67% | 38.70% | 27.63% | 110. Haripur (KP) | 53.45% | 40.20% | 15.16% |
| 35. Sheerani (B) | 80.31% | No Estimates | 49.57% | 73. Pakpattan (P) | 68.45% | 29.90% | 25.91% | 111. Mansehra (KP) | 53.20% | 46.70% | 23.83% |
| 36. Killa Saifullah (B) | 78.82% | 57.00% | 47.04% | 74. Hafizabad (P) | 67.62% | 34.30% | 17.07% | 112. Chitral (KP) | 51.06% | 60.70% | 21.29% |
| 37. Dera Ghazi Khan (P) | 78.52% | 55.00% | 37.20% | 75. Mardan (KP) | 67.03% | 51.30% | 19.95% | 113. Karachi City (S) | 49.85% | 38% | 3.94% |
| 38. Tando Allah Yar (S) | 78.32% | 59.50% | 32.38% | 76. Tor Ghar (KP) | 66.43% | No Estimates | No Estimates | 114. Abbottabad (KP) | 44.27% | 40.60% | 16.10% |

**Source: Author's own estimation comparison with 2009 and 2017 estimates**

*** % ages calculated from the estimates reported in ICA Pakistan 2017**

While, Faisalabad, Rahim Yar Khan and Lahore have 3.78, 4.12 and 5.50 million food insecure people, respectively. The grey zone represent areas with no data. As, Punjgur and Kach in Baluchistan and FATA.

The comparison and discussion revealed that this study has contributed in terms of highlighting the food insecurity affected districts about which no estimates were available in SDPI (2009). Additionally, this study has highlighted the districts more food insecure population which was not indicated in ICA (WFP, 2017), rather, those districts were presented as less vulnerable to food insecurity in ICA (WFP, 2017). Finally, this study indicated the figure of actual food insecure districts in contrast with ICA (WFP, 2017), in which, districts vulnerable to food insecurity have been indicated. The detailed comparison is presented in Table 4.4.

# CHAPTER 5

# PARAMETRIC GWR ANALYSIS; MAPPING AND DISCUSSTION

As, it is stated in the research gap that spatial correlation of determining factors of food security is not addressed in food security related studies in Pakistan. Therefore, the indication of area specific determinants of food security is another primary objective of this study. This objective is achieved through applying the geographically weighted regression (GWR) technique at district level in Pakistan.

This chapter comprises detailed analysis and mapping of Parametric GWR estimates at district level in Pakistan. The difference between parametric and semi parametric GWR estimates lies in the fact that, in case of later technique, the spatially invariant variables are taken as Global independent variables after applying the Geographical variability Test on all the candidate variables. While, the variables which passed the Geographical variability Test, are considered as Local independent variables.

## 5.1 Parametric GWR Estimates at District Level in Pakistan

Overall, the Global model had the Adjusted $R^2$ of 89.69%, while the GWR local model had an Adjusted $R^2$ of 88.6%. This section provides detailed tabular and map visualization analysis of the district specific significant determining variables of food insecurity in Pakistan based on the parametric GWR estimates. The maps of parameter estimates and the relevant t-values are presented in this section, which identify the spatially variant factors affecting food insecurity across the Pakistani districts.

### 5.1.1 Edu-1

The variable Edu-1 represents educational attainment status 'No Schooling'. It was a binary variable and its proportion is taken by district for GWR analysis. As depicted in the Fig.5.1,

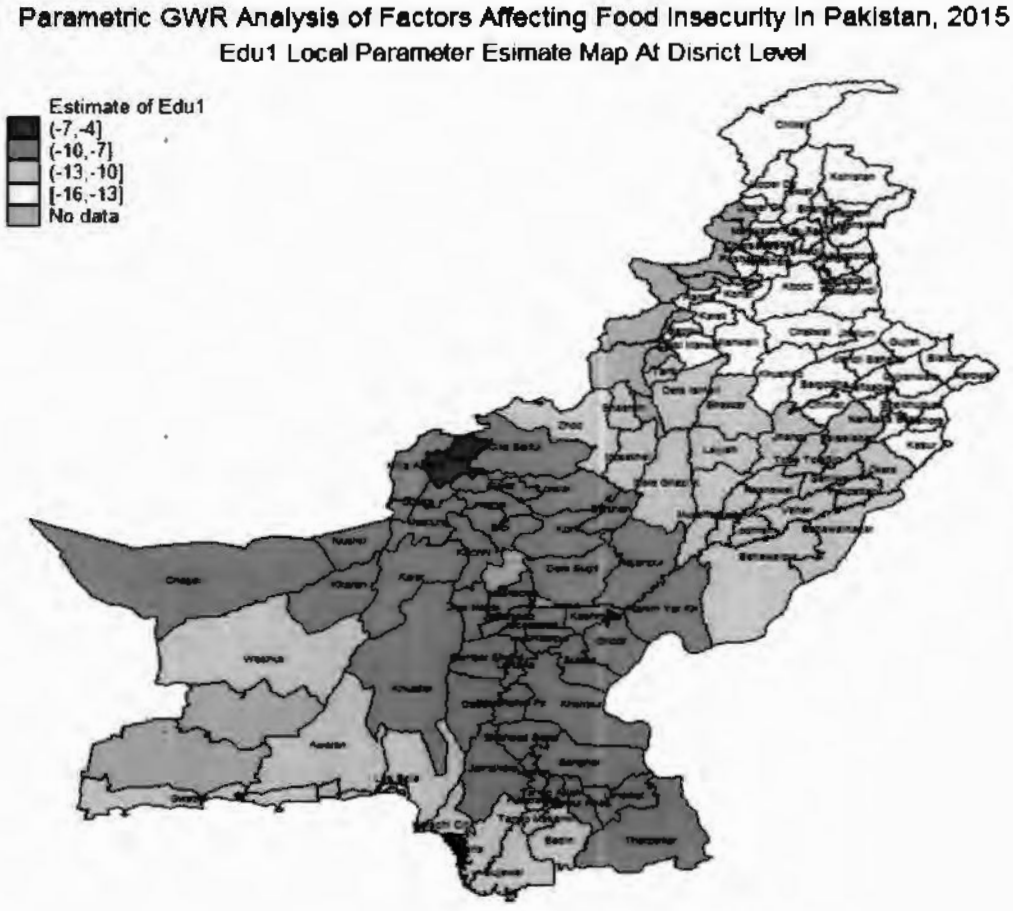


**Figure 5.1** Edu-1 Local Parameter Estimate, Parametric GWR Analysis

the negative sign of the local parameter estimate shows that with increase in 'no schooling' as educational attainment status, the food insecurity incidence goes down. Such relation might exists due to the fact that when most of the expenditures by the households are made on food, nothing is spent on education. It might be the case that those who do not go to school contribute to the household expenditures on food by working. Also, it is possible

that the expenditure saved from not going to school might be spend on food. In other words, as the proportion of 'no schooling status reduces on district level, less is spent on food, thus food insecurity incidence goes up.

As far as, the significance of the variable Edu1 is concerned, it is spatially variable across the districts. In some districts, it is insignificant, while in others it is significant in determining the food insecurity incidence. In case of three districts from Baluchistan i.e Ziarat, Pishin and Killa Abdullah, Edu1 is insignificant as depicted in the Fig.5.2, with dark

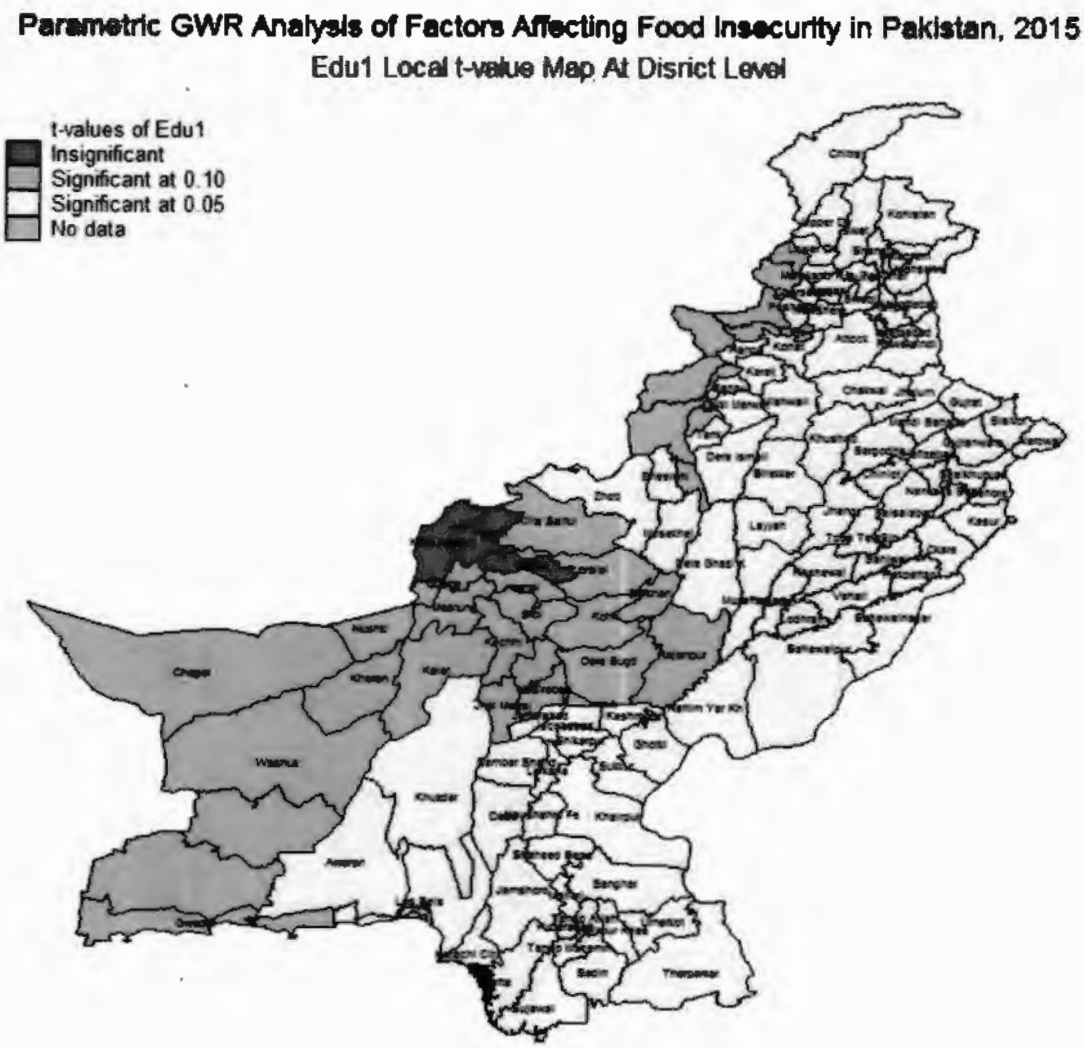


**Figure 5.2** Edu-1 Local t-value, Parametric GWR

purple Zones. While, it is less significant (at 10%) in most of the districts from Baluchistan except for Awaran, Khuzdar and Las Bela, for which it is more significant (at 5%). For all districts from other three provinces including Islamabad, Edu1 is more significant (at 5%) in determining the food insecurity incidence.

### 5.1.2 Edu Ratio-1

The variable Edu Ratio-1 indicates the proportion of household members having no schooling. For GWR analysis, its average is taken at district level. On the average, at district level, the proportion of household members having no schooling reduces, it means

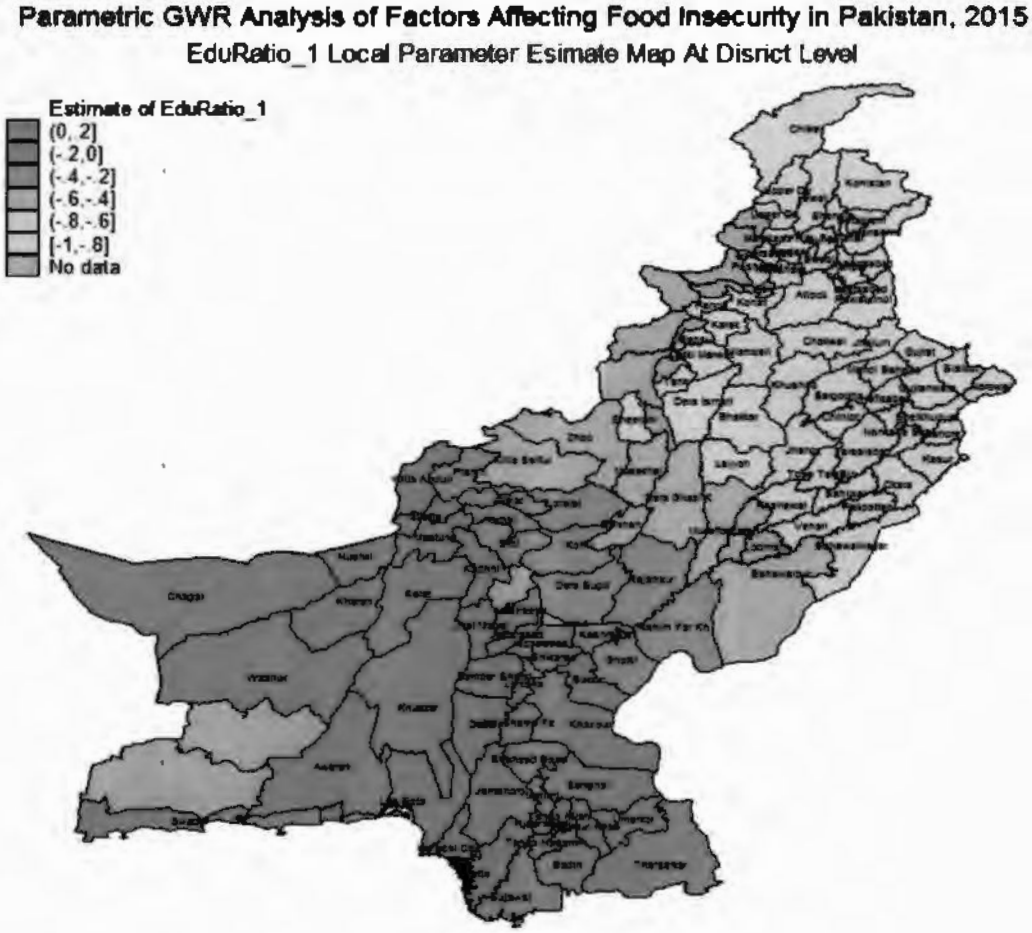


**Figure 5.3** Edu Ratio-1 Local Parameter Estimate, Parametric GWR

more expenditures are made on education. So, the food insecurity incidence increases with the reduced food expenditure below subsistence level. As, it is shown in the Fig.5.3 that in most of the districts the sign of the local parameter estimate is negative. For some districts, positive sign is an exception. It might be because of some additional factors, such as increase in household income result in reducing both the proportion of members with no schooling and the food insecurity incidence in these districts.

Moreover, the significance of Edu Ratio-1 variable is spatially variant across the districts

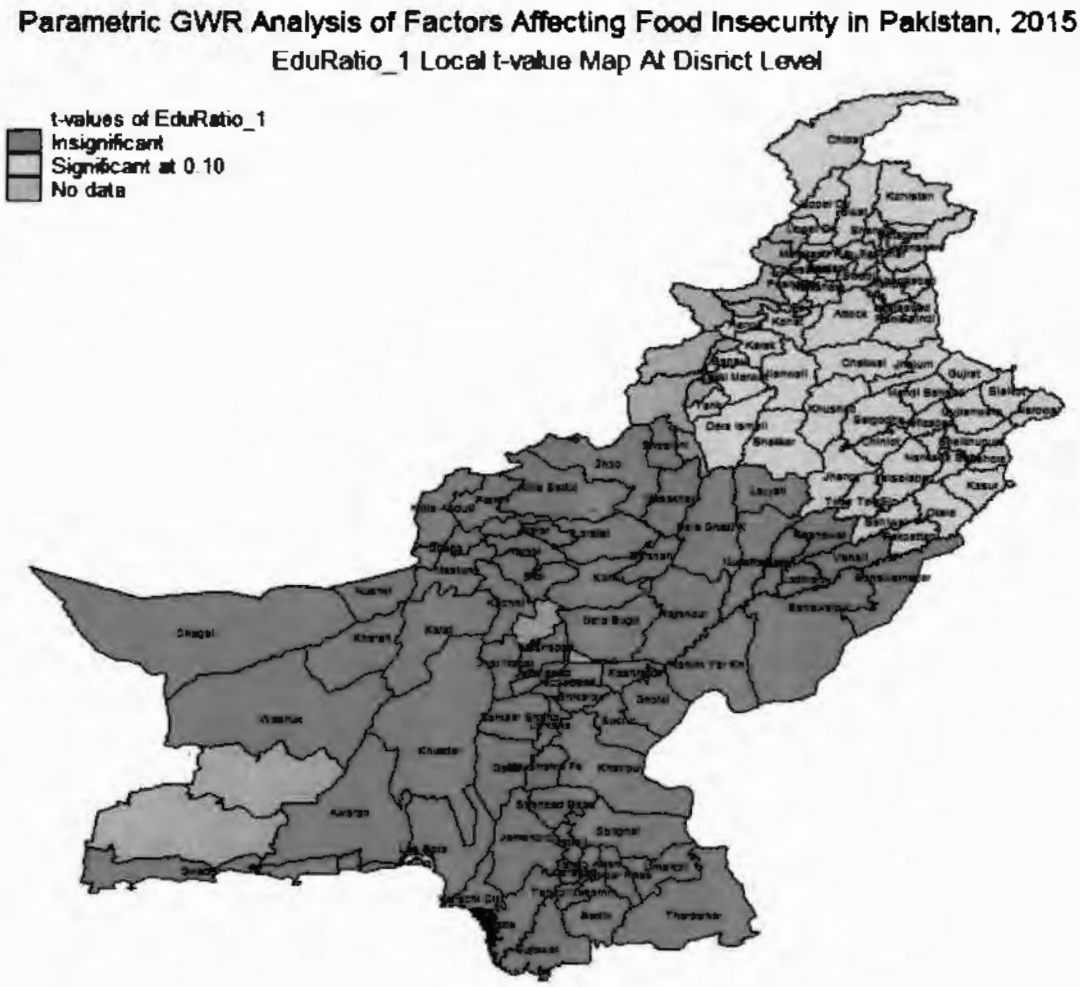


**Figure 5.4** Edu Ratio-1 Local t-value, Parametric GWR

of Pakistan in determining the food insecurity incidence. As, reflected by the Fig.5.4, the variable under consideration is insignificant in all the districts of Baluchistan and Sindh as well as in few districts of Punjab, as indicated by orange zones. However, it is significant (at 10%) in all the districts of KPK and most of the districts in Punjab including Islamabad, as shown by the yellow zones.

### 5.1.3 Edu Ratio-2

The variable Edu Ratio-2 represents the proportion of household members having primary

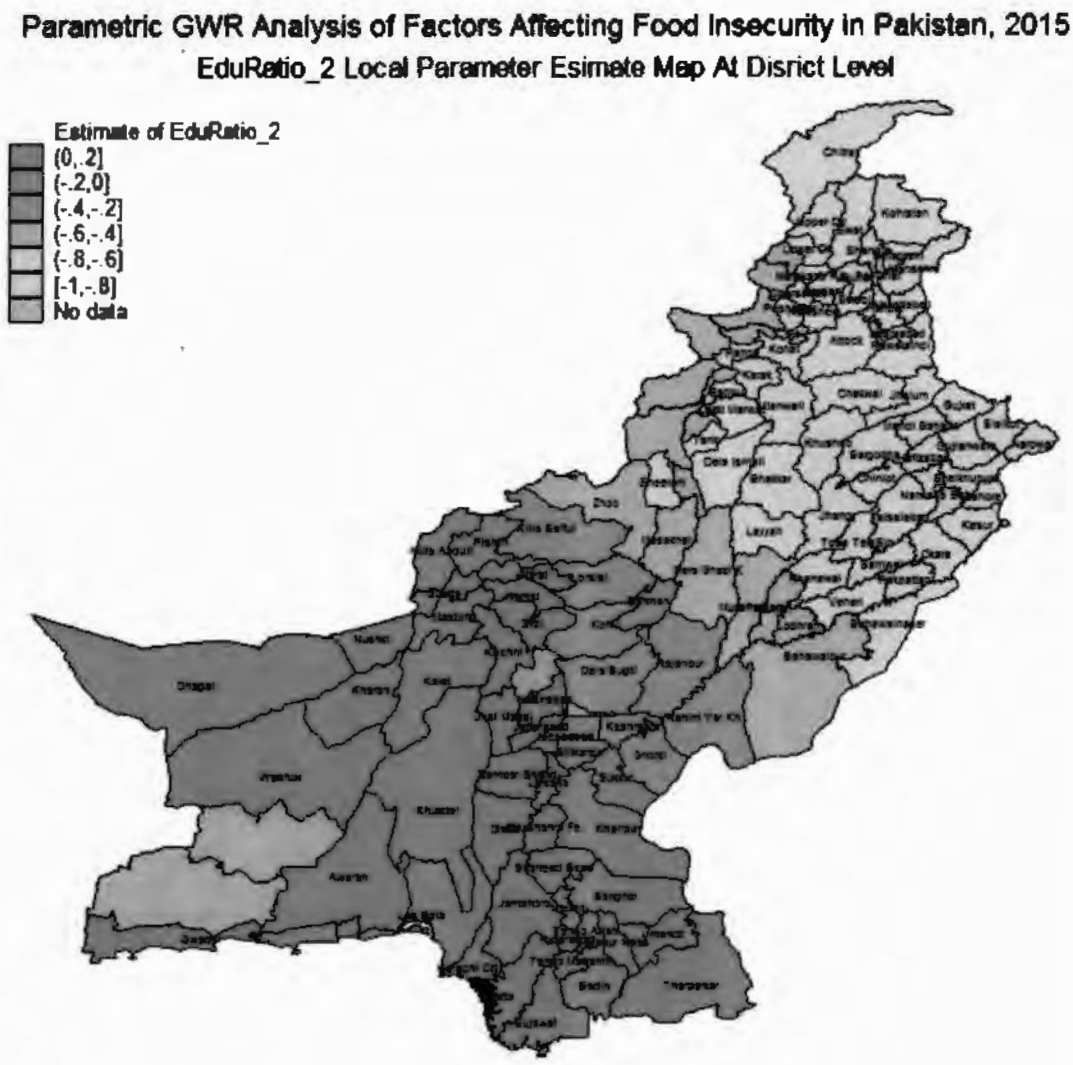


**Figure 5.5** Edu Ratio-2 Parameter Estimate, Parametric GWR

education. The variable is averaged at district level for GWR analysis. On the average, at district level, as the proportion of household members having primary education increases, the food insecurity incidence decreases. This result is in accordance with the fact that the education has a positive impact on the food security status of households. The results suggest that education leads to reduce food insecurity. Those who have already attained primary education may contribute better to the household income than the illiterate one.

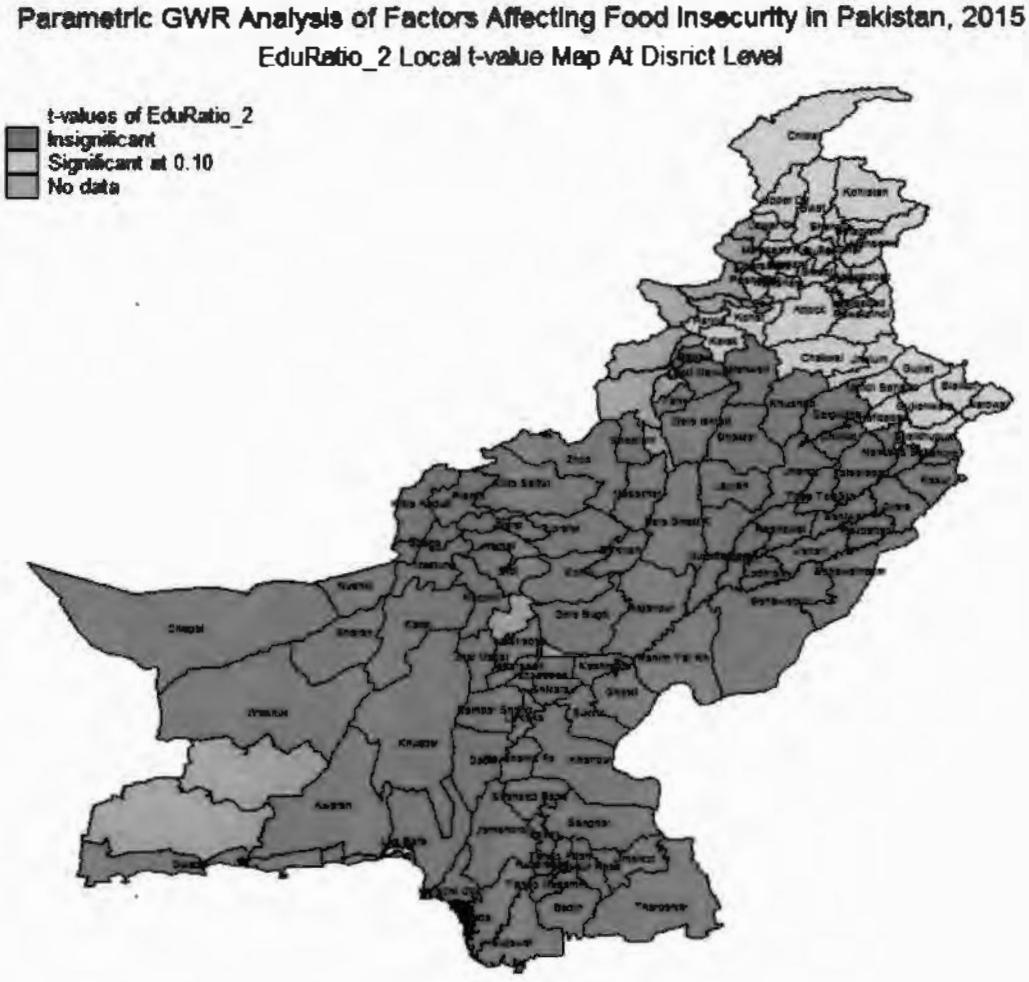


**Figure 5.6** Edu Ratio-2 Local t-value, Parametric GWR

Non-intuitive positive relation between educational access and poverty found in a study for Kenya. Such results might be explained by the educational facilities established by the non-

governmental organizations (NGOs). It might also be the case of educational facilities in such areas have not played any role in reducing poverty (Kristjanson et al., 2005). As, it is shown in the Fig.5.5 that in most of the districts the sign of the local parameter estimate is negative. For some districts, positive sign is an exception. It might be due to some additional factors. Furthermore, the Fig.5.6 shows that the Edu Ratio-2 has spatially varying relationship with the food insecurity incidence across the districts in Pakistan. In case of all districts of Sindh and Baluchistan, as well as, in most of the districts of Punjab and KPK, Edu Ratio-2 is insignificant, as indicated by the orange zones. However, it is significant (at 10%) in determining the food insecurity incidence in some of the districts of KPK and Punjab including Islamabad, as highlighted by the yellow zones.

### 5.1.4 Edu Ratio-3

The variable Edu Ratio-3 represents the proportion of household members having middle education. The variable is averaged at district level for GWR analysis. On the average, at district level, as the proportion of household members having middle education increases, the food insecurity incidence decreases. This result is in accordance with the fact that education has a positive impact on the food security status of households. As, it is shown in the Fig.5.7 that for all of the districts, the sign of the local parameter estimate is negative. Furthermore, the Fig.5.8 represents that the Edu Ratio-3 has spatially varying relationship with the food insecurity incidence across the districts in Pakistan. In case of all districts of Sindh and Baluchistan, as well as, in some of the districts of Punjab, Edu Ratio-3 is insignificant, as indicated by the orange zones. However, it is significant (at 10%) in determining the food insecurity incidence in all of the districts of KPK and most of the districts in Punjab including Islamabad, as highlighted by the yellow zones.


**Figure 5.7** Edu Ratio-3 Local Parameter Estimate, Parametric GWR

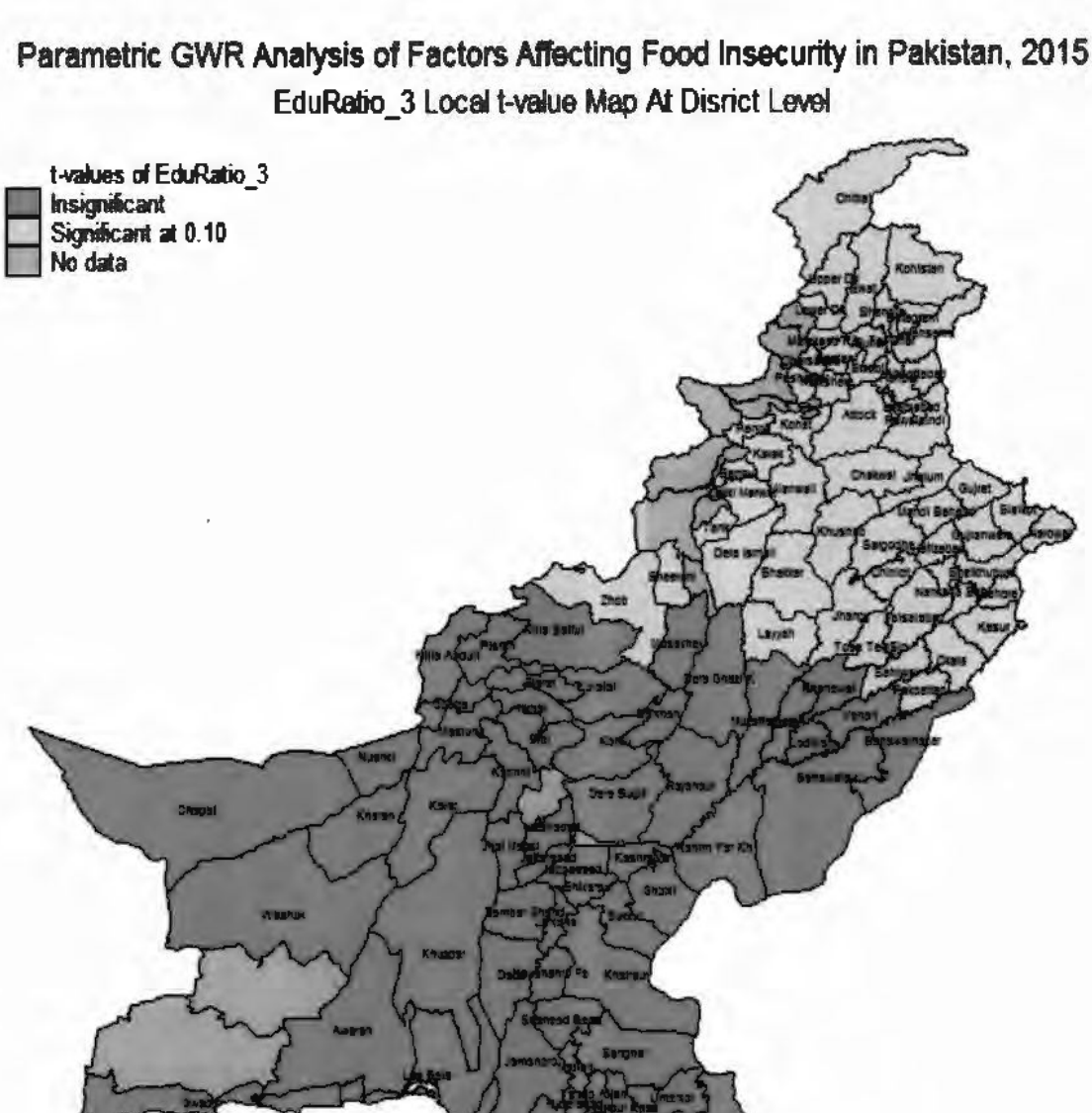


**Figure 5.8** Edu Ratio-3 Local t-value Estimate, Parametric GWR

### 5.1.5 Edu Ratio-4

The variable Edu Ratio-4 represents proportion of household members having secondary

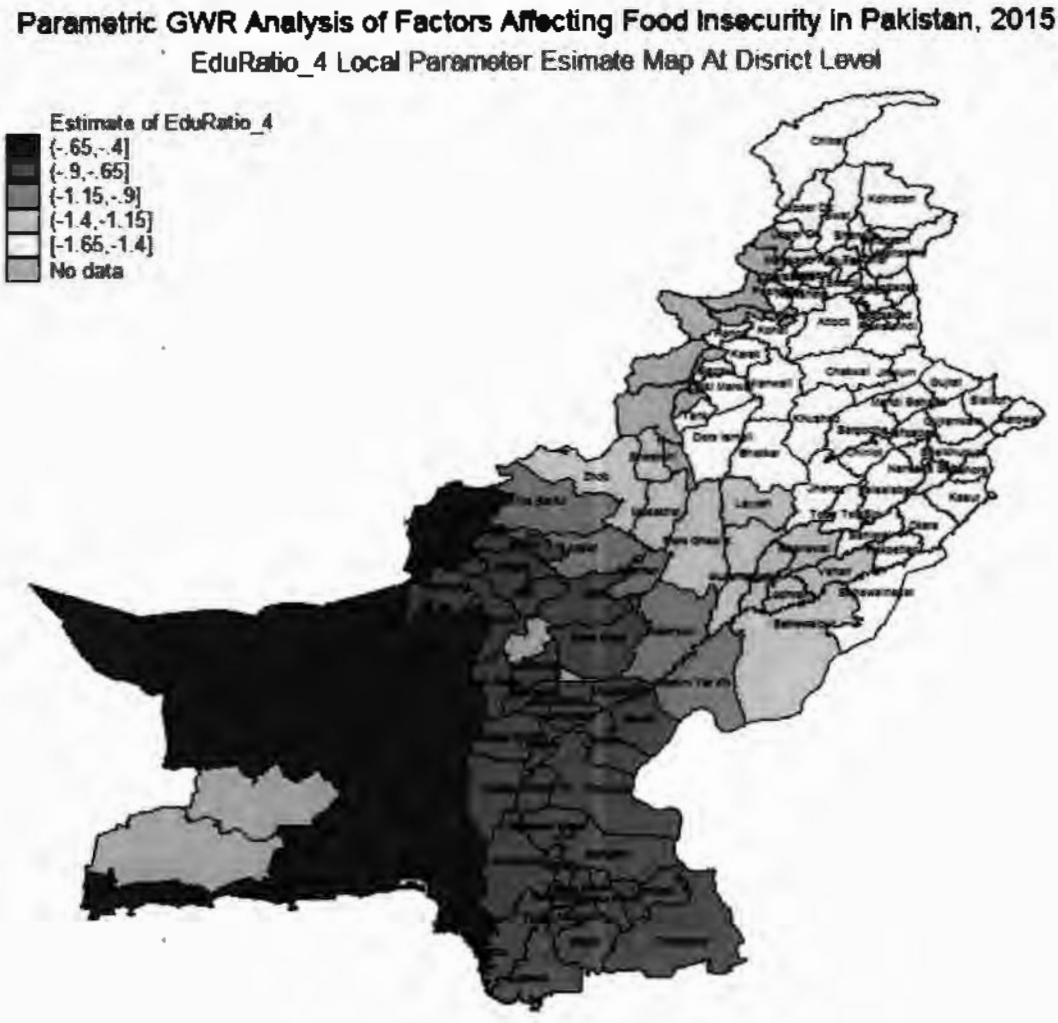


**Figure 5.9** Edu Ratio-4 Local Parameter Estimate, Parametric GWR

and above education. The variable is averaged at district level for GWR analysis. On the average, at district level, as the proportion of household members having secondary and above education increases, the food insecurity incidence decreases. This result is in accordance with the fact that education has a positive impact on the food security status of

households. As, it is shown in the Fig.5.9 that for all of the districts, the sign of the local parameter estimate is negative.

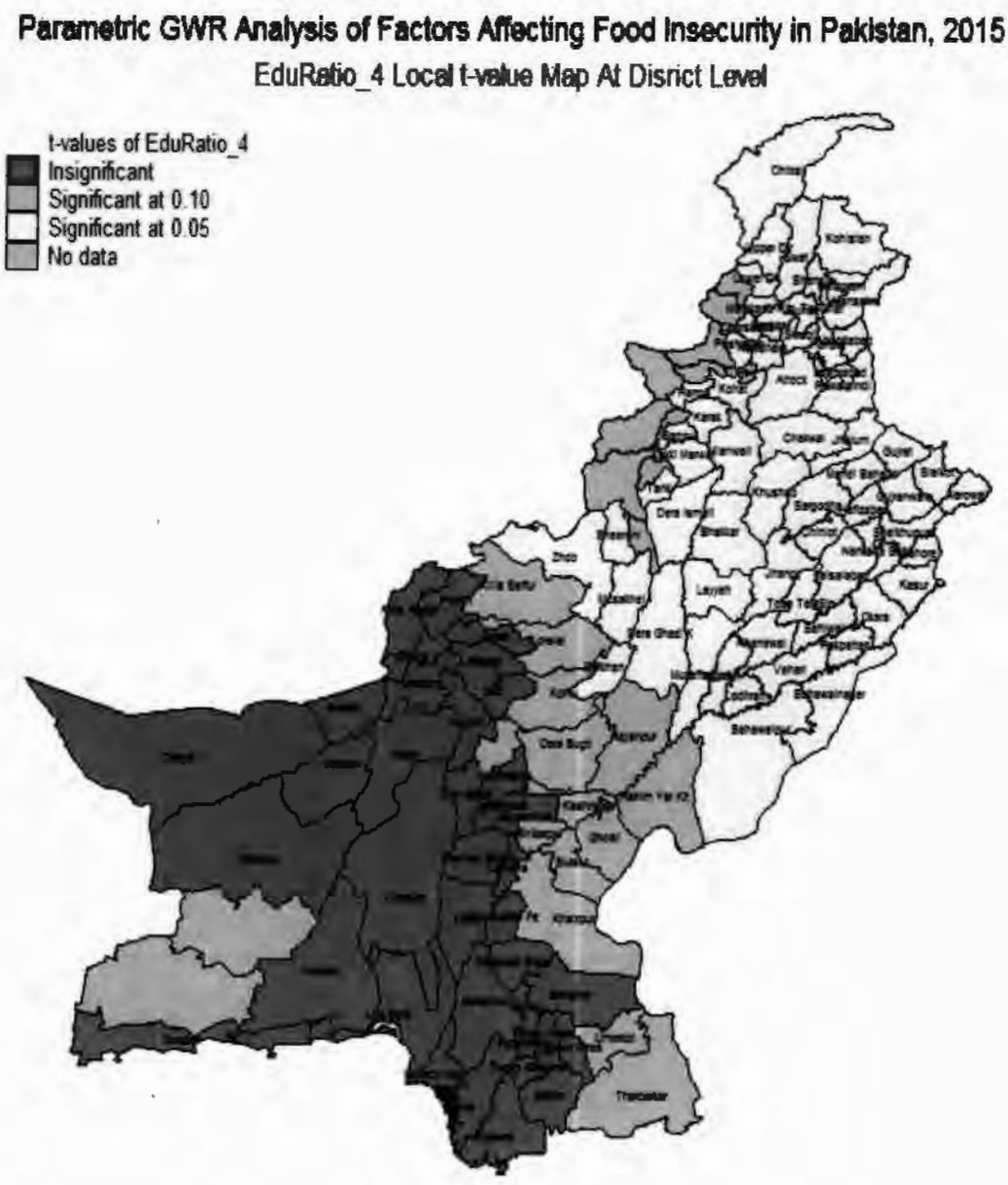


**Figure 5.10** Edu Ratio-4 Local t-value Estimate, Parametric GWR

Furthermore, the Fig.5.10 represents that the Edu Ratio-4 has spatially varying relationship with the food insecurity incidence across the districts in Pakistan. In case of Baluchistan, for most of the districts, Edu Ratio-4 is insignificant, as indicated by the dark purple zones, except for 8 districts. Of which, for 4 districts (Zhob, Sheerani, Musakhail and Barkhan), it is highly significant (at 5%), as depicted by mauve zones. While, for remaining 4 districts (Killa Saifullah, Loralai, Kohlu and Dera Bugti) it is less significant (at 10%), as shown by the light purple zones. On the other hand, in all the districts of KPK and Punjab, the concerned variable is highly significant (at 5%) as shown by the mauve zones, except for Rajanpur and Rahim Yar Khan. For which it is less significant as shown by the light purple zones. Similarly, in case of Sindh, it is less significant (at 10%) in determining the food insecurity incidence in Kashmor, Shikarpur, Khairpur, Ghotki, Sukkar, Umerkot and Tharparkar as shown by the light purple zones. While, it is insignificant in the rest of the districts from Sindh, as highlighted by the dark purple zones.

### 5.1.6 Boy

The variable boy represents no. of male children < 15 year of age in a household. For GWR analysis, it is averaged at district level. According to the results, the local parameter estimates have positive sign, as depicted in Fig.5.11. It shows a direct relationship between food insecurity incidence and average number of boys per household at district level.

The significance of the variable Boy is spatially variant across the Pakistani districts as shown in Fig.5.12. It is insignificant in all of the districts of KPK and Punjab except for Rajanpur and Rahim Yar Khan. For Rajanpur it is less significant and for Rahim Yar Khan it is more significant. In case of Sindh and Baluchistan, it is highly significant for all

districts except for Loralai, Barkhan and Killa Saifullah, for which it is less significant determinant of food insecurity incidence.

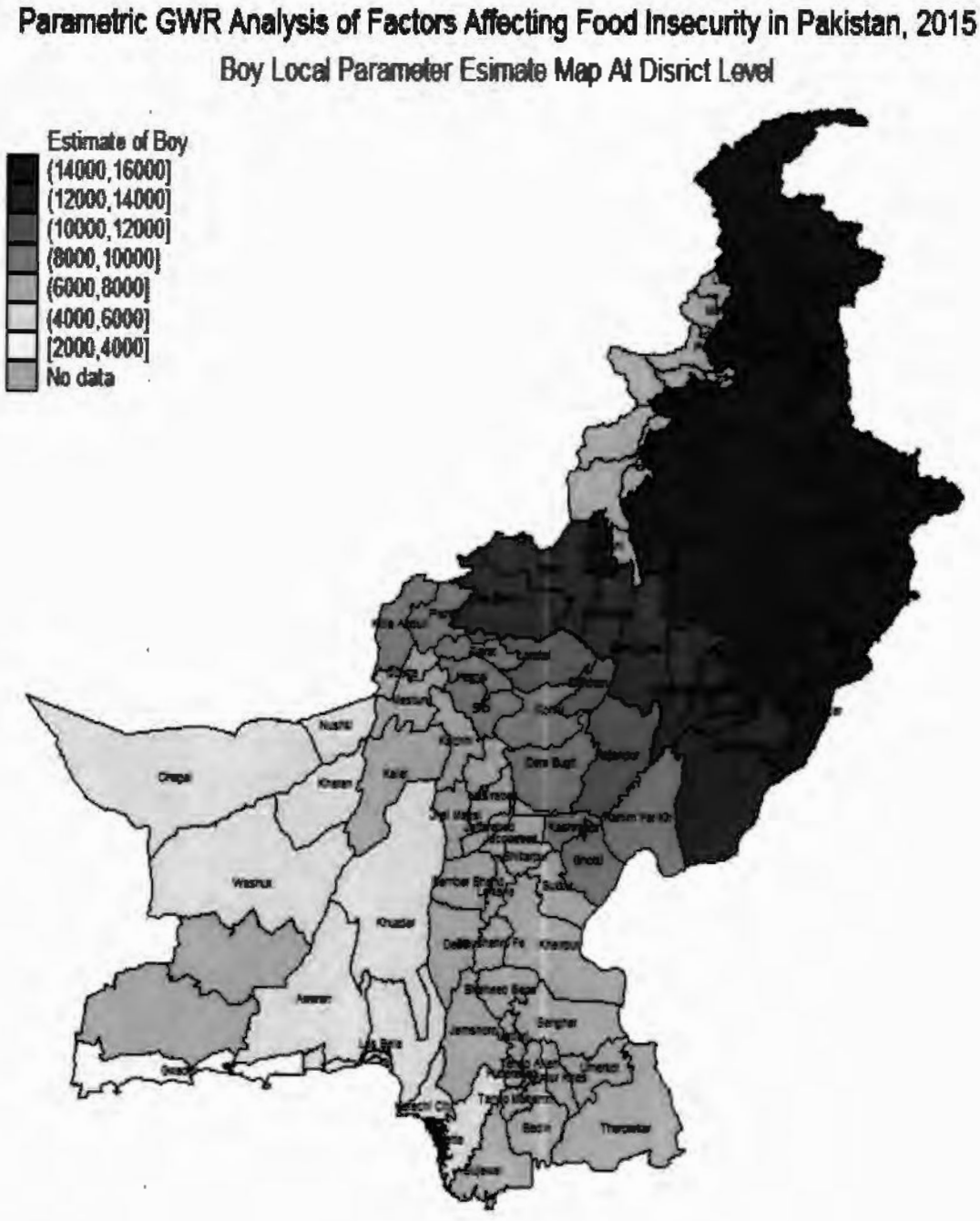


**Figure 5.11** Boy Local Parameter Estimate, Parametric GWR

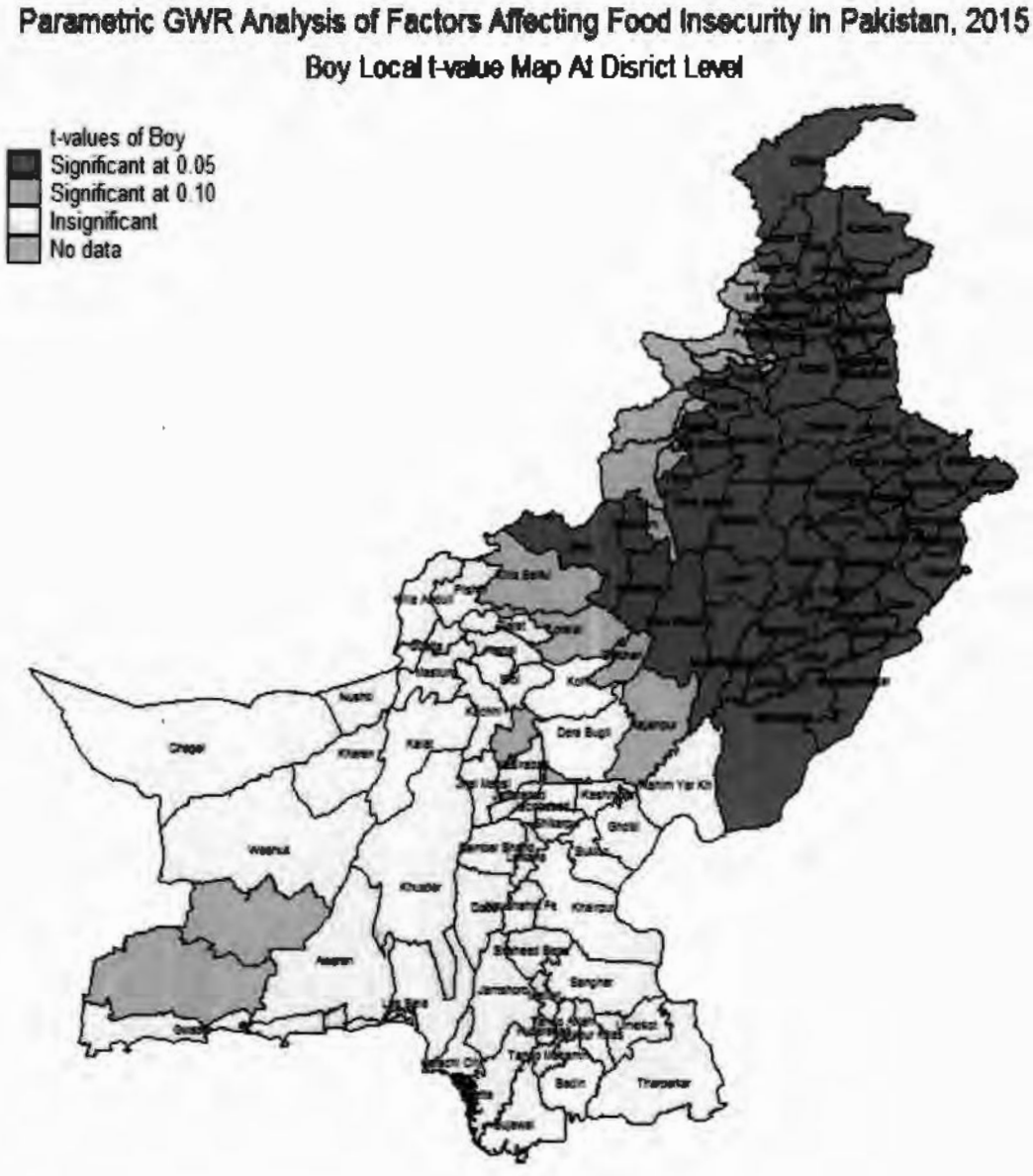


**Figure 5.12** Boy Local t-value Estimate, Parametric GWR

### 5.1.7 Girl

The variable Girl represents no. of female children < 15 year of age in a household. For GWR analysis, it is averaged at district level. According to the results, the local parameter

estimates have positive sign, as depicted in Fig.5.13. It shows a direct relationship between food insecurity incidence and average number of girls per household at district level.

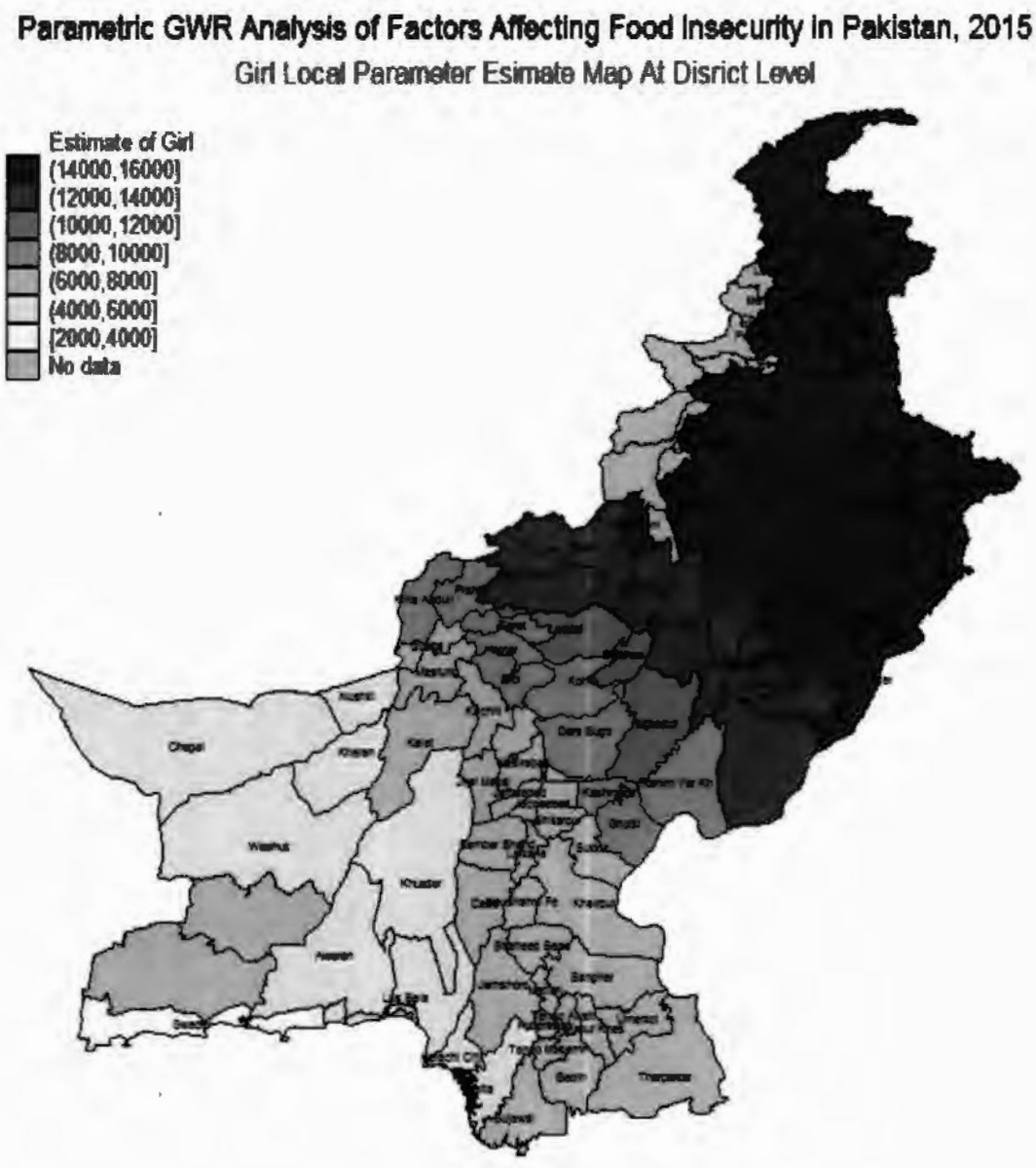


**Figure 5.13** Girl Local Parameter Estimate, Parametric GWR

The significance of the variable Girl is spatially variant across the Pakistani districts as shown in Fig.5.14. It is insignificant in all of the districts of KPK and Punjab except for Rajanpur and Rahim Yar Khan. For Rajanpur it is less significant and for Rahim Yar Khan

it is more significant. In case of Sindh and Baluchistan, it is highly significant for all districts except for Loralai, Barkhan and Killa Saifullah, for which it is less significant determinant of food insecurity incidence.

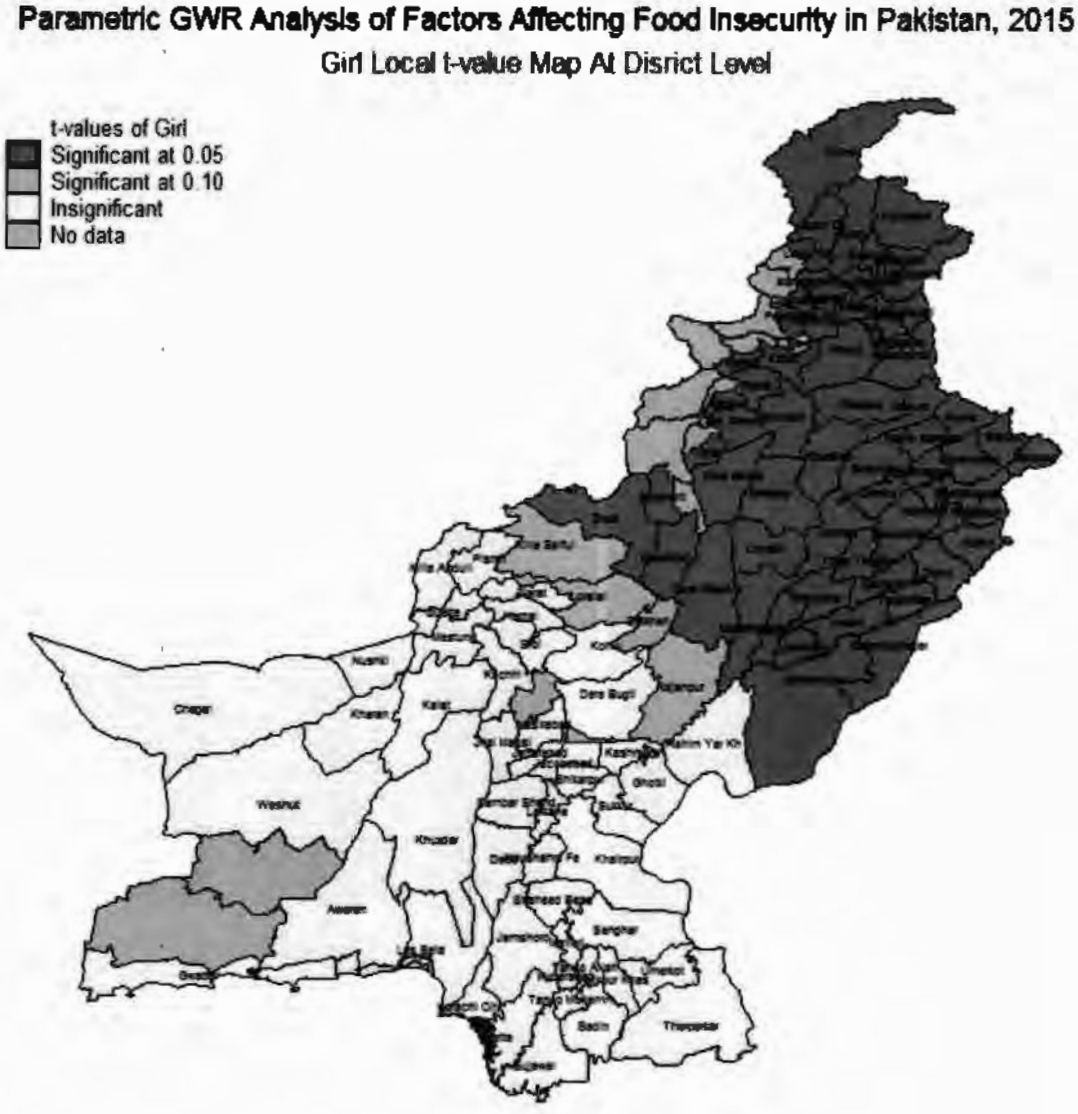


**Figure 5.14** Girl Local t-value Estimate, Parametric GWR

### 5.1.8 Kid

The variable Kid represents no. of children < 15 year of age in a household. For GWR analysis, it is averaged at district level. According to the results, the local parameter

estimates have negative sign, as depicted in Fig.5.15. It shows an indirect relationship between food insecurity incidence and average number of children per household at district level. Which might be due to the fact that the caloric requirement or food requirement is less for children as compared with adults. Also, the child labour might result in more income available to be spent on food.

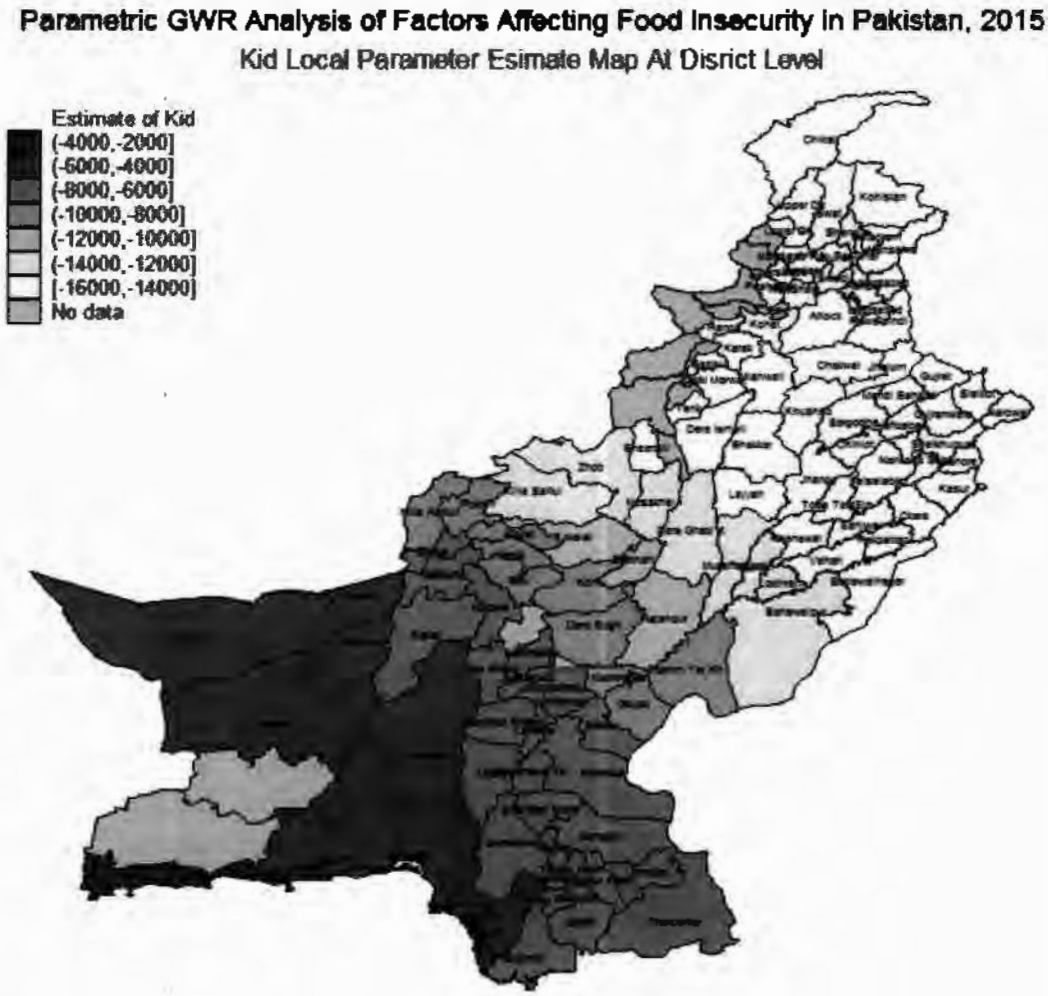


**Figure 5.15** Kid Local Parameter Estimate, Parametric GWR

The variable kid is insignificant in all districts of Sindh and Baluchistan except for Loralai, Barkhan and Killa Saifullah, for which it is less significant determinant of food insecurity

incidence. It is highly significant for all districts of KPK and Punjab, except for Rajanpur and Rahim Yar Khan. For Rajanpur it is less significant and for Rahim Yar Khan it is insignificant in determining the food insecurity incidence, as shown in the Fig.5.16.

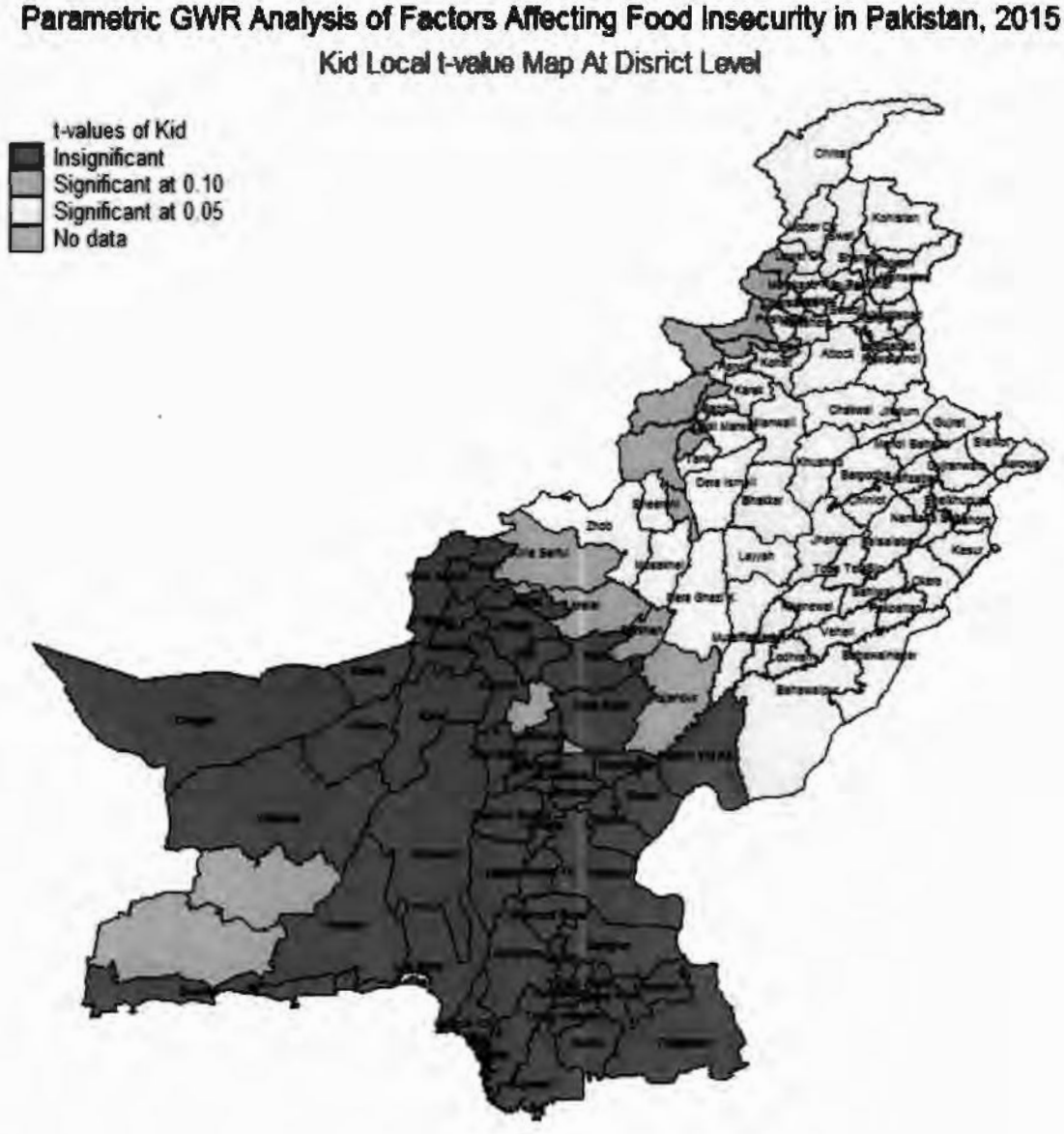


**Figure 5.16** Kid Local t-value Estimate, Parametric GWR

### 5.1.9 Girl Ratio

The variable Girl Ratio is the proportion of girls out of total number of children in a household. For GWR analysis, it is averaged at district level. As shown in the Fig.5.17, the sign of the local parameter estimate is positive. The coefficient estimate is larger in districts from KPK and Baluchistan. As, if there are more girls than boys, due to customs girls do not work outside.

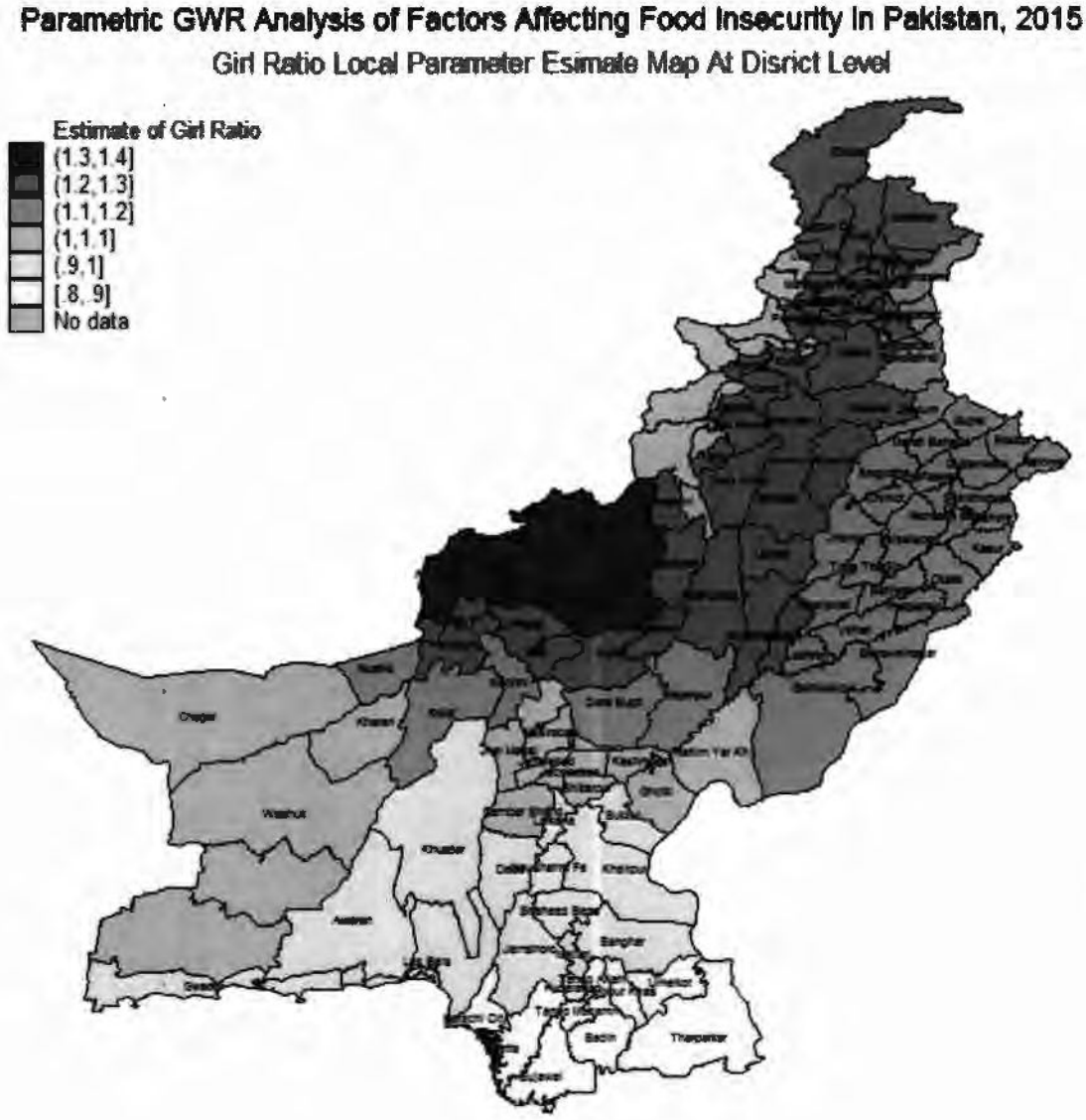


**Figure 5.17** Girl Ratio Local Parameter Estimate, Parametric GWR

So, the income available for food expenditure will be less and there will be high food insecurity incidence. Or, due to customs households in such districts do not spend much on the food requirement of girls as much as they spend for boys.

According to the results shown in Fig.5.18, the variable Girl Ratio is highly significant in all of the districts in Pakistan.

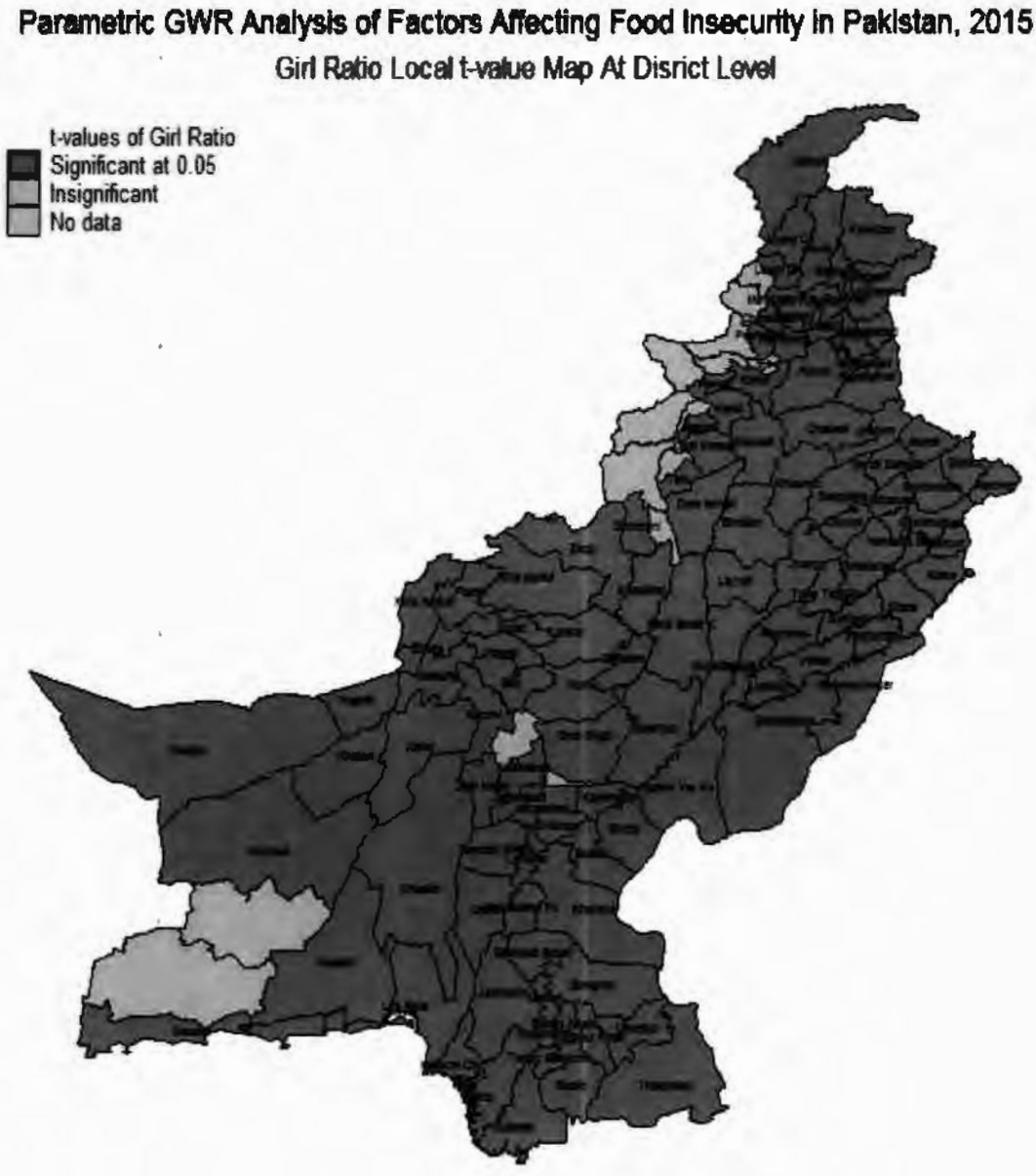


**Figure 5.18** Girl Ratio Local t-value Estimate, Parametric GWR

### 5.1.10 No Girl

The variable No Girl is a binary variable, where its value equal 1 means no girl and 0 otherwise. For the GWR analysis, its proportion is taken at district level. The negative sign of the local parameter estimates as shown in Fig.5.19, indicate that lower the proportion of no girl at district level, higher will be the food insecurity incidence.

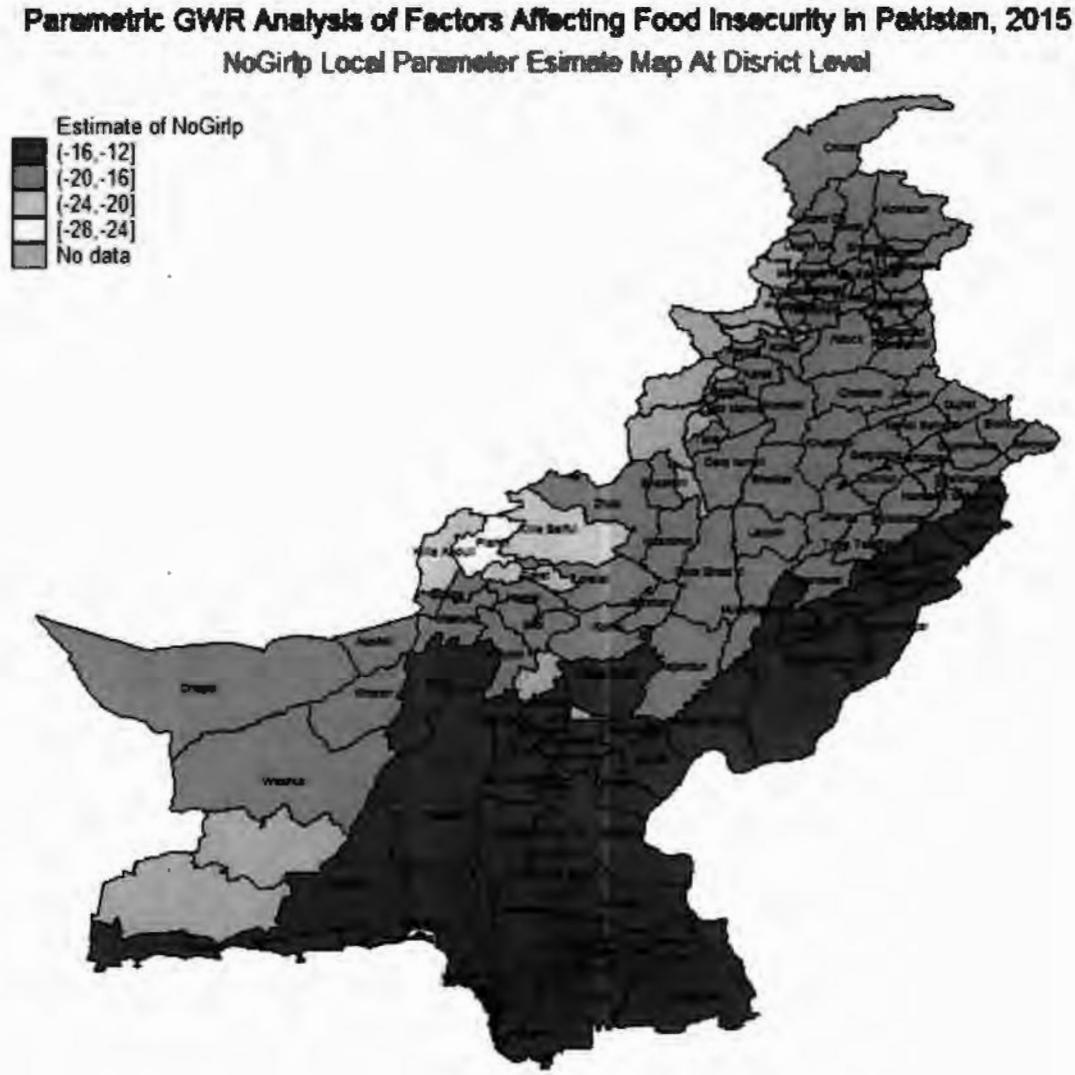


**Figure 5.19** No Girl Local Parameter Estimate, Parametric GWR

The variable No Girl has spatially varying relationship with the food insecurity incidence across the districts in Pakistan, as visualized in Fig.5.20. It is significant (at 10%) for all

the districts of Punjab including Islamabad, and highly significant (at 5%) for Dera Ghazi Khan. It is significant (at 10%) for all of the districts of KPK except for Dera Ismail Khan, Tank, Laki Marwat and Bannu, for which, it is highly significant. In case of Sindh, it is insignificant for Sanghar, Tando Muhammad, Tando Allah Yar, Thatta, Hyderabad, Badin, Tharparkar, Umerkot, Sujawal, and Mirpukhas, while it significant (at 10%) for rest of the districts. For Baluchistan, it is less significant for most of the districts and highly significant for some districts.

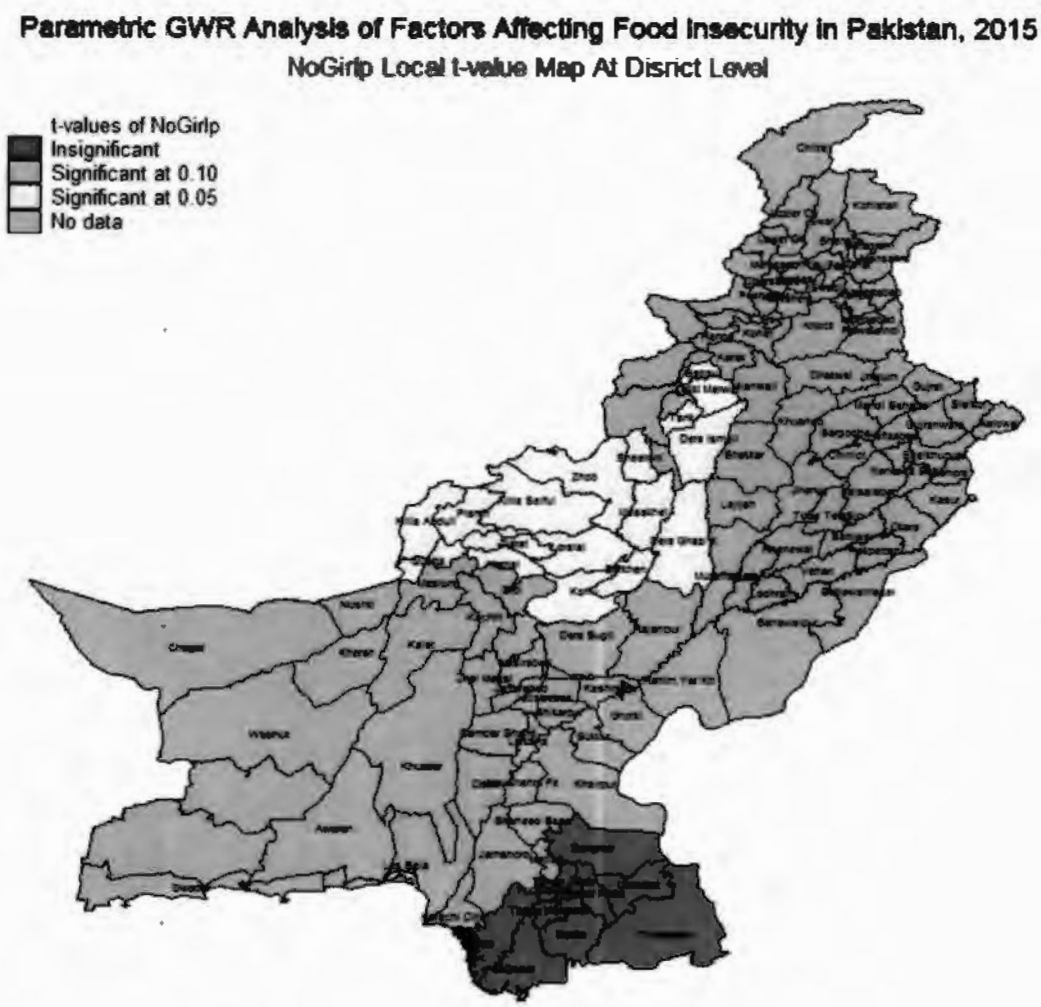


**Figure 5.20** No Girl Local t-value Estimate, Parametric GWR

### 5.1.11 No Kid

The variable No Kid is a binary variable, where its value equal 1 means no Kid and 0 otherwise. For the GWR analysis, its proportion is taken at district level. The positive sign of the local parameter estimates as shown in Fig.5.21, indicate that lower the proportion of households with no kid at district level, lower will be the food insecurity incidence.

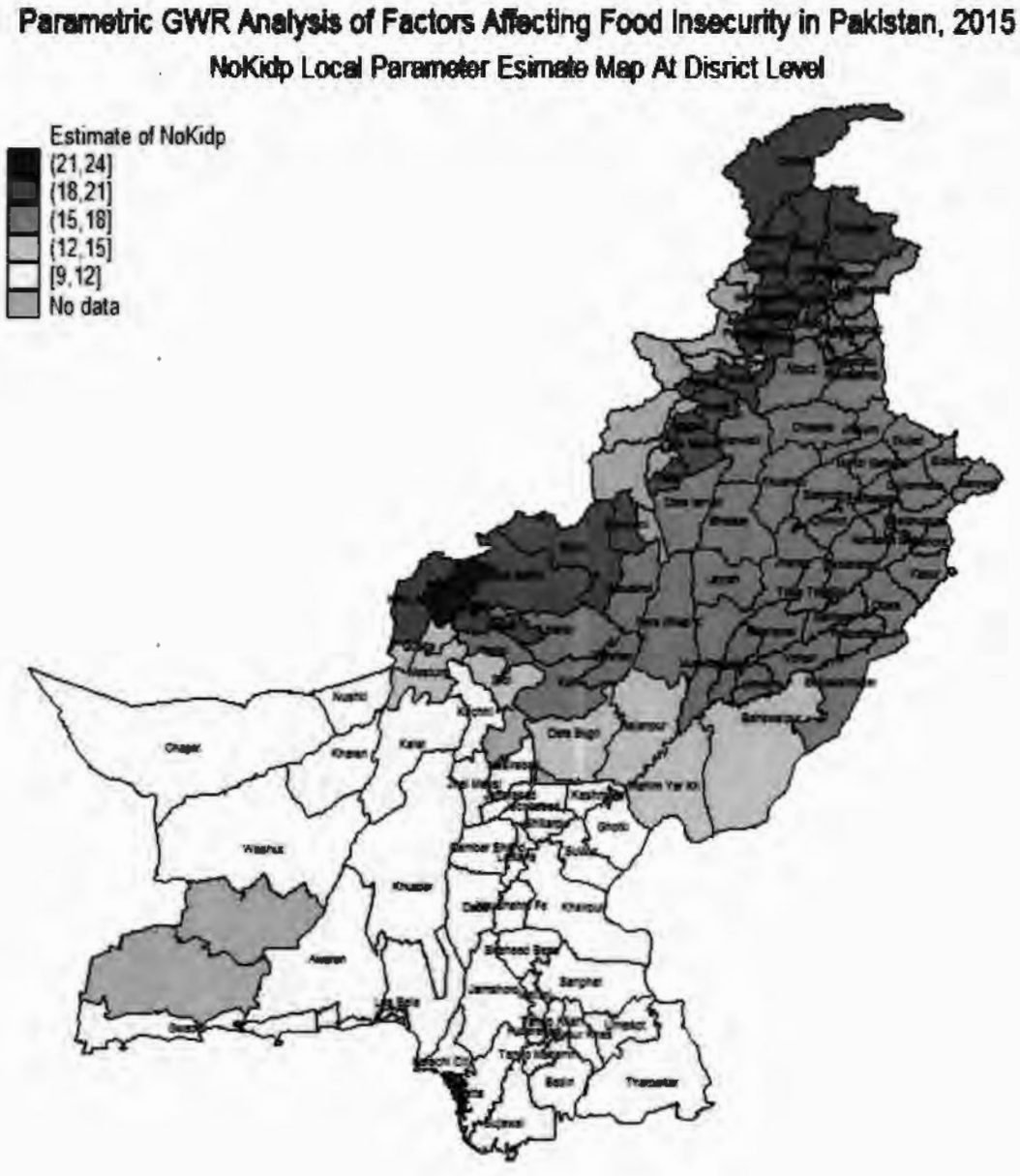


**Figure 5.21** No Kid Local Parameter Estimate, Parametric GWR

As the households with all adult members will require more food expenditures. The variable No Kid is highly significant in all the districts of Punjab and KPK including Islamabad. On the other hand, in case of Sindh, it is highly significant for Jacobabad, Ghotki, Kashmor and Shikarpur, while it is less significant for rest of the districts.

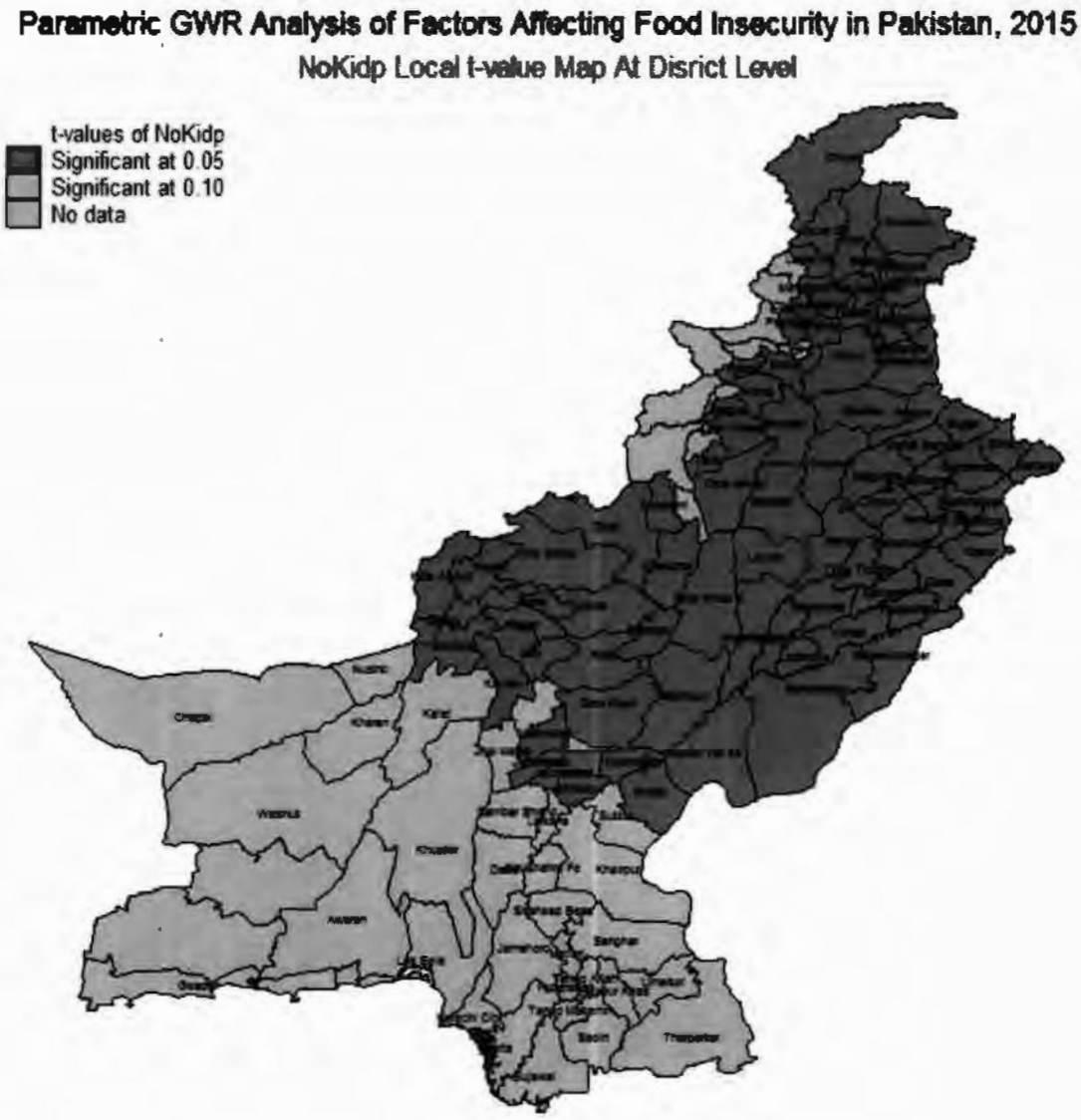


**Figure 5.22** No Kid Local t-value Estimate, Parametric GWR

However, in Baluchistan, it is highly significant for approximately half of the districts and less significant for the rest of the districts, as depicted in the Fig.5.22.

### 5.1.12 Sex Ratio

The variable Sex Ratio is the proportion of females in a household. For the GWR analysis it is averaged at district level. For almost all of the districts, the sign of the local parameter estimate is positive, as shown in the Fig.5.23. It means on the average, the more is the proportion of female members in a household, the more is the food insecurity incidence at district level.

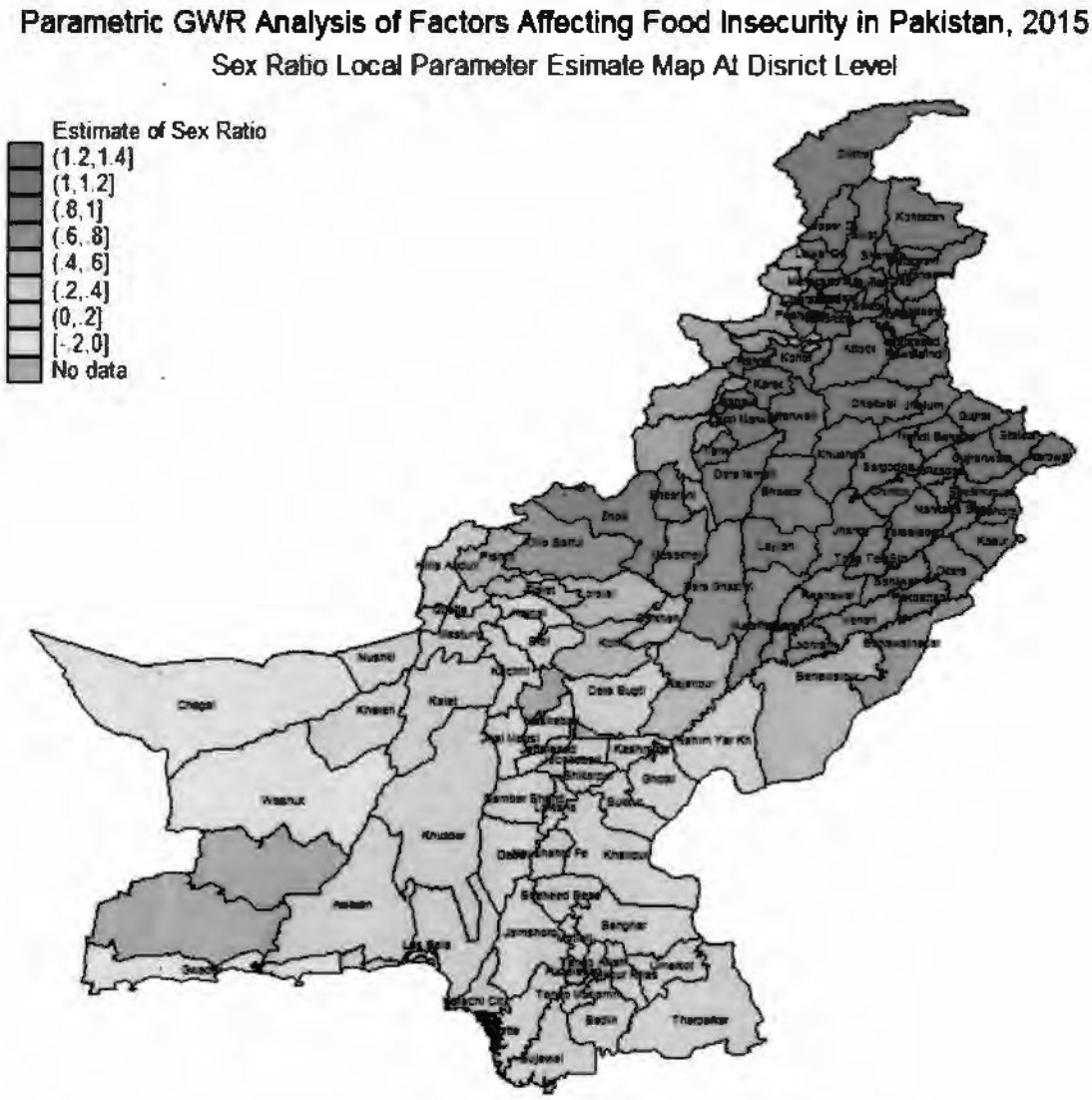


**Figure 5.23** Sex Ratio Local Parameter Estimate, Parametric GWR

The significance of variable Sex Ratio is spatially varying in determining the food insecurity incidence across the districts in Pakistan. It is insignificant in all the districts of Sindh and Baluchistan. Contrarily, in KPK, it is significant (at 10%) in all districts except for Dera Ismail Khan. However, in case of Punjab, it is significant for some districts as indicated by orange zone in the Fig.5.24, while for most of the districts it is insignificant.

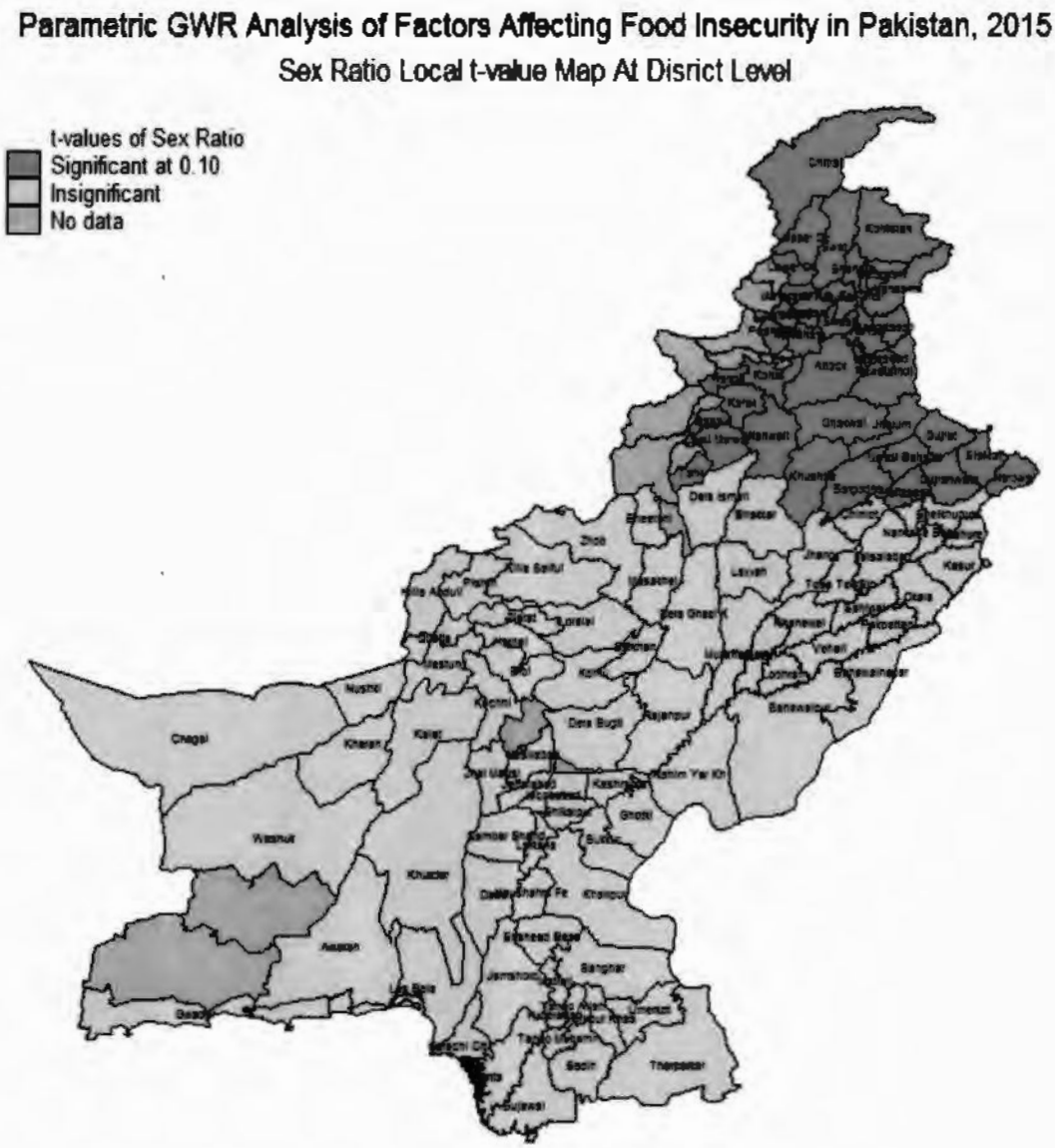


**Figure 5.24** Sex Ratio Local t-value Estimate, Parametric GWR

### 5.1.13 Sex ratio Adult Men

The variable Sex Ratio Adult Men is the proportion of adult men (15<age<65) in a household. Its average is taken at district level, for the GWR analysis. The sign of the local parameter estimate is positive, as shown in the Fig.5.25. As the caloric requirement of Adult men is more, the higher is the proportion of adult men on the average at district level, the more will be the food insecurity incidence.

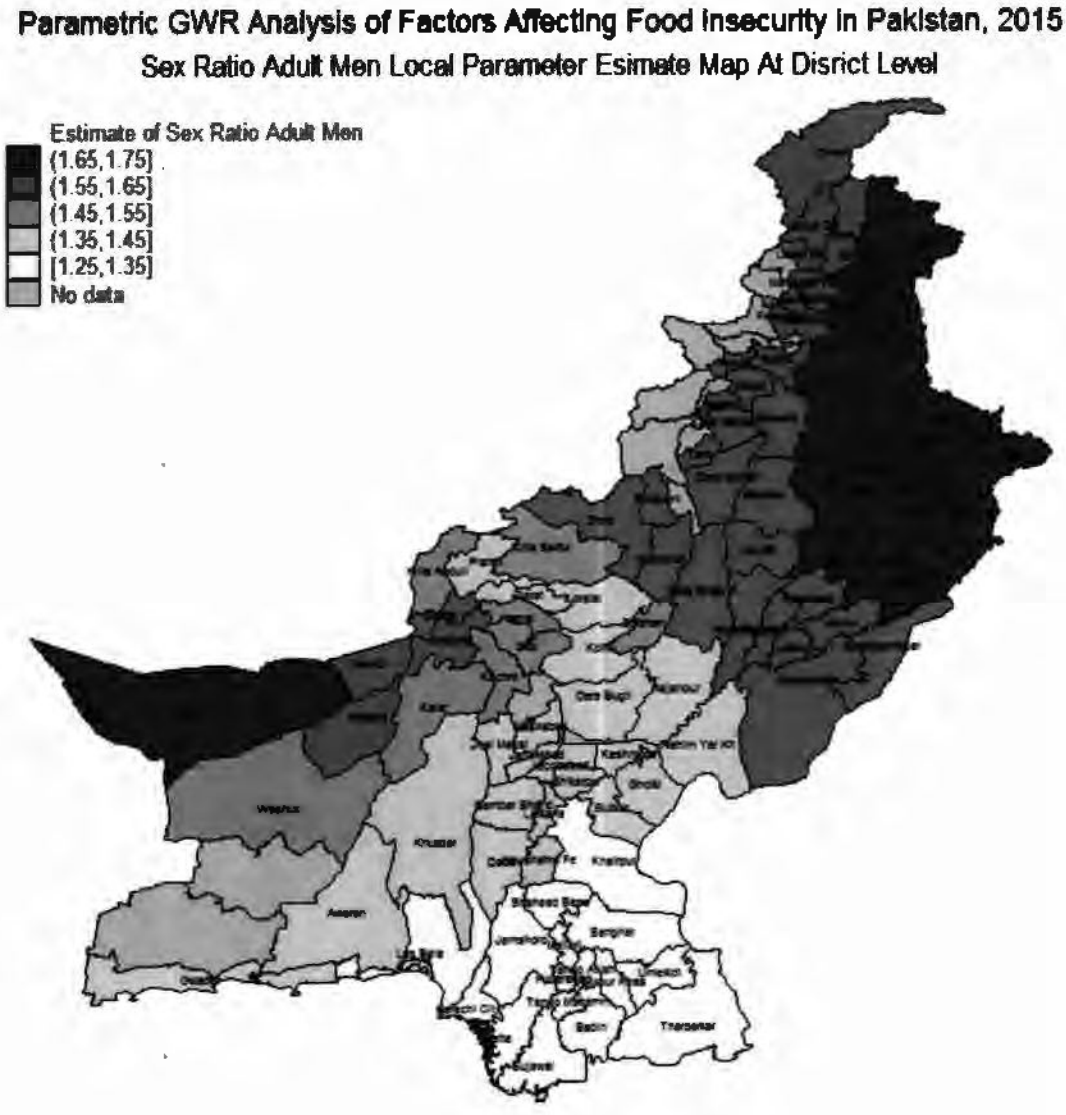


**Figure 5.25** Sex Ratio Adult Men Local Parameter Estimates, Parametric GWR

The variable Sex Ratio Adult Men has spatially varying significance in determining the food insecurity incidence across the districts in Pakistan as shown in Fig.5.26. It is highly significant in all districts of KPK except for Upper Dir, Lower Dir and Chitral, for which it is less significant. Similarly, in Punjab, it is highly significant for all the districts except for Rajanpur and Rahim Yar Khan, whereas, it is less significant. In Baluchistan, for Lasbela and Gawadar, it is insignificant, while, it is less significant for rest of the districts. Similarly, in Sindh, it is insignificant in case of Karachi, Hyderabad, Sujawal, Badin, Thatta and Tandu Muhammad, while it is less significant for the rest of the districts.

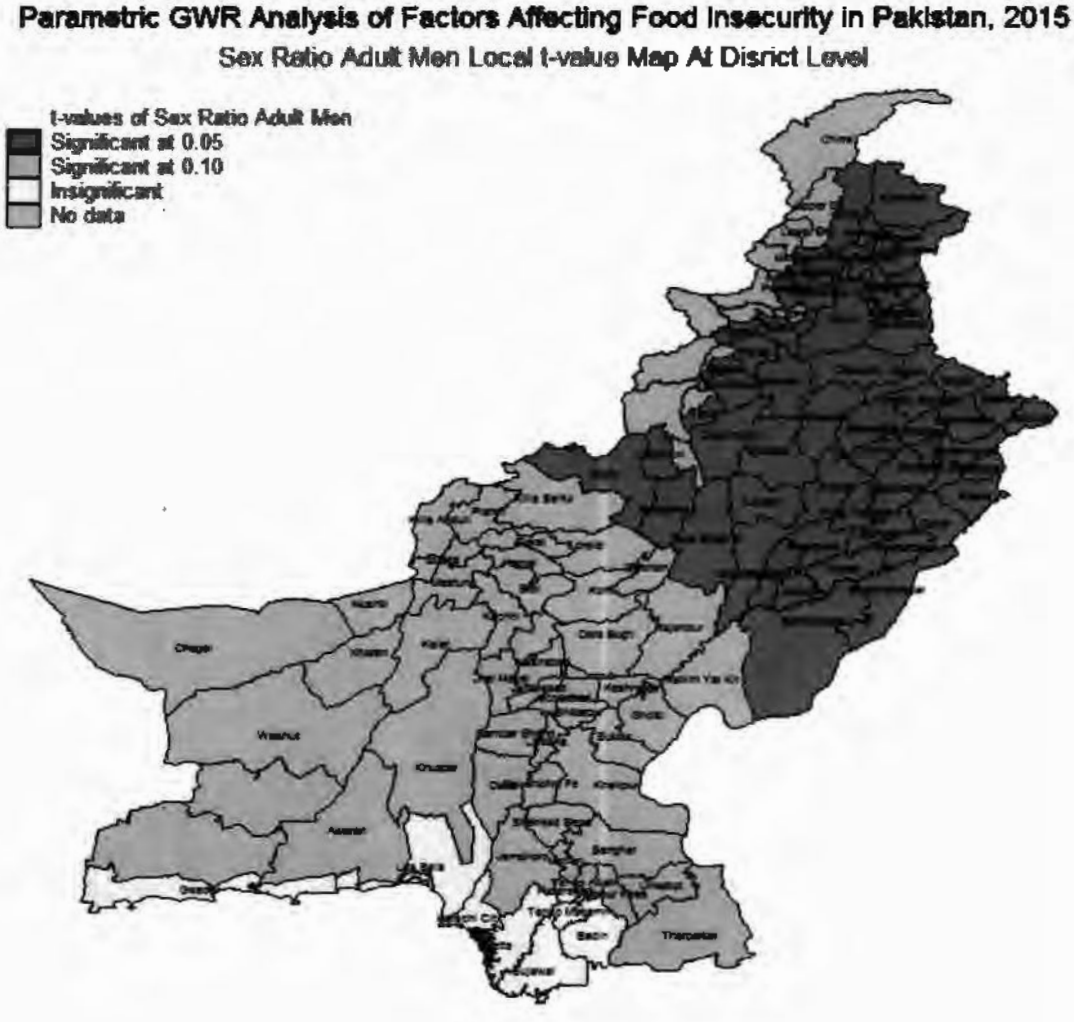


**Figure 5.26** Sex Ratio Adult Men Local t-value Estimates, Parametric GWR

### 5.1.14 Language New-4

The variable Language New-4 represents Pashto as household language. It's a binary variable with 1 equal Pashto and 0 otherwise. For the GWR analysis, its proportion is taken at district level. As depicted in the Fig.5.27, the sign of the local parameter estimate is negative.

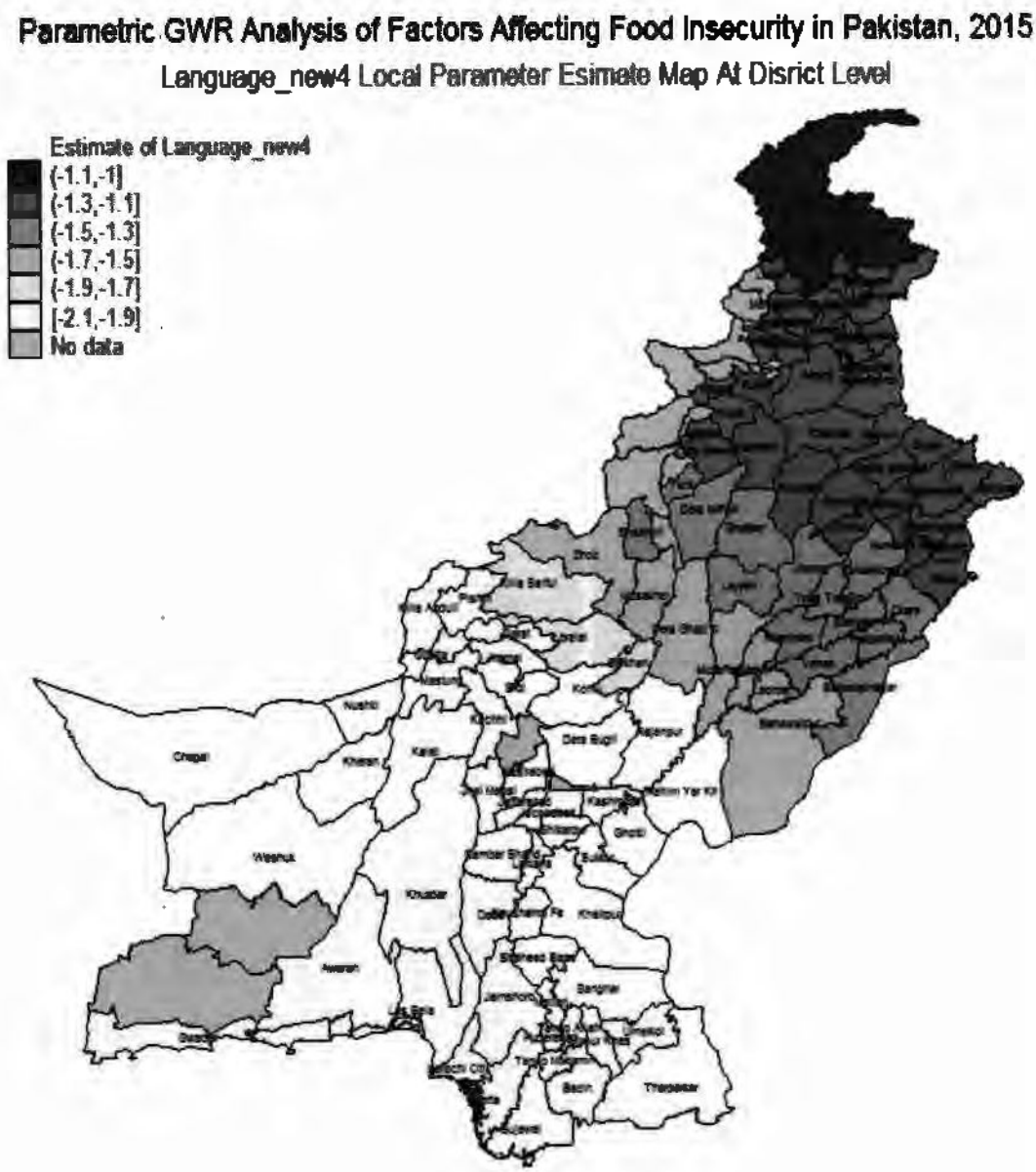


**Figure 5.27 Language new-4** Local Parameter Estimates, Parametric GWR

As shown in the Fig.5.28, the variable Language new-4 is significant across all the districts, in determining the food insecurity incidence in Pakistan.

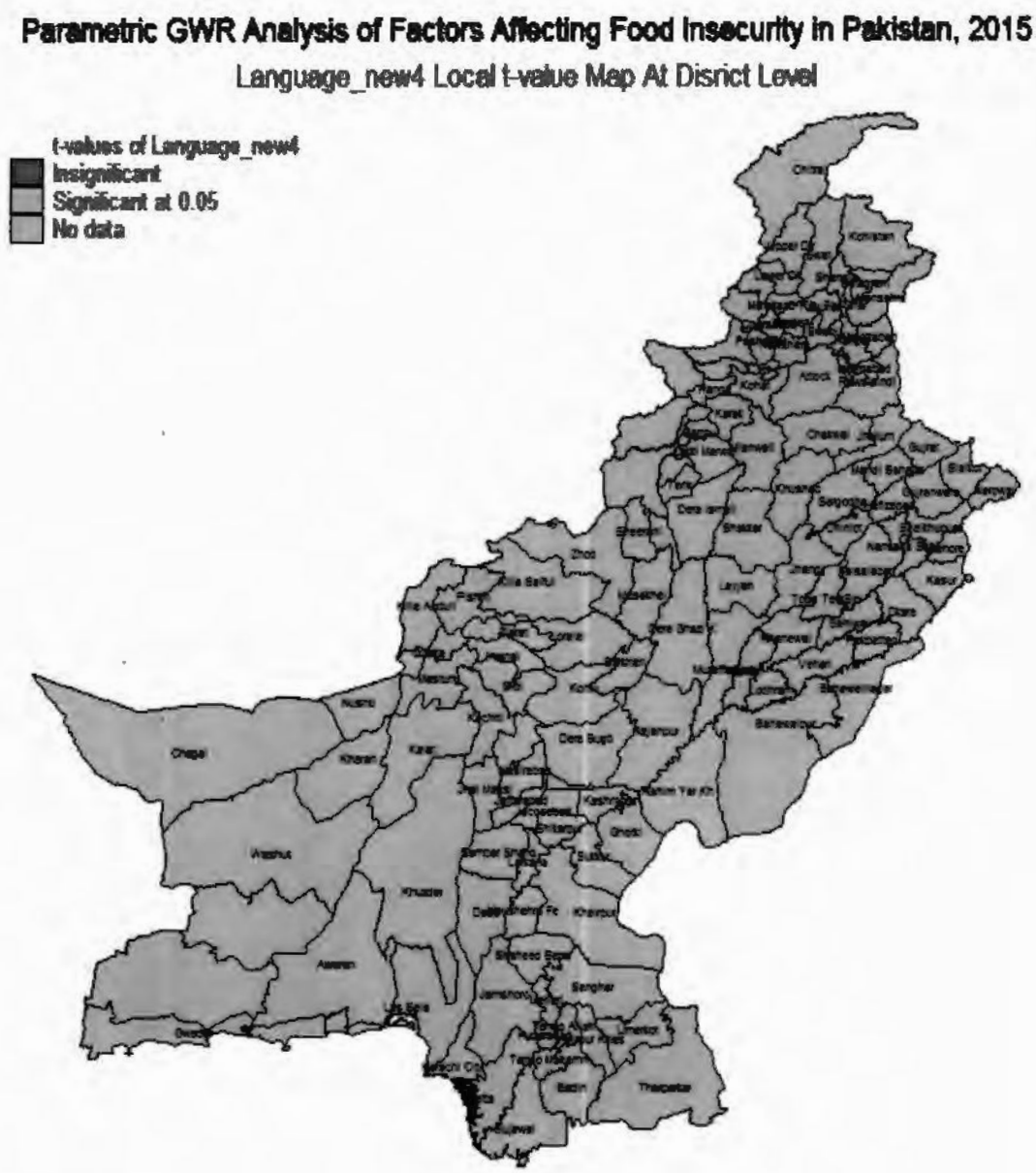


**Figure 5.28 Language new-4** Local t-value Estimates, Parametric GWR

### 5.1.15 Language New-5

The variable Language New-5 represents languages other than Urdu, Sindhi, Punjabi and Pashto as household language. It's a binary variable with 1 equal other language and 0

otherwise. For the GWR analysis, its proportion is taken at district level. As depicted in the Fig.5.29, the sign of the local parameter estimate is positive.

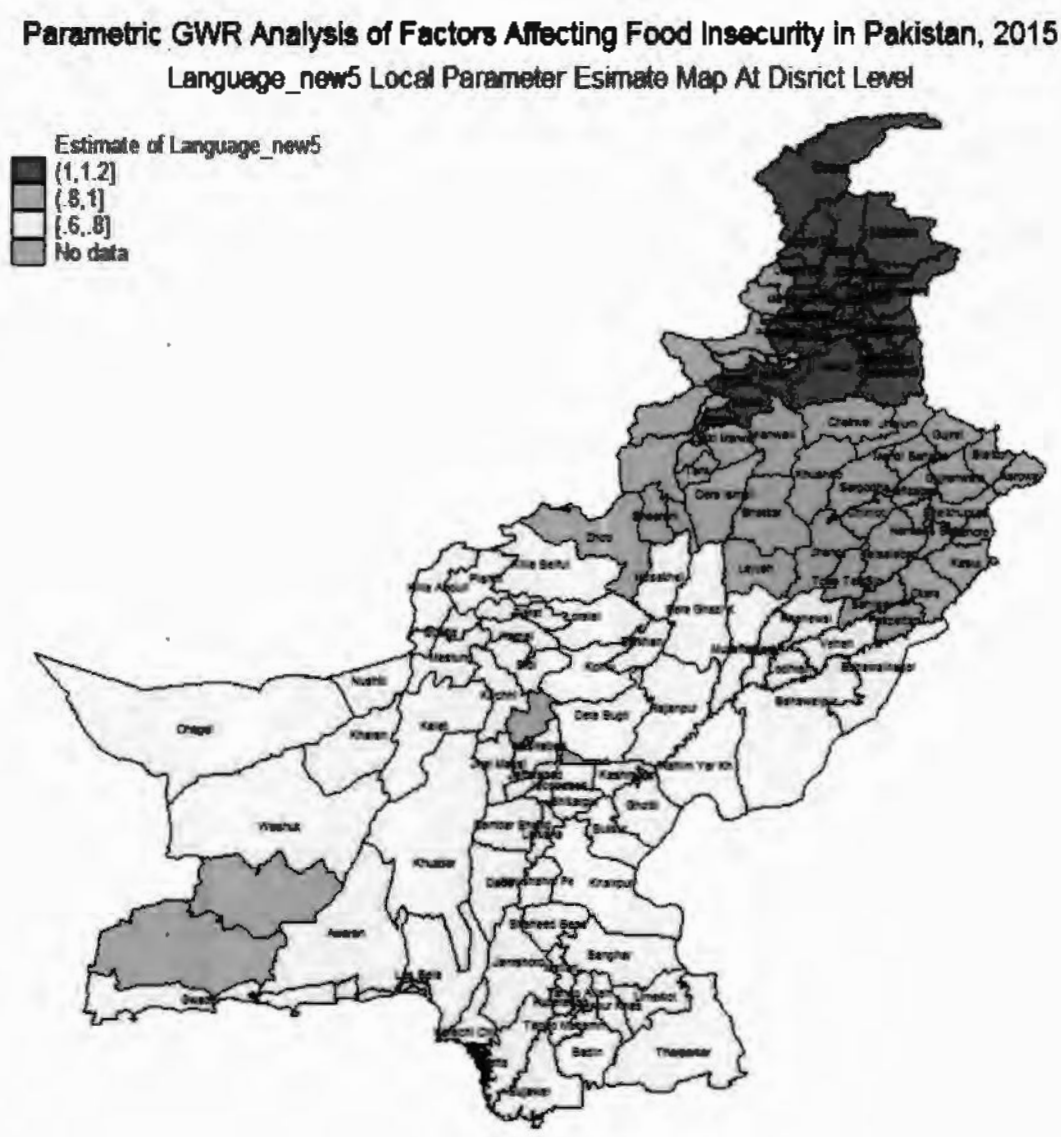


**Figure 5.29 Language new-5** Local Parameter Estimates, Parametric GWR

The variable Language New-5 has spatially varying significance in determining the food insecurity incidence across the districts in Pakistan as shown in Fig.5.30. It is highly significant in all districts of KPK and Sindh. Similarly, in Punjab, it is highly significant

for all the districts except for Rajanpur and Rahim Yar Khan, whereas, it is less significant. In Baluchistan, it is highly significant for most of the districts, while, it is less significant for some districts.

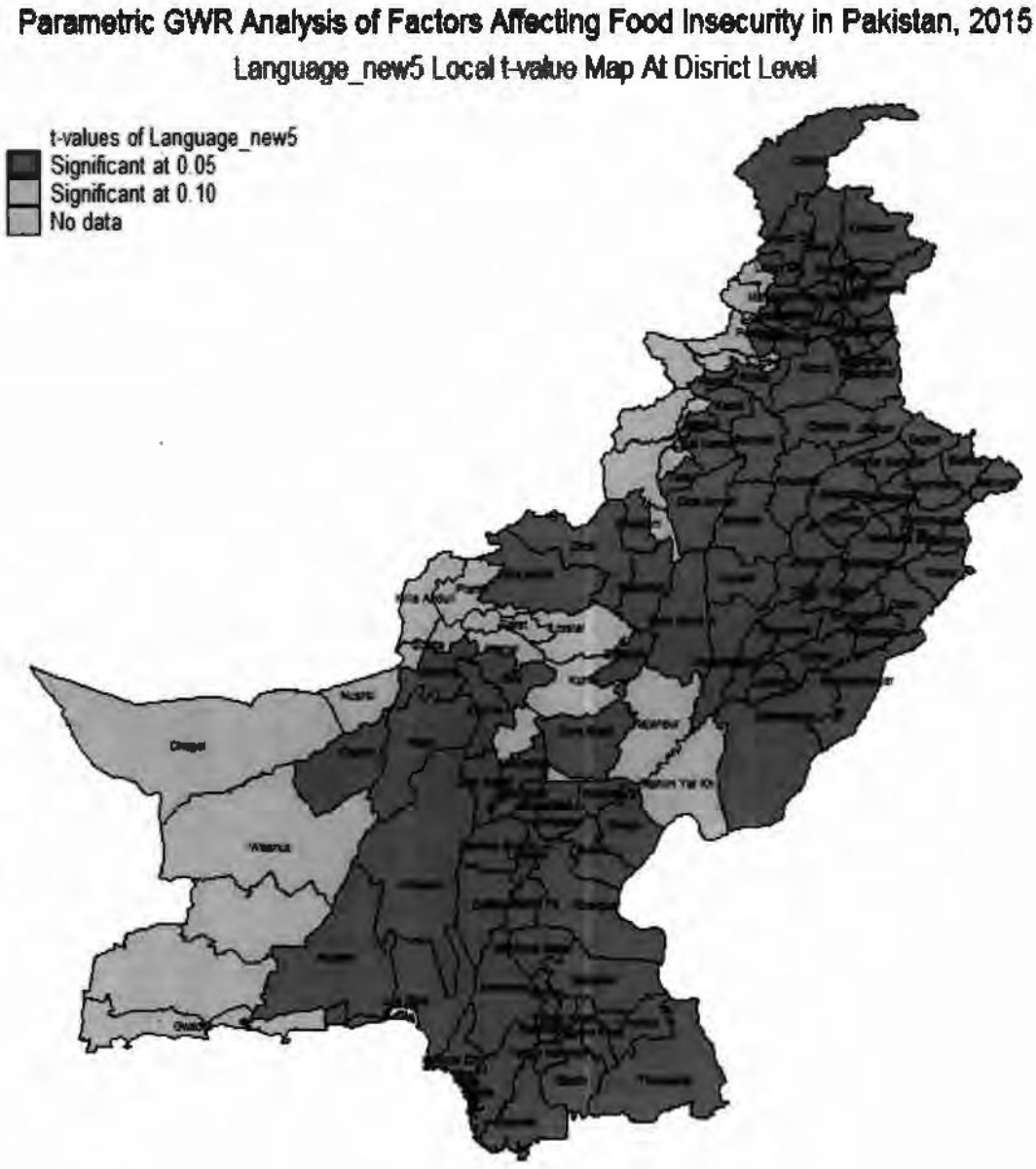


**Figure 5.30 Language new-5** Local t-value Estimates, Parametric GWR

### 5.1.16 Marital-2

The variable Marital-2 represents the marital status of a household member as married. It is a binary variable with 1 equal married and 0 otherwise. Its proportion is taken at district level. The sign of the local parameter estimate is positive for all the districts, representing its direct relationship with the food insecurity incidence as depicted in Fig.5.31.

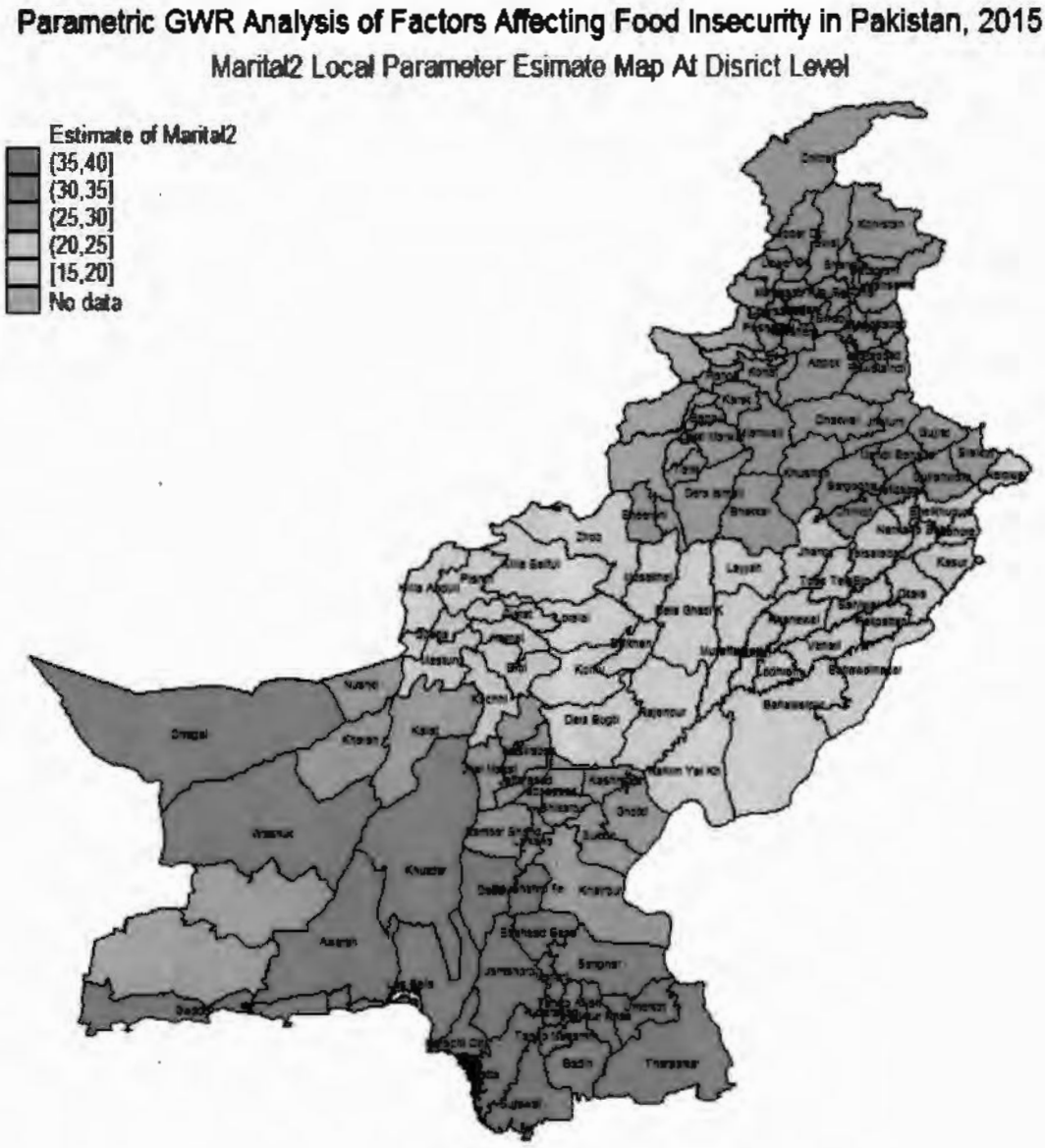


**Figure 5.31 Marital-2** Local Parameter Estimates, Parametric GWR

The significance of the variable Marital-2 is spatially varying across the districts in Pakistan, as depicted in the Fig.5.32. The variable is significant in all districts of KPK. On the other hand, it is insignificant in all districts of Baluchistan except for Sheerani, Gawadar, Awaran and Las Bela. However, in case of Punjab and Sindh, it is significant in some districts and insignificant in other.

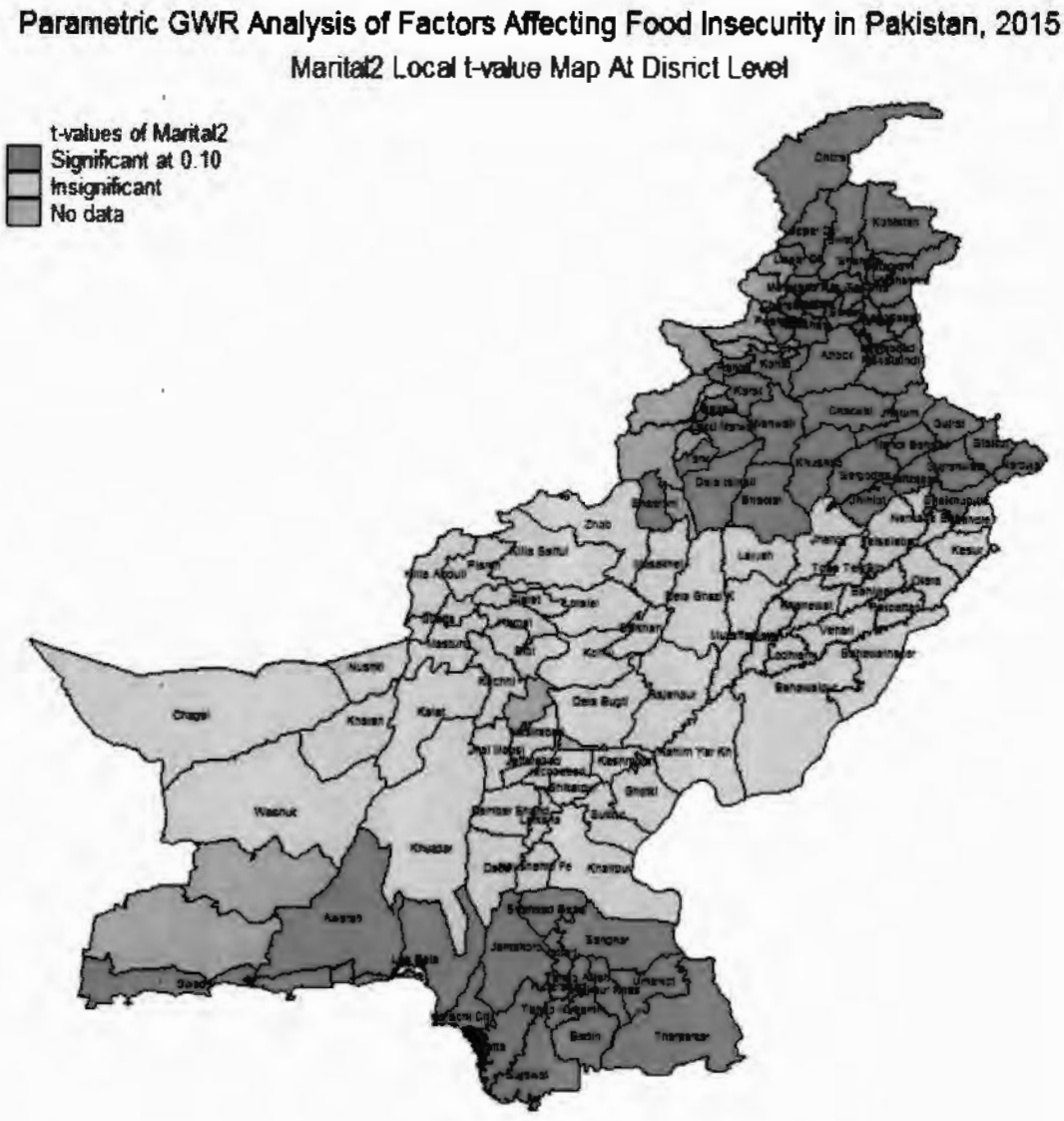


**Figure 5.32 Marital-2** Local t-value Estimates, Parametric GWR

### 5.1.17 Marital-3

The variable Marital- represents the marital status of a household member as widow/ divorced. It is a binary variable with 1 equal widow/ divorced and 0 otherwise. Its proportion is taken at district level. The sign of the local parameter estimate is positive for all the districts, representing its direct relationship with the food insecurity incidence, as depicted in Fig.5.33.

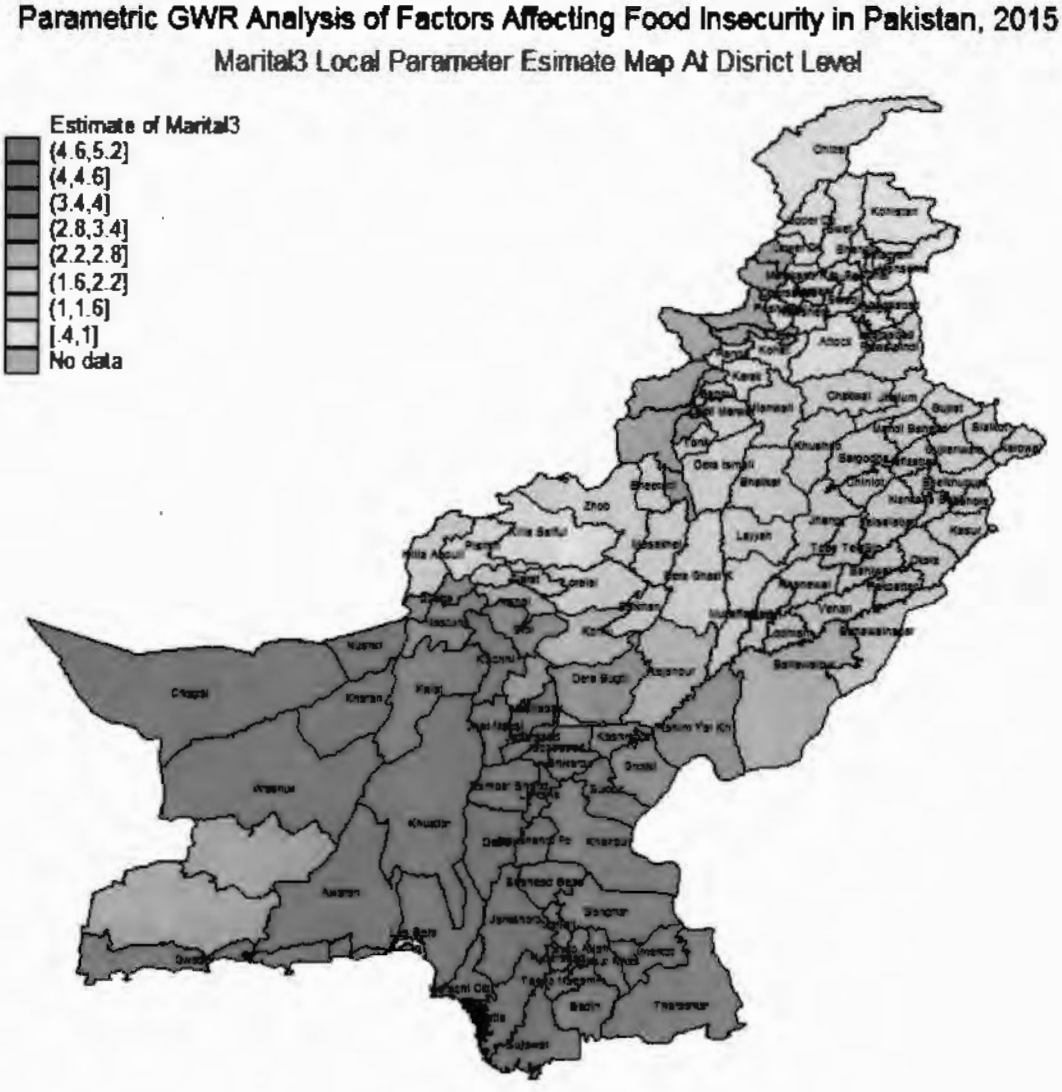


**Figure 5.33 Marital-3** Local Parameter Estimates, Parametric GWR

The variable Marital-3 has spatially varying relationship with the food insecurity incidence across the districts in Pakistan, as visualized in Fig.5.34. The variable is insignificant in case of all the districts of KPK and Punjab including Islamabad. Conversely, it is significant in most of the districts of Sindh except for Jacobabad, Sakkar, Ghotki, Shikarpur and Kashmor. However, in Baluchistan, the variable is significant in Gawadar, Chaghi, Awaran, Las Bela, Khuzdar, Washuk, Kalat, Jhal Magsi and Kharan districts.

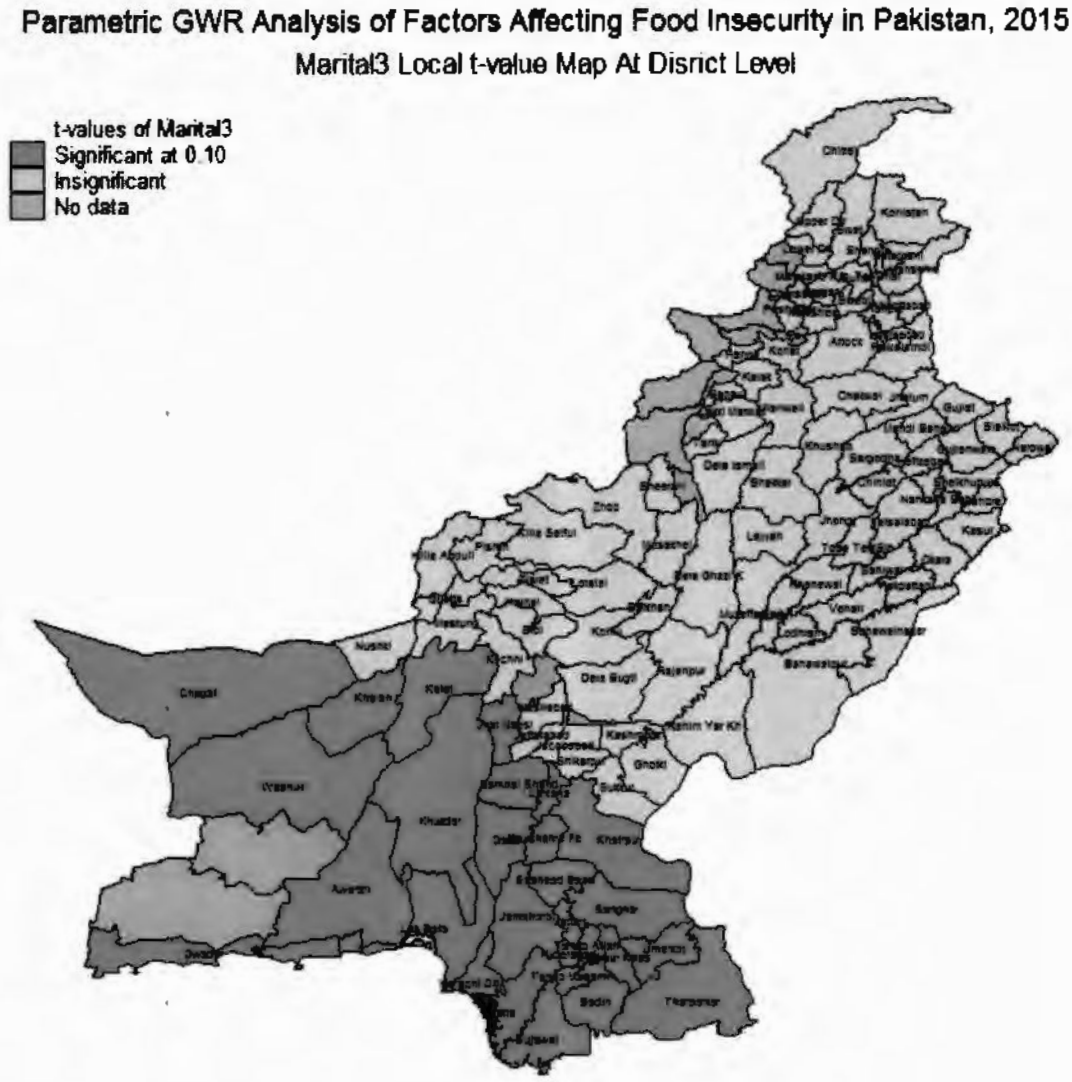


**Figure 5.34 Marital-3** Local t-value Estimates, Parametric GWR

### 5.1.18 Ownership-1

The variable Ownership-1 represents the housing status of the household as owned. It is a binary variable with 1 equal owned housing and 0 otherwise. For the sake of GWR analysis, its proportion is taken at district level. According to the results depicted in the Fig.5.35, the sign of the local parameter estimate is negative in case of all districts of Sindh and most of the districts in Baluchistan. While it is positive for the KPK and Punjab districts. It might be due to some additional factors.

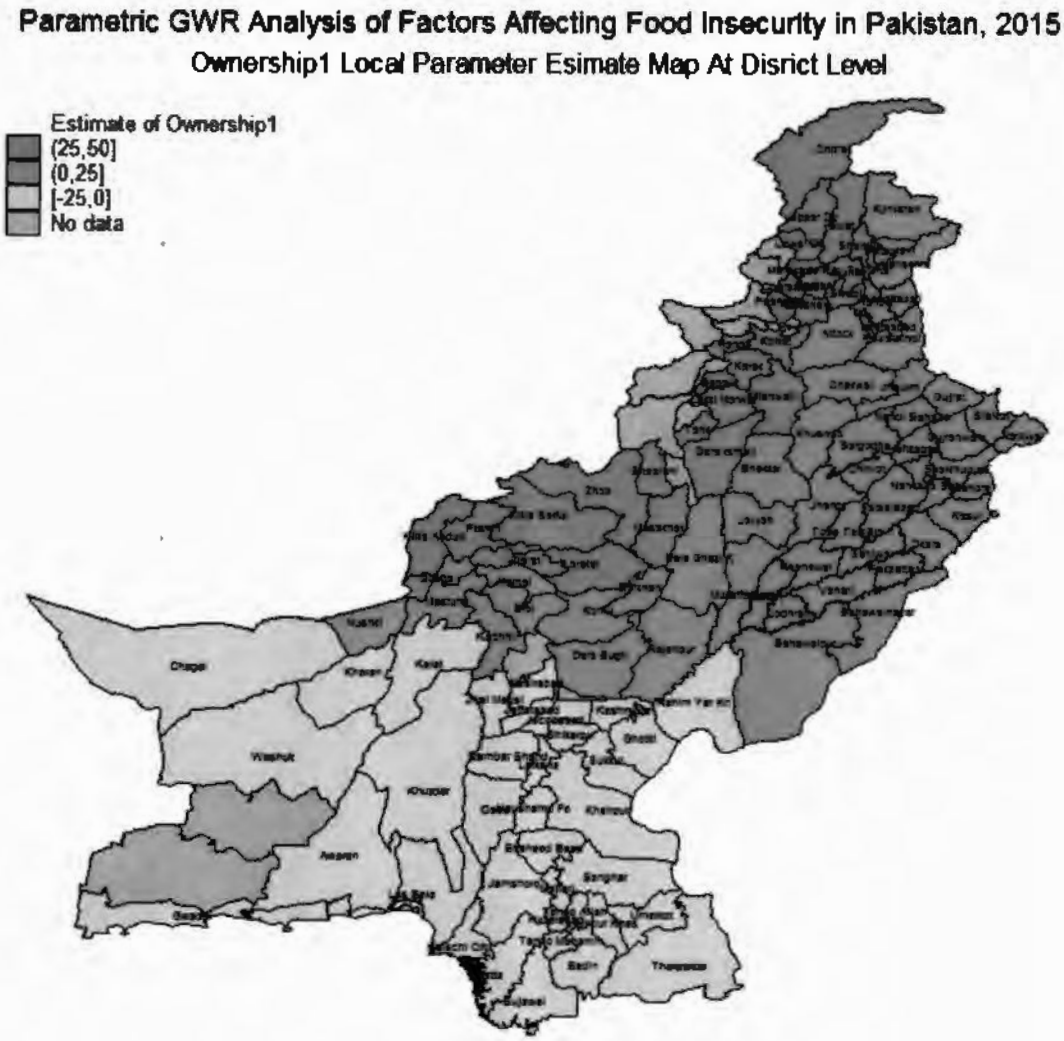


**Figure 5.35 Ownership-1** Local Parameter Estimates, Parametric GWR

The variable Ownersip-1 has spatially varying significance across the districts in determining the food insecurity incidence in Pakistan. As shown in the Fig.5.36, the variable is significant only in Killa Abdullah, district of Baluchistan. While, it is insignificant in all other districts of Pakistan.

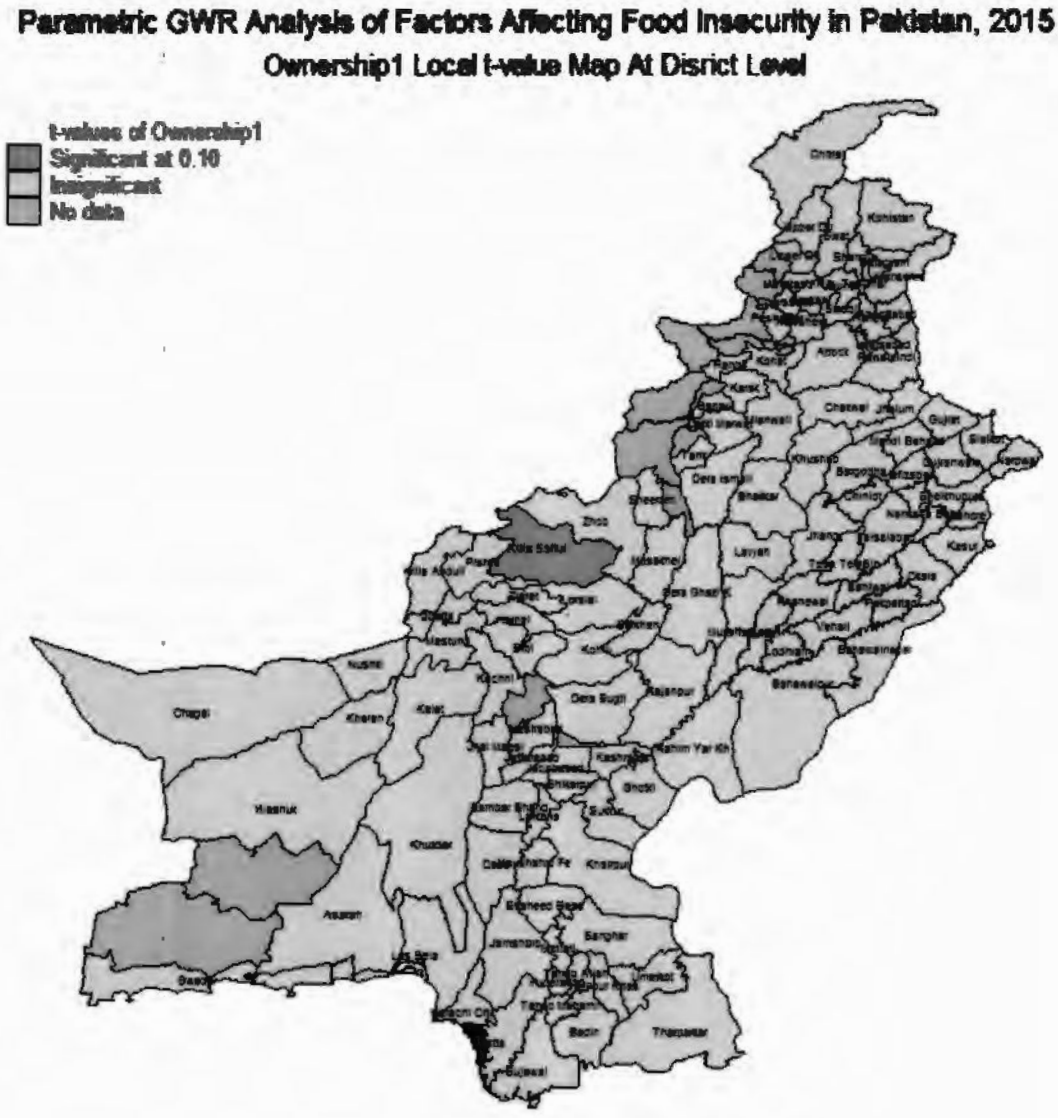


**Figure 5.36 Ownership-1** Local t-value Estimates, Parametric GWR

### 5.1.19 Ownership-3

The variable Ownership-3 represents the housing status of the household as rent free. It is a binary variable with 1 equal rent free housing and 0 otherwise. For the sake of GWR analysis, its proportion is taken at district level. According to the results depicted in the Fig.5.37, the sign of the local parameter estimate is negative in case of all districts in Pakistan. It means, higher is the proportion of rent free housing, less is the food insecurity incidence.

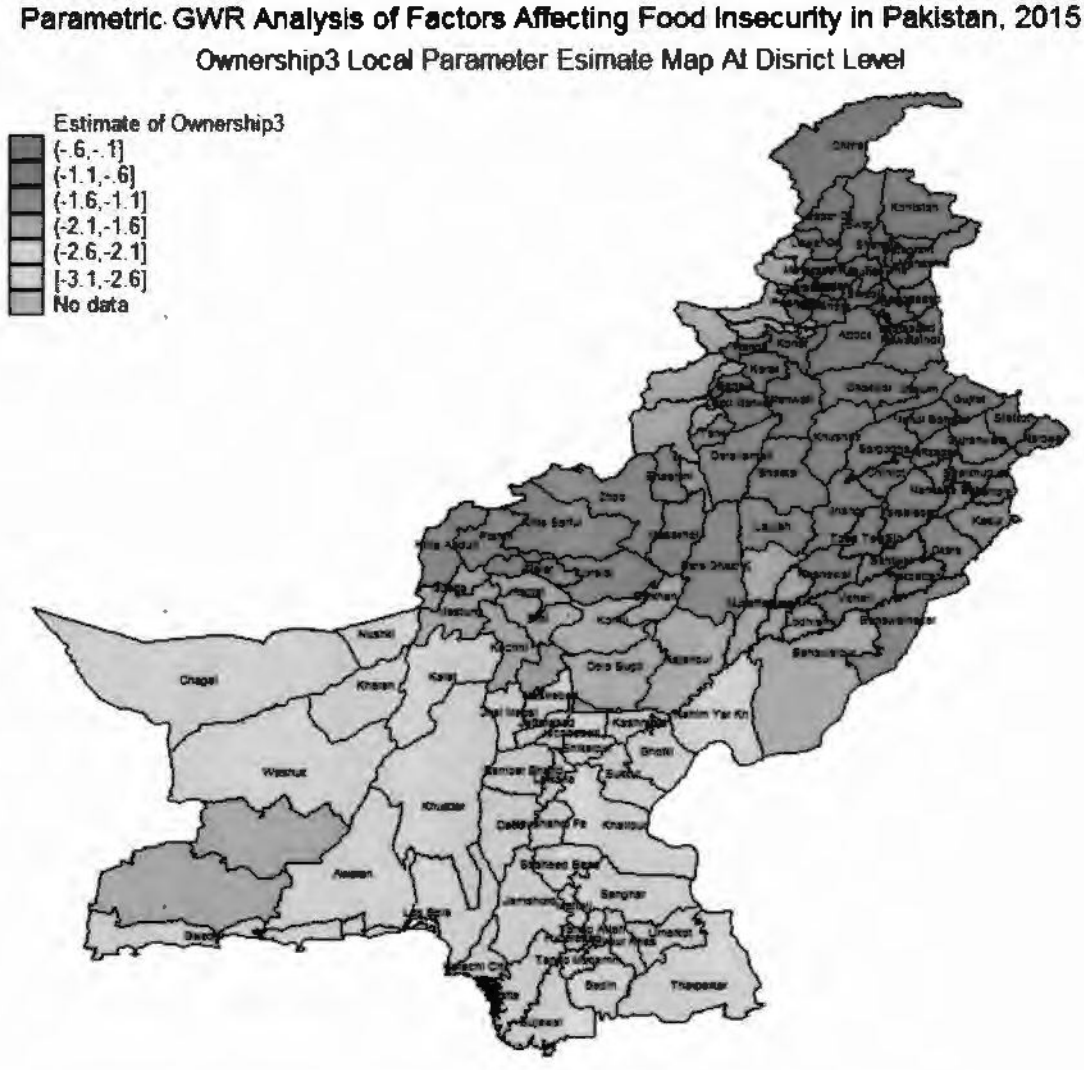


**Figure 5.37 Ownership-3** Local Parameter Estimates, Parametric GWR

The variable has spatially varying significance in determining the food insecurity incidence across districts in Pakistan. As shown in the Fig.5.38, it is insignificant in all the districts of KPK. Similarly, in Punjab, it is significant only in Rajanpur, Rahim Yar Khan and Bahawalpur district, while, insignificant in rest of the districts. Conversely, it is significant in all the districts of Sindh. However, in Baluchistan, it is significant in almost half of the districts and insignificant in rest of the districts.

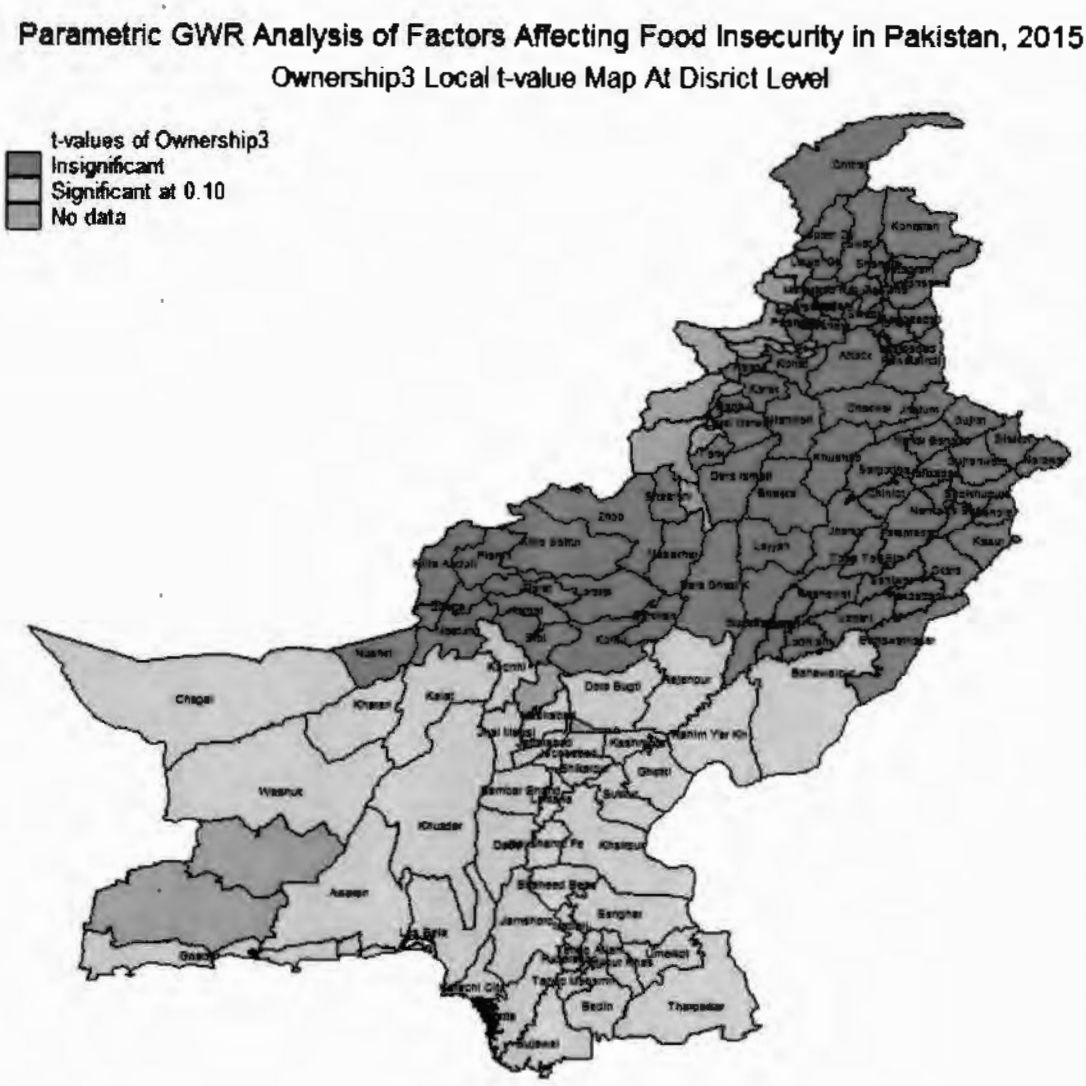


**Figure 5.38 Ownership-3** Local t-value Estimates, Parametric GWR

### 5.1.20 Piped Water

The variable Piped Water represents the main source of drinking water as piped water in a household. It is a binary variable with 1 equal piped water and 0 otherwise. For the GWR analysis, its proportion is taken at district level. As shown in the Fig.5.39, the sign of the local parameter estimates is negative, indicating that higher is the proportion of drinking water source is piped water lower is the food insecurity incidence.

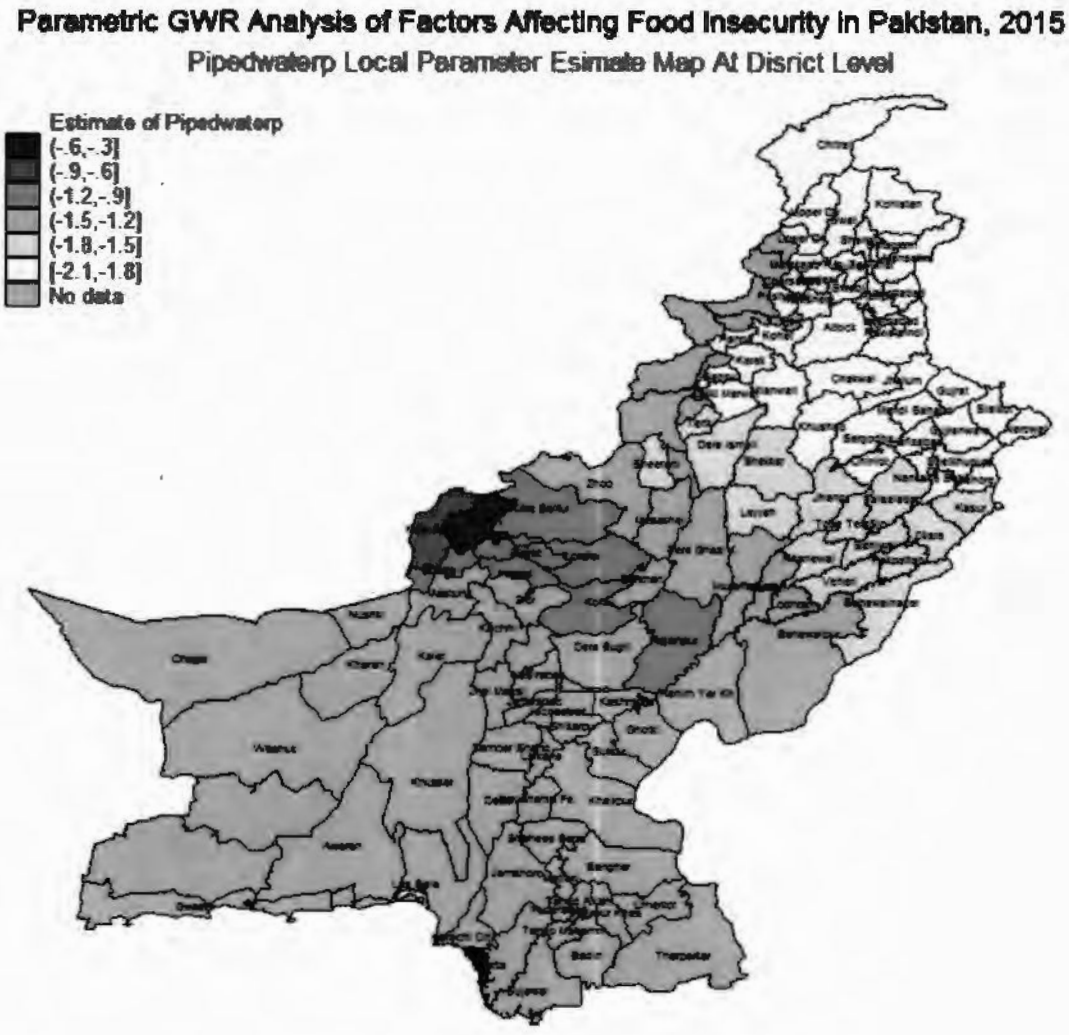


**Figure 5.39 Piped Water** Local Parameter Estimates, Parametric GWR

The variable has spatially varying relationship with food insecurity incidence across the districts in Pakistan. As depicted in the Fig.5.40, it is highly significant in all the districts of KPK and Punjab except for Rajanpur and Rahim Yar Khan, where, it is less significant. Similarly, in Sindh, it is highly significant in all the districts except for Karachi, Thatta and Sujawal, where, it is less significant. However, in Baluchistan, it is insignificant in three districts (Killa Abdullah, Pishin and Ziarat) and significant in the rest of the districts, of which, it is highly significant in Khuzdar, Jhal Magsi, Nasirabad and Jaffarabad.

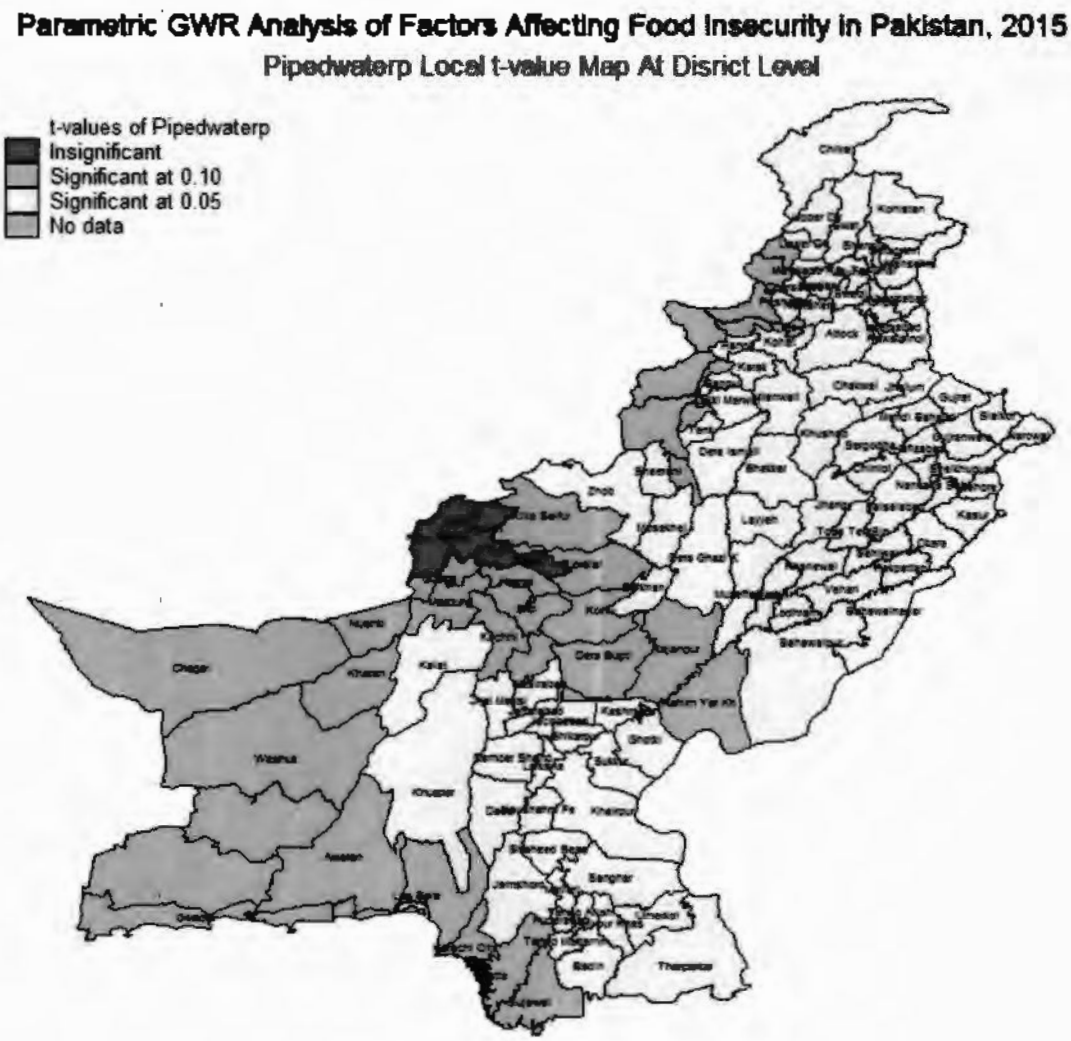


**Figure 5.40 Piped Water** Local t-value Estimates, Parametric GWR

### 5.1.21 Water-2

The variable Water-2 represents the main source of drinking water as hand pump in a household. It is a binary variable with 1 equal hand pump and 0 otherwise. For the GWR analysis, its proportion is taken at district level. As shown in the Fig.5.41, the sign of the local parameter estimates is positive.

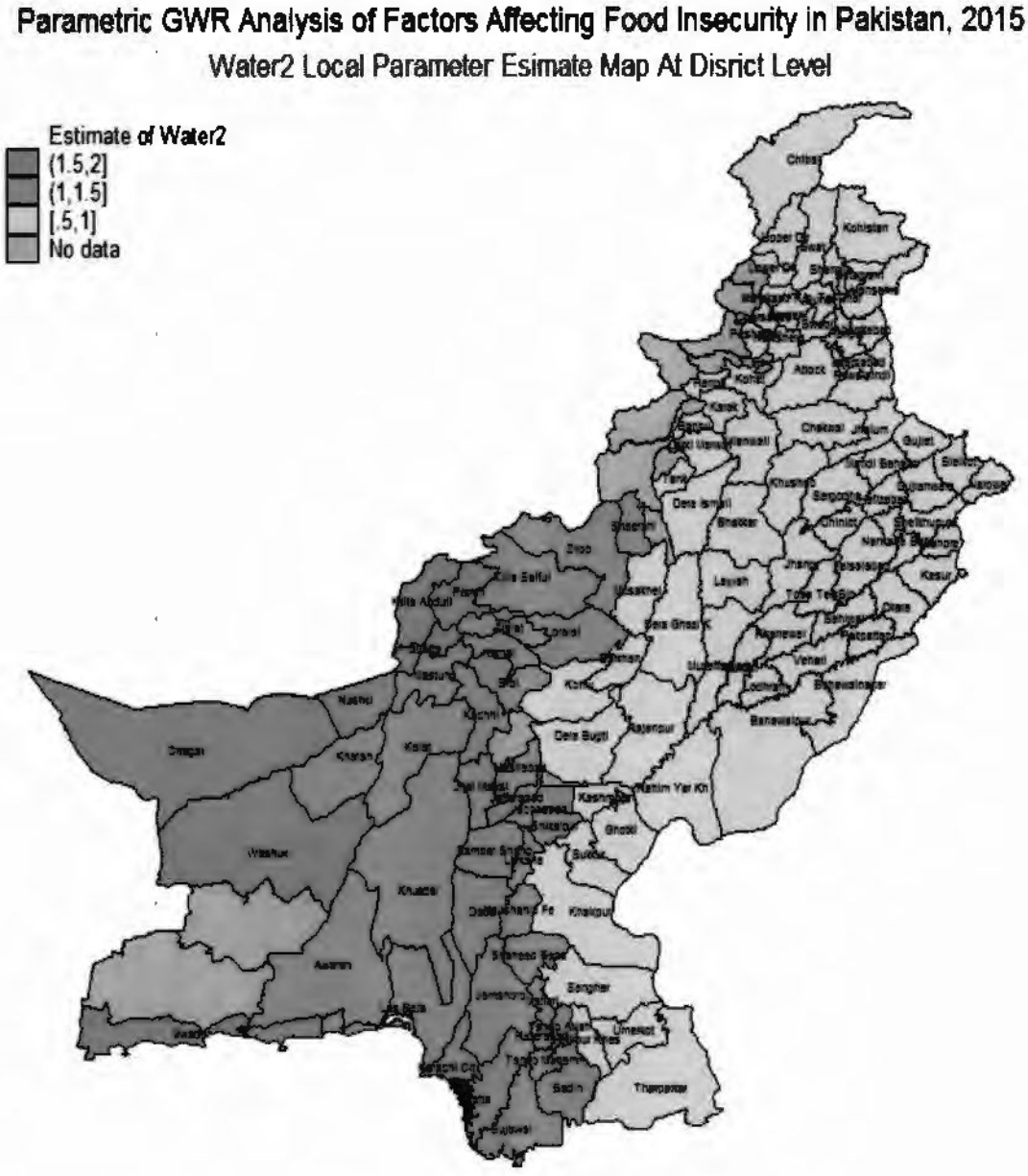


**Figure 5.41 Water-2** Local Parameter Estimates, Parametric GWR

The variable Water-2 has spatially varying significance across the districts of Pakistan, as depicted in Fig.5.42, the variable is significant only in the 5 districts form Baluchistan, including Pishin, Killa Abdullah, Chaghi, Nushki and Quetta. While, it is insignificant in case of all other districts of Pakistan.

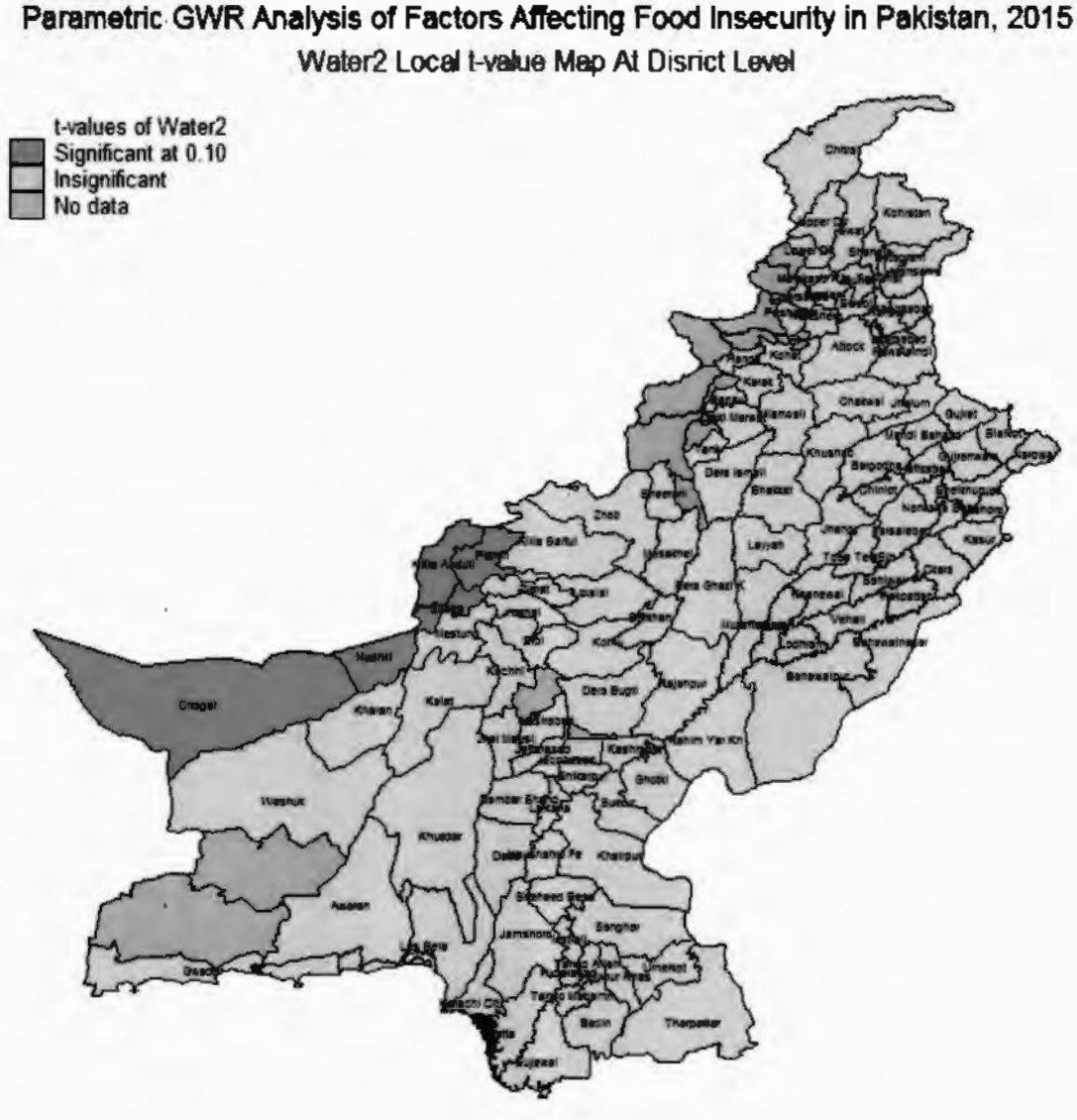


**Figure 5.42 Water-2** Local t-value Estimates, Parametric GWR

### 5.1.22 Toilet Type-1

The variable Toilet Type-1 represents the flush toilet connected to the sewerage in a household. It is a binary variable with 1 equal flush toilet connected to the sewerage and 0 otherwise. For the GWR analysis, its proportion is taken at district level. As shown in the Fig.5.43, the sign of the local parameter estimates is negative. It indicates that higher is the proportion of flush toilet connected to the sewerage, lower is the food insecurity incidence.

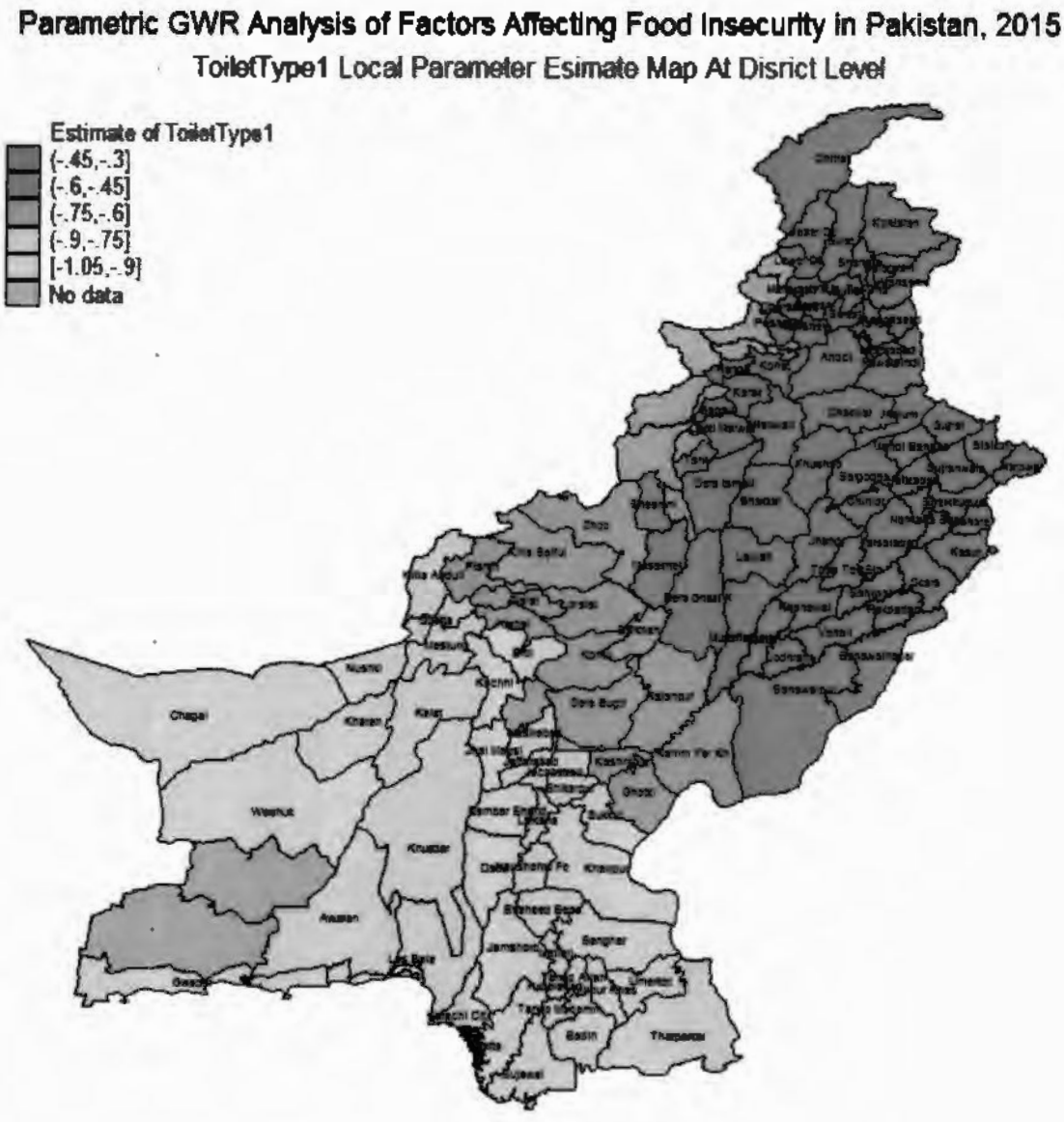


**Figure 5.43 Toilet Type-1** Local Parameter Estimates, Parametric GWR

The variable Toilet Type-1 has spatially varying relation to the food insecurity incidence across districts in Pakistan. As visualized in Fig.5.44, the variable is insignificant in all the districts of KPK and Punjab including Islamabad. Conversely, it is significant across all the districts of Sindh. However, it is insignificant in few districts of Baluchistan but significant in all other districts.

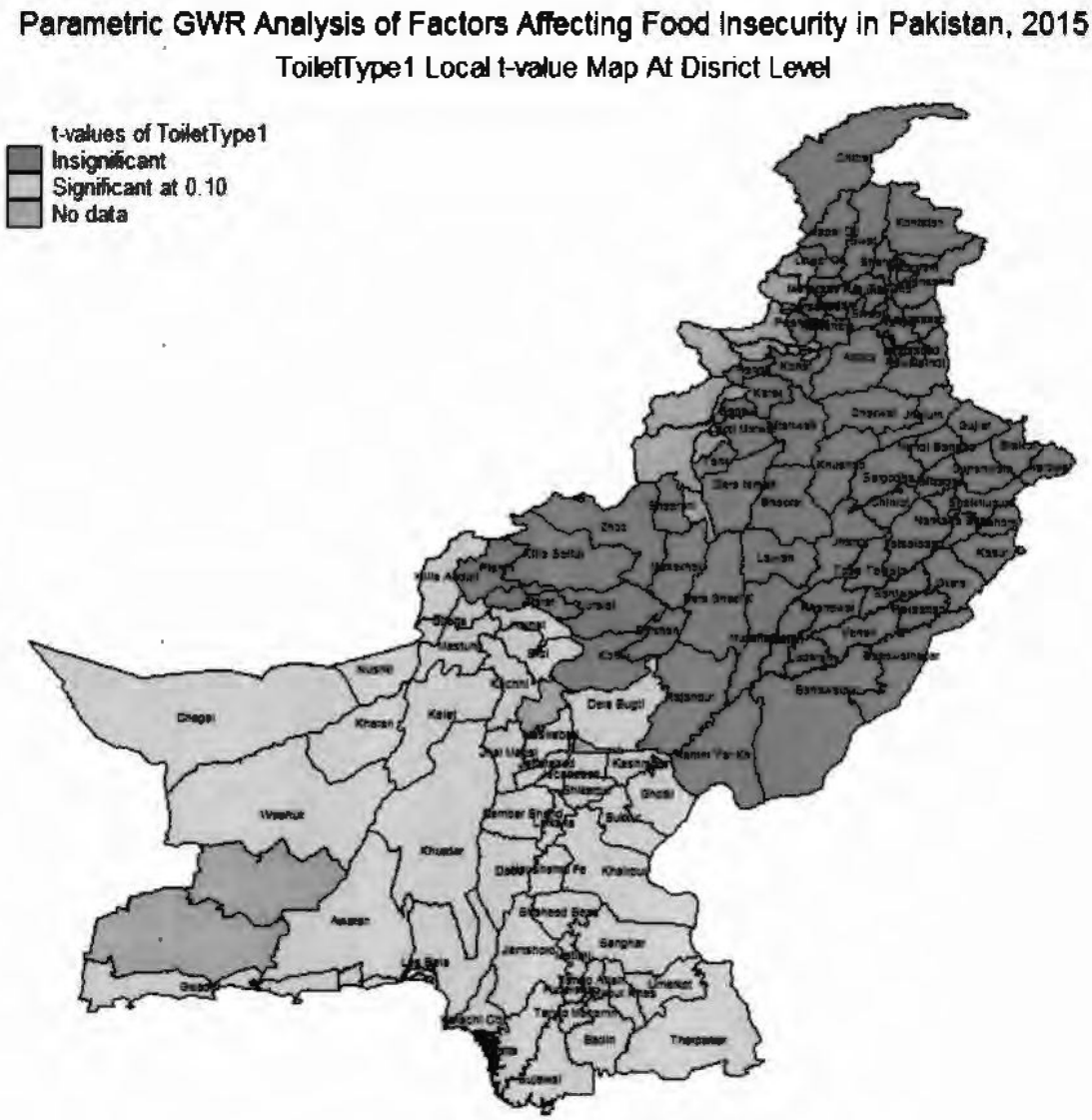


**Figure 5.44 Toilet Type-1** Local t-value Estimates, Parametric GWR

### 5.1.23 Residential Building

The variable Residential Building represents property status of a household. It is a binary variable with 1 equal own residential building and 0 otherwise. For the GWR analysis, its proportion is taken at district level. As shown in the Fig.5.45, the sign of the local parameter estimates is negative. It indicates that higher is the proportion of owned residential building, lower is the food insecurity incidence.

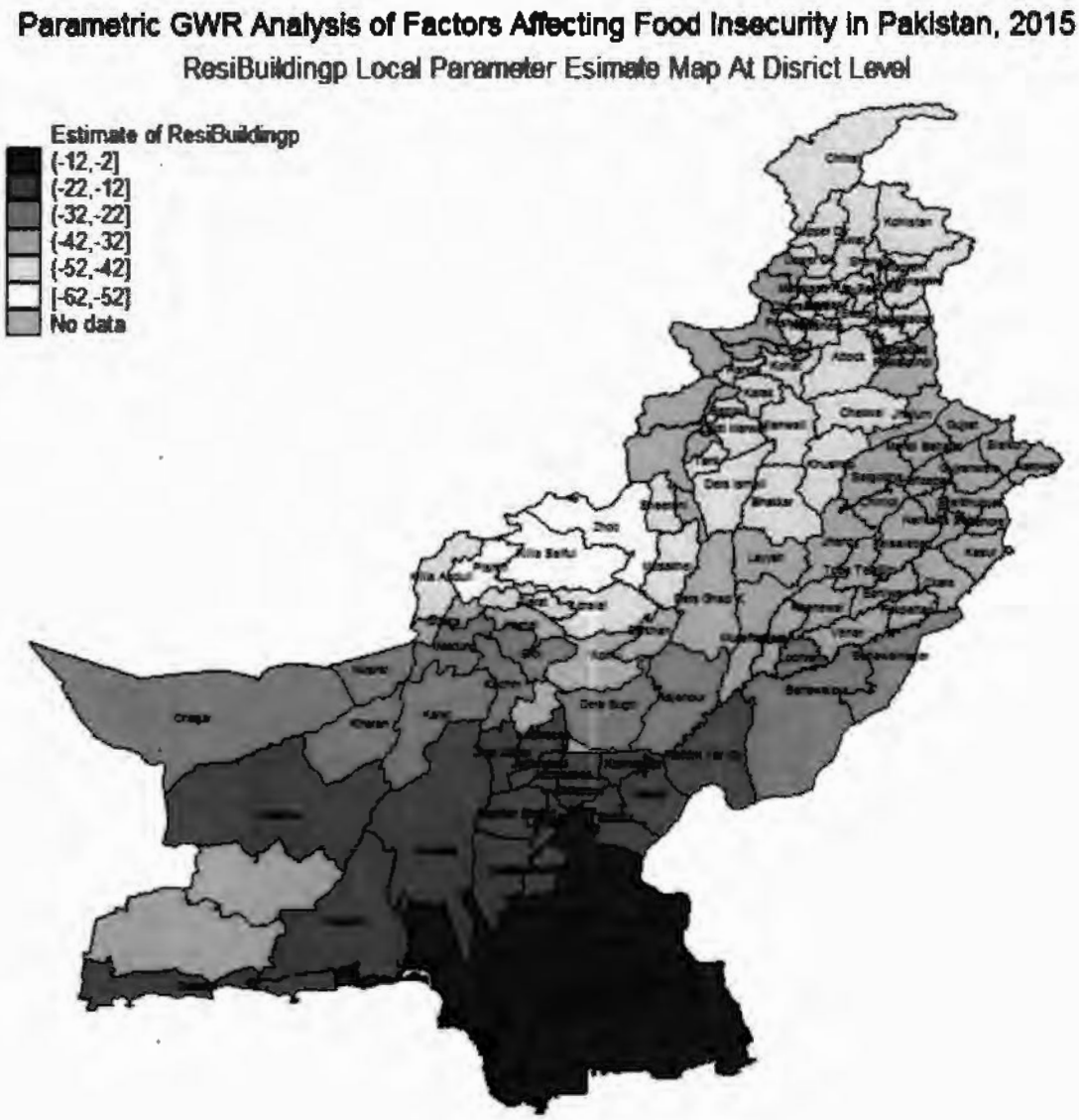


**Figure 5.45 Residential Building** Local Parameter Estimates, Parametric GWR

The variable Residential Building has spatially varying relation to the food insecurity incidence across districts in Pakistan. As visualized in Fig.5.46, the variable is insignificant in all the districts of Sindh. Conversely, it is significant across all the districts of KPK. However, it is significant in few districts of Baluchistan and Punjab but insignificant in all other districts. It is highly significant in Killa Abdulla and Zhob districts of Baluchistan.

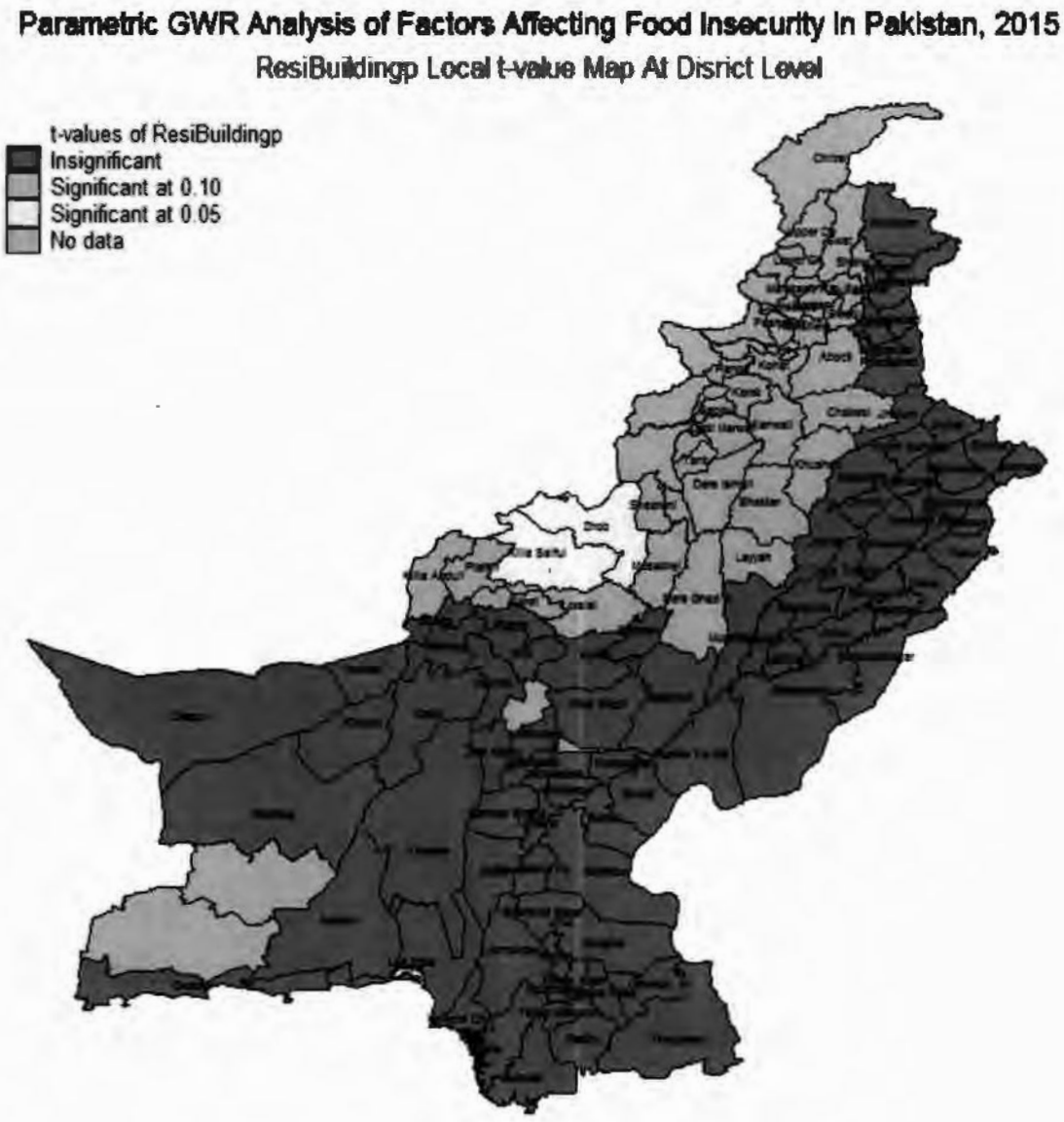


**Figure 5.46 Residential Building** Local t-value Estimates, Parametric GWR

### 5.1.24 Room

The variable Room represents no. of rooms in a household. For the GWR analysis, its average is taken at district level. As shown in the Fig.5.47, the sign of the local parameter estimates is negative for most of the districts. It indicates that on the average, more are the rooms available per household, lower is the food insecurity incidence at district level.

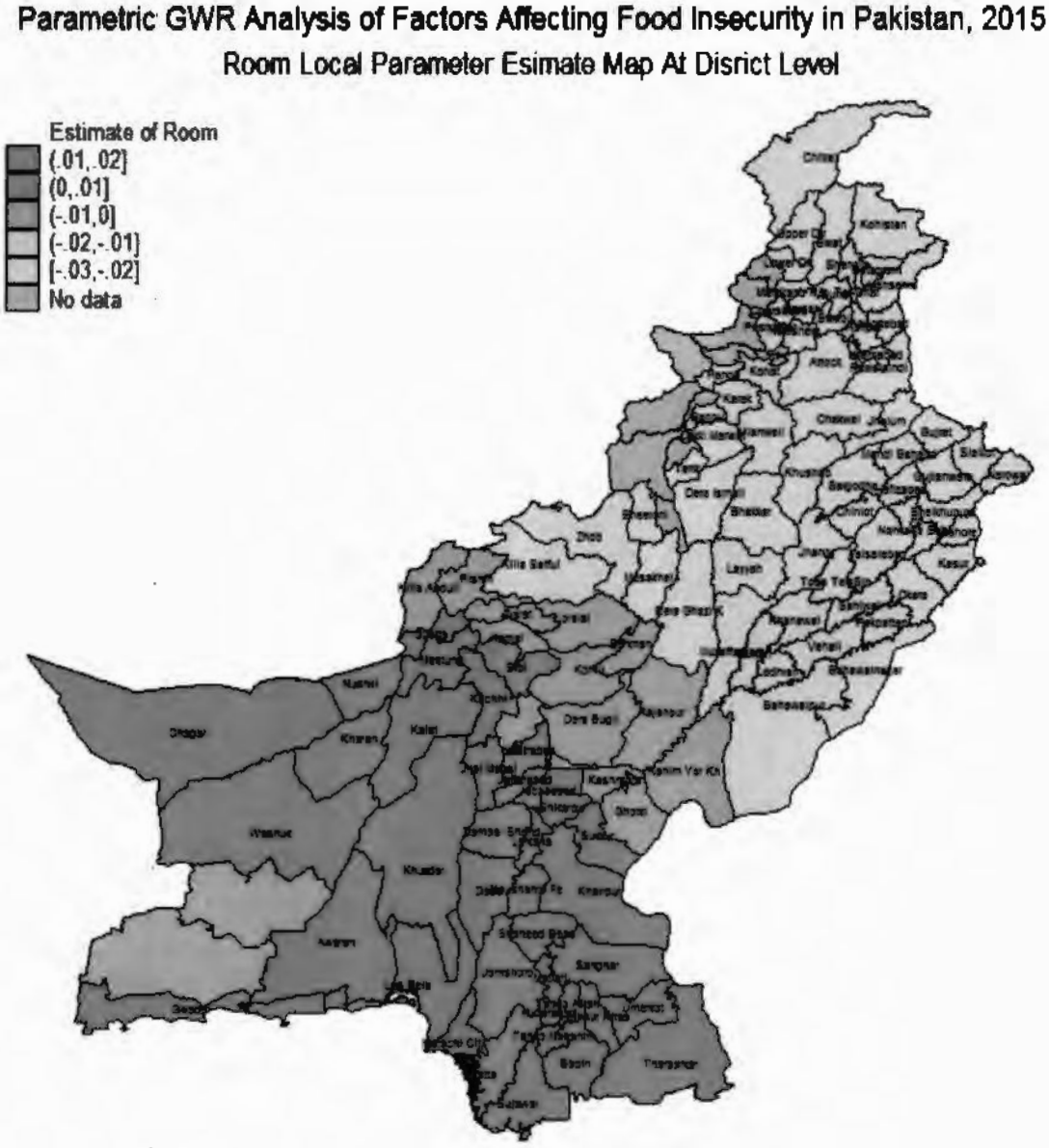


**Figure 5.47 Room** Local Parameter Estimates, Parametric GWR

The variable Room has spatially varying relation to the food insecurity incidence across districts in Pakistan. As visualized in Fig.5.48, the variable is insignificant in all the districts of Sindh and Baluchistan. Conversely, it is significant across all the districts of KPK. However, it is significant in approximately half of the districts in Punjab but insignificant in rest of the districts.

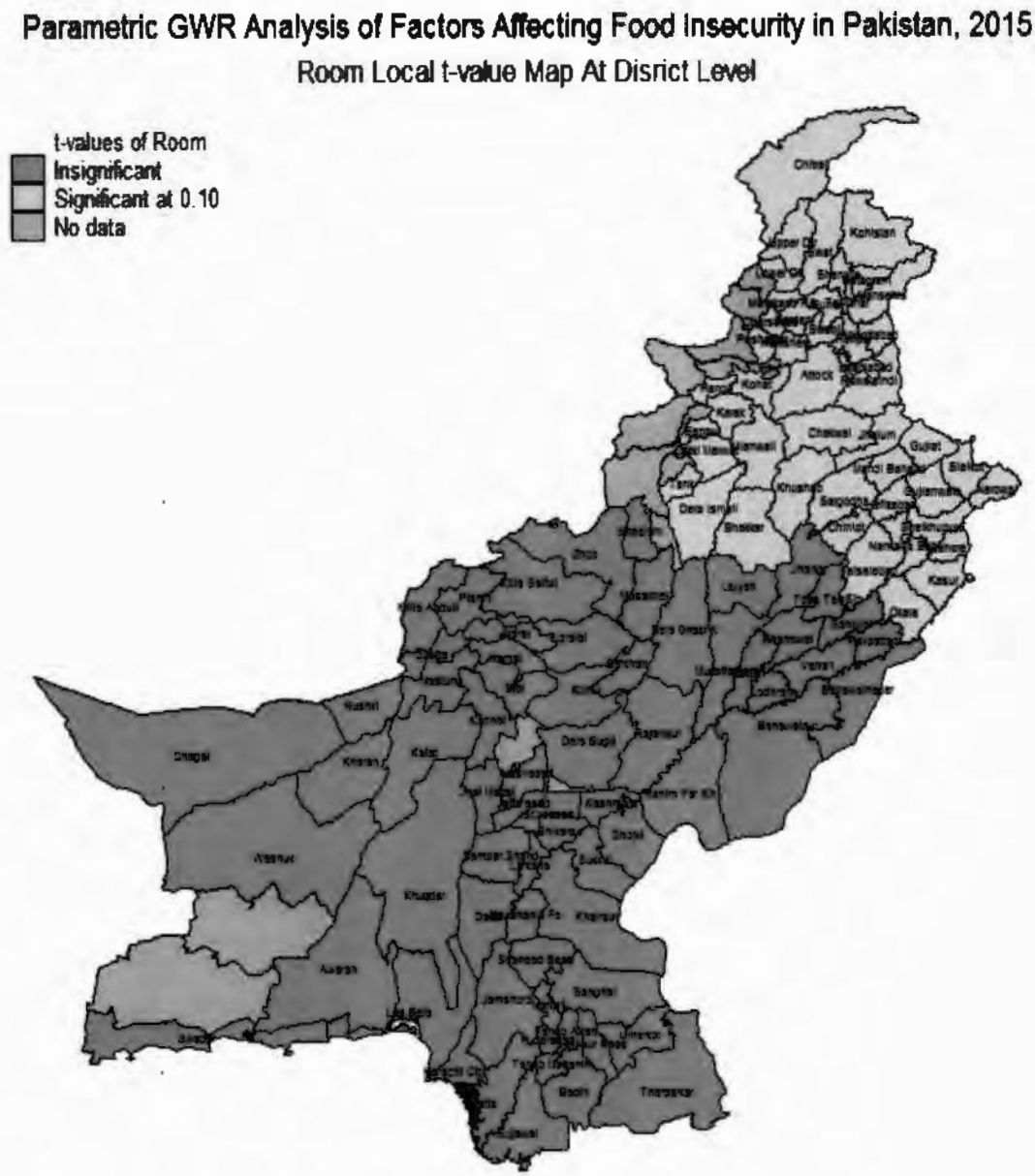


**Figure 5.48 Room** Local t-value Estimates, Parametric GWR

# CHAPTER 6

# SEMI PARAMETRIC GWR ANALYSIS; MAPPING AND DISCUSSTION

This chapter comprises detailed analysis and mapping of Semi Parametric GWR estimates at district level in Pakistan. In semi parametric GWR estimates, the spatially invariant variables are taken as Global independent variables after applying the Geographical variability Test on all the candidate variables. While, the variables which passed the Geographical variability Test, are considered as Local independent variables.

## 6.1 Semi Parametric GWR Estimates at District Level in Pakistan

Overall, the Global model had the Adjusted $R^2$ of 89.69%, while the GWR local model had an Adjusted $R^2$ of 90.5%. This section provides detailed tabular and map visualization analysis of the district specific significant determining variables of food insecurity in Pakistan based on the semi parametric GWR estimates. The maps of parameter estimates and the relevant t-values are presented in this section, which identify the spatially variant factors affecting food insecurity across the Pakistani districts.

### 6.1.1 Edu-1

The variable Edu-1 represents educational attainment status 'No Schooling'. It was a binary variable and its proportion is taken by district for GWR analysis. As, depicted in Fig.6.1, the negative sign of the local parameter estimate shows that with increase in 'no schooling' as educational attainment status, the food insecurity incidence goes down. Such relation might exists due to the fact that when most of the expenditures by the households are made on food, nothing is spent on education. In other words, as the proportion of 'no schooling

status reduces on district level, less is spent on food, thus food insecurity incidence goes up.

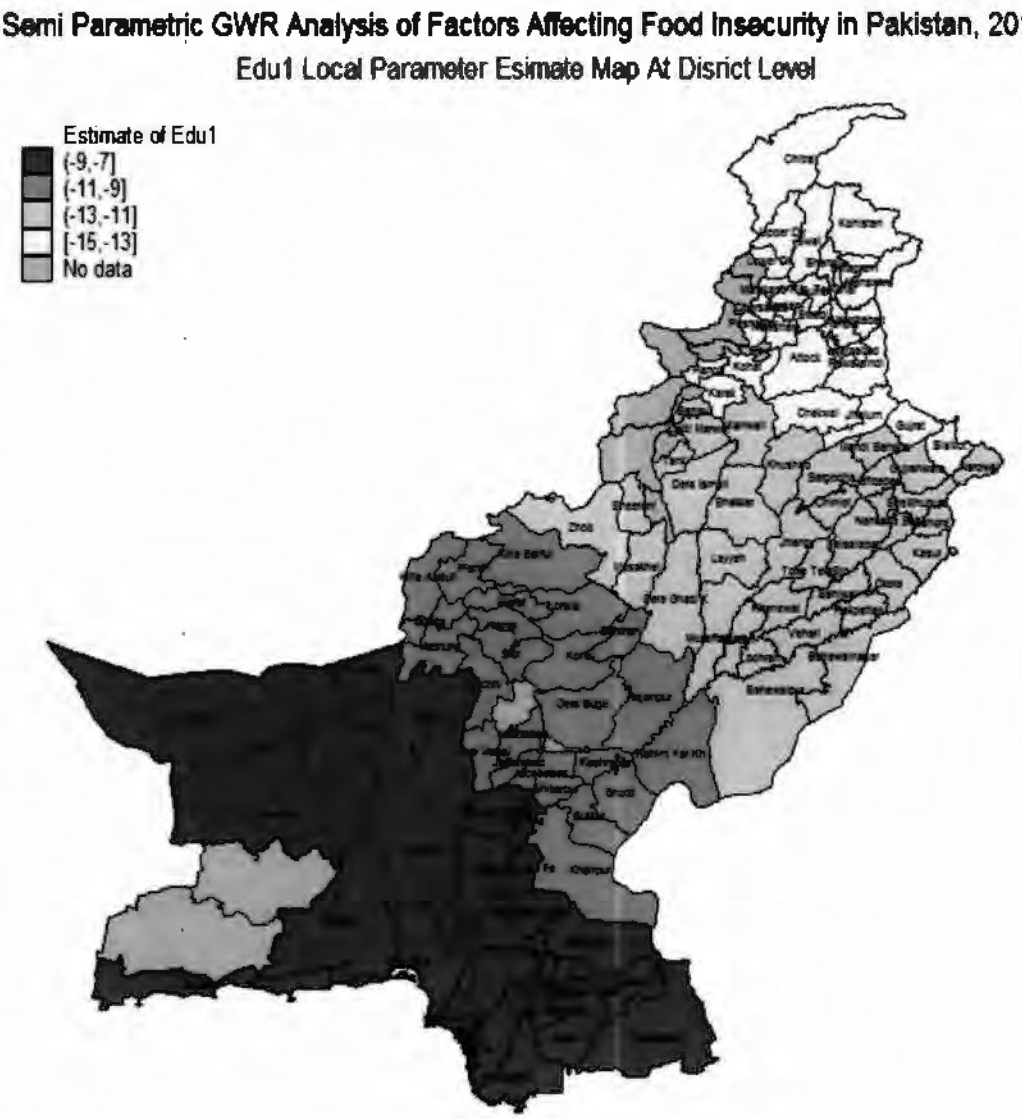


**Figure 6.1 Edu-1** Local Parameter Estimates, Semi Parametric GWR

As far as, the significance of the variable Edu1 is concerned, it is spatially variable across the districts. In some districts, it is insignificant, while in others it is significant in determining the food insecurity incidence. In case of only one district from Baluchistan i.e Gawadar, Edu1 is insignificant as depicted in the Fig.6.2, with dark purple Zones. While,

it is less significant (at 10%) in most of the districts from Baluchistan except for few districts, for which, it is more significant (at 5%). In Sindh, it is highly significant in the districts of Kashmor and Ghotki, while it is less significant in all other districts. For all districts from KPK and Punjab including Islamabad, Edu1 is more significant (at 5%) in determining the food insecurity incidence.

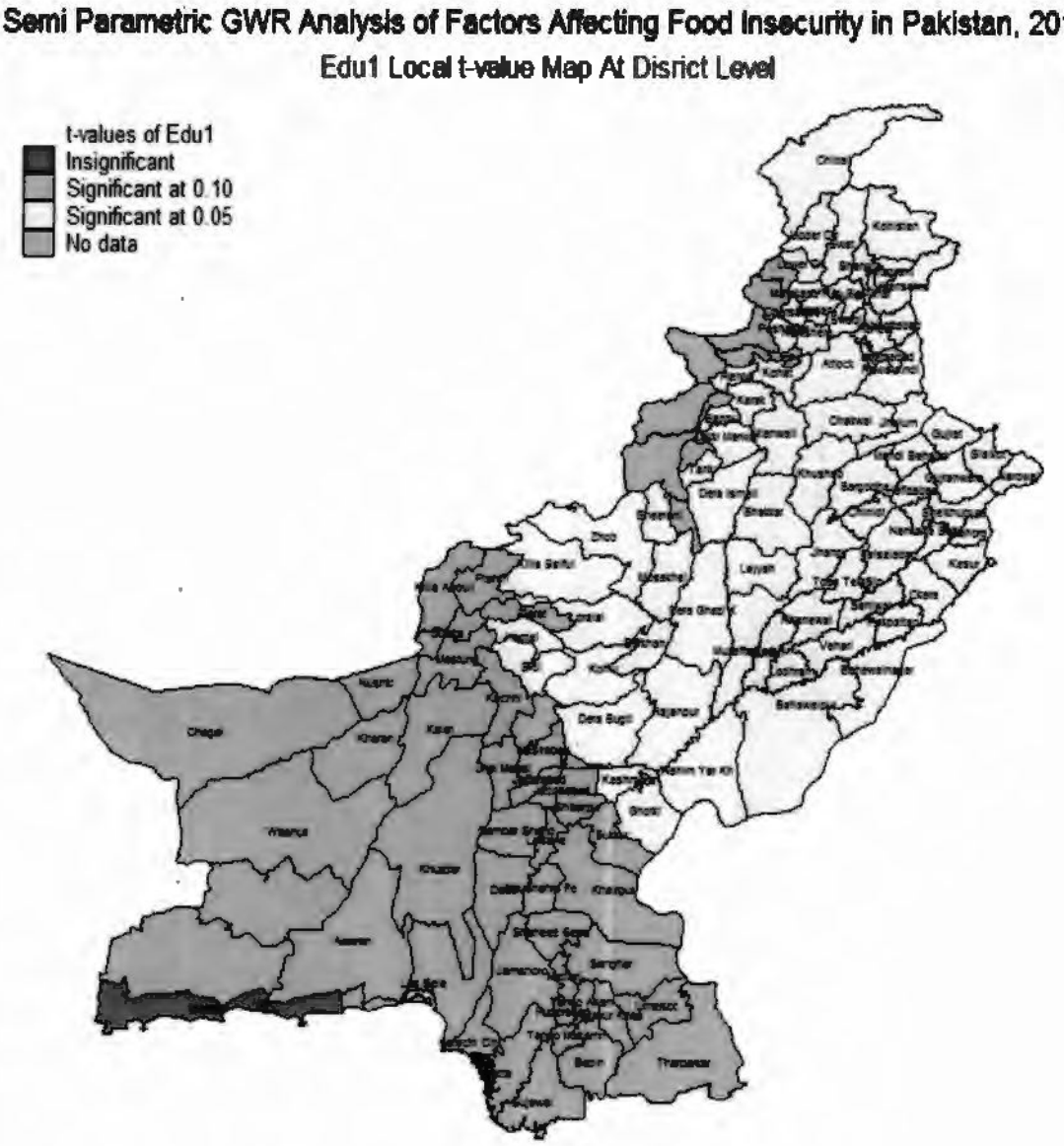


**Figure 6.2 Edu-1** Local t-value Estimates, Semi Parametric GWR

### 6.1.2 Edu Ratio-1

The variable Edu Ratio-1 indicates the proportion of household members having no schooling. For GWR analysis, its average is taken at district level. On the average, at district level, the proportion of household members having no schooling reduces, it means more expenditures are made on education. So, the food insecurity incidence increases with

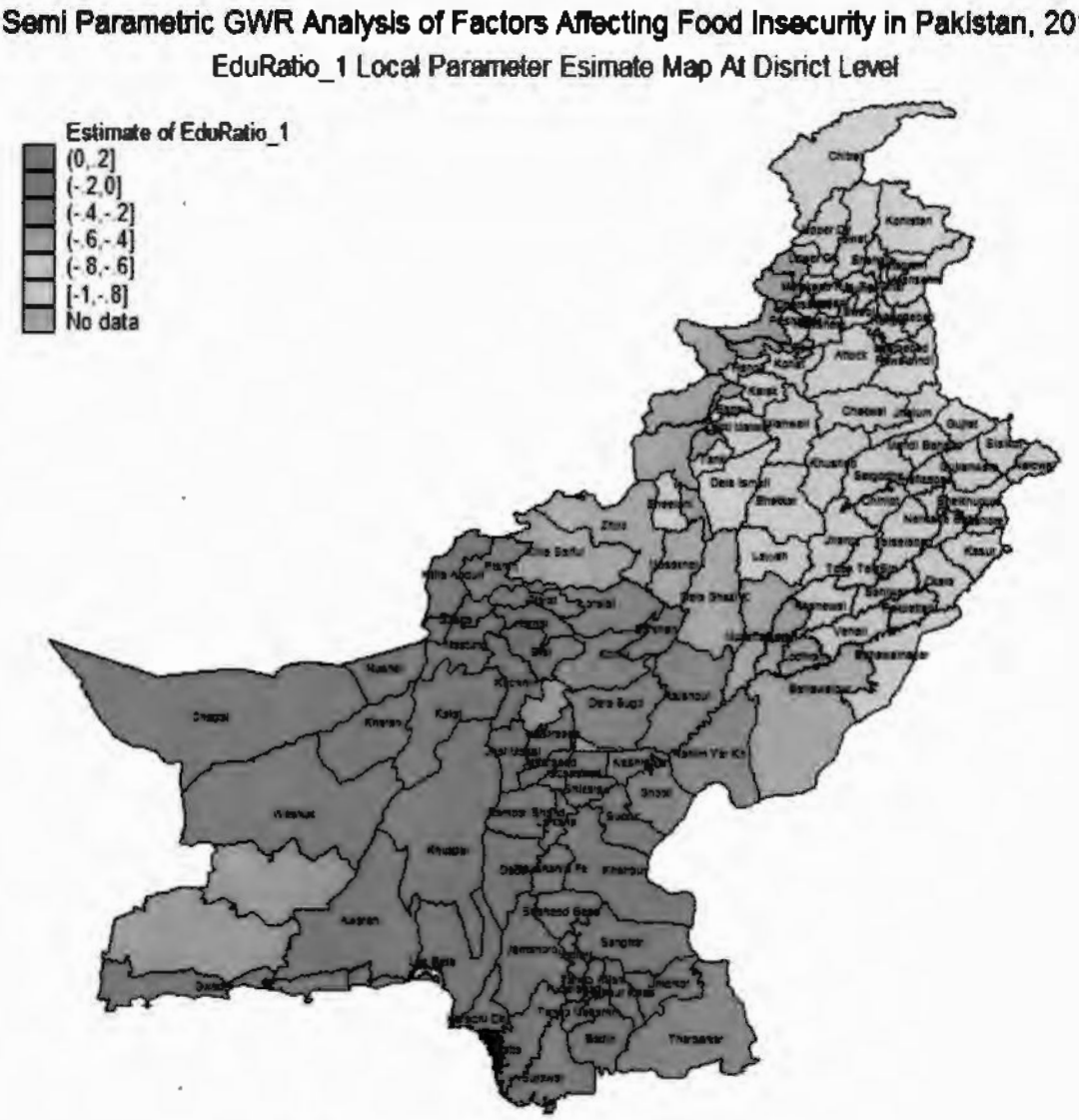


**Figure 6.3 Edu Ratio-1** Local Parameter Estimates, Semi Parametric GWR

the reduced food expenditure below subsistence level. As, it is shown in the Fig.6.3 that in most of the districts the sign of the local parameter estimate is negative. For some districts,

positive sign is an exception. It might be because of some additional factors, such as increase in household income result in reducing both the proportion of members with no schooling and the food insecurity incidence in these districts.

Moreover, the significance of Edu Ratio-1 variable is spatially variant across the districts of Pakistan in determining the food insecurity incidence. As, reflected by the Fig.6.4, the variable under consideration is insignificant in all the districts of Baluchistan and Sindh as

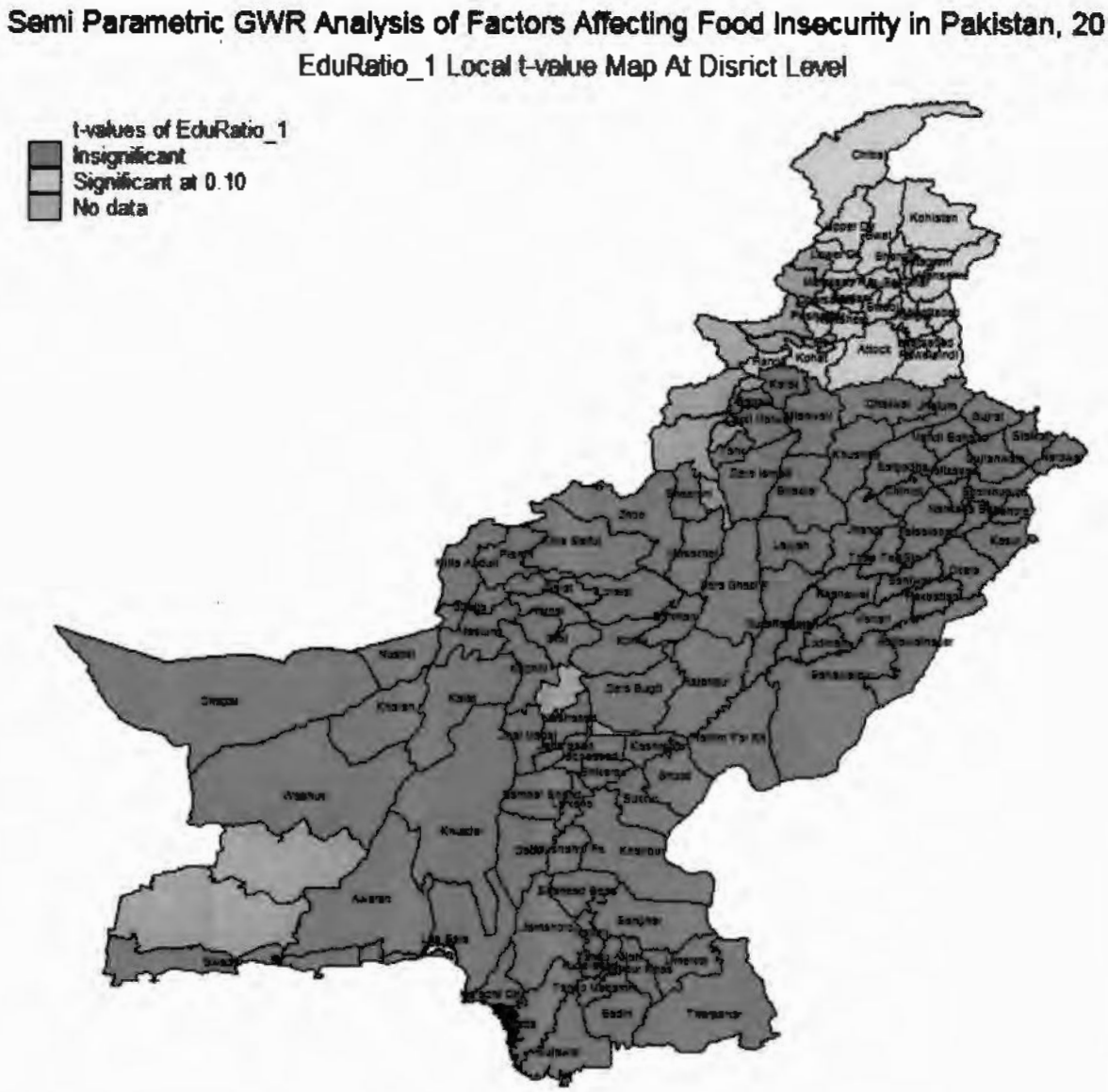


**Figure 6.4 Edu Ratio-1** Local t-value Estimates, Semi Parametric GWR

well as in most of the districts of Punjab, as indicated by orange zones. However, it is significant (at 10%) in most of the districts of KPK and some of the districts in Punjab including Islamabad, as shown by the yellow zones.

### 6.1.3 Edu Ratio-3

The variable Edu Ratio-3 represents the proportion of household members having middle education. The variable is averaged at district level for GWR analysis. On the average, at district level, as the proportion of household members having middle education increases,

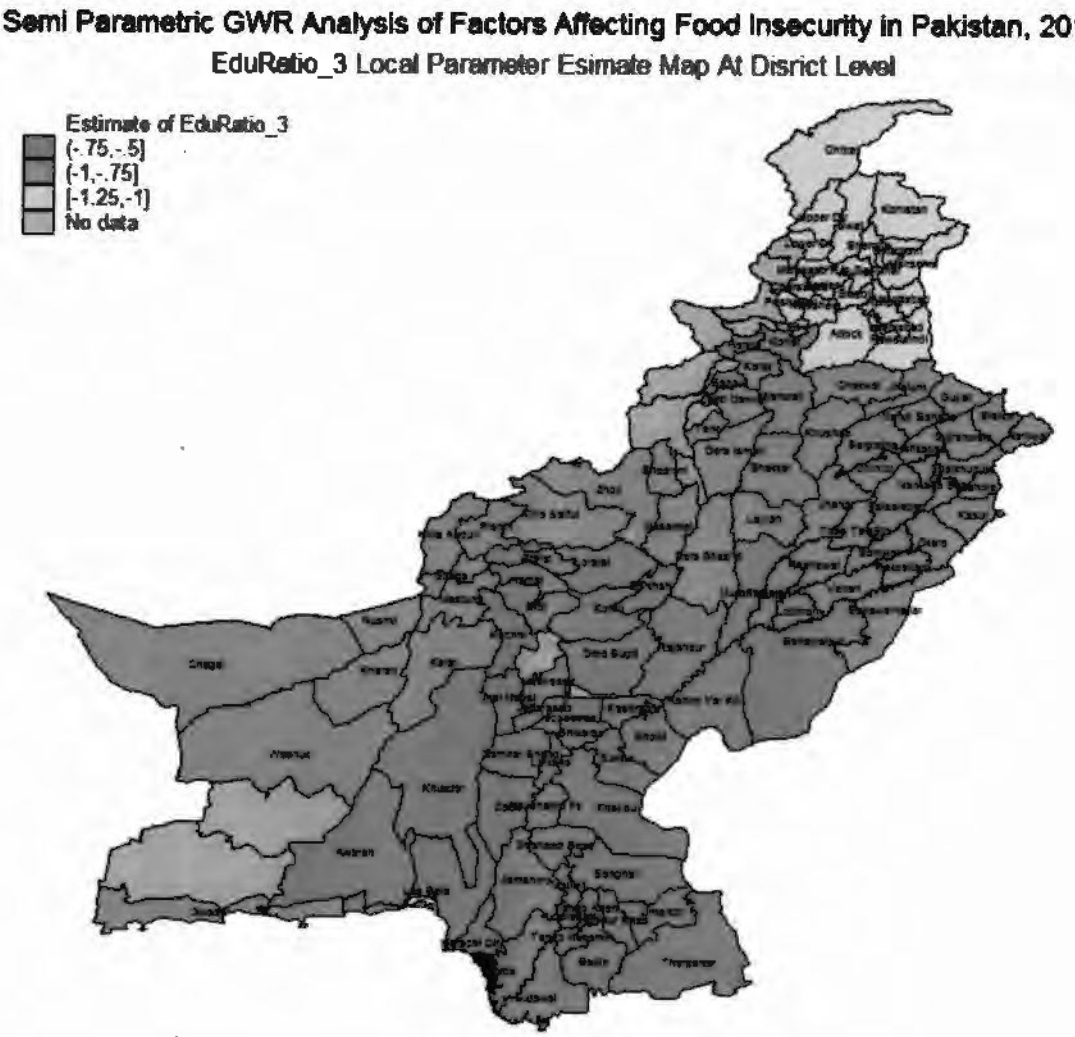


**Figure 6.5 Edu Ratio-3** Local Parameter Estimates, Semi Parametric GWR

the food insecurity incidence decreases. This result is in accordance with the fact that education has a positive impact on the food security status of households. As, it is shown in the Fig.6.5 that for all of the districts, the sign of the local parameter estimate is negative.

Furthermore, the Fig.6.6 represents that the Edu Ratio-3 has spatially varying relationship with the food insecurity incidence across the districts in Pakistan. In case of all districts of

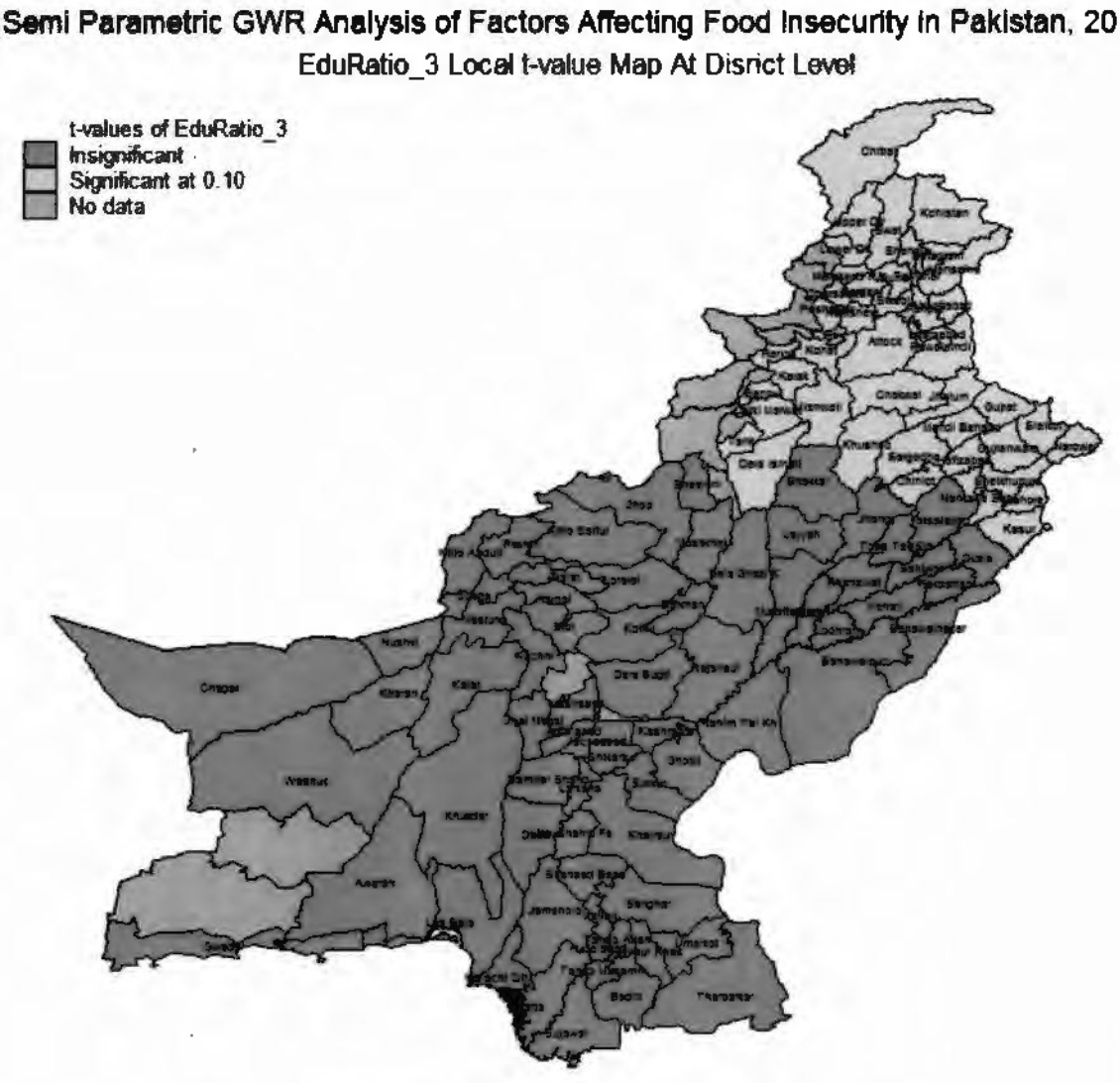


**Figure 6.6 Edu Ratio-3** Local t-value Estimates, Semi Parametric GWR

Sindh and Baluchistan, as well as, in almost half of the districts of Punjab, Edu Ratio-3 is insignificant, as indicated by the orange zones. However, it is significant (at 10%) in

determining the food insecurity incidence in all of the districts of KPK and remaining districts in Punjab including Islamabad, as highlighted by the yellow zones.

### 6.1.4 Edu Ratio-4

The variable Edu Ratio-4 represents the proportion of household members having secondary and above education. The variable is averaged at district level for GWR analysis.

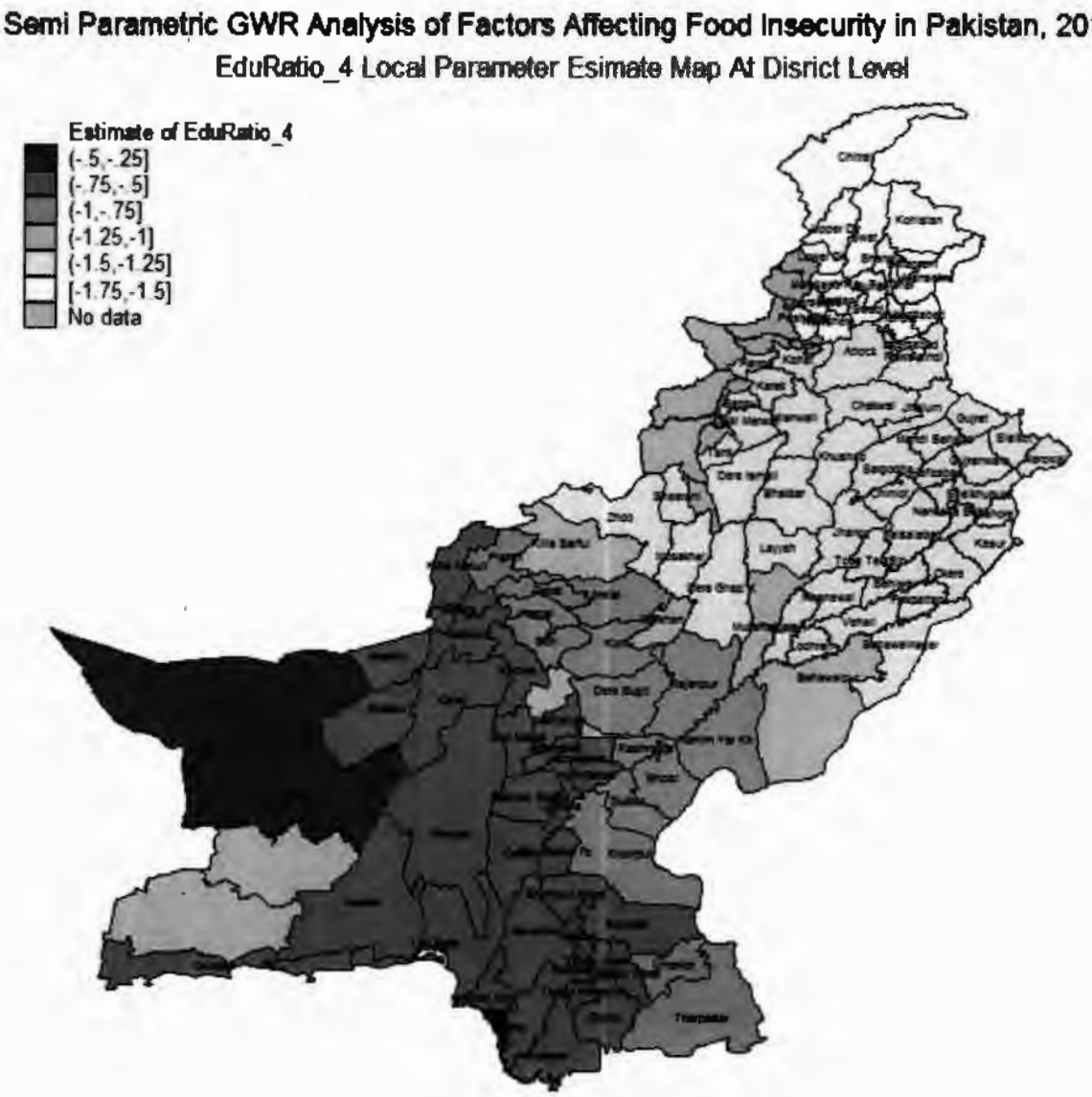


**Figure 6.7 Edu Ratio-4** Local Parameter Estimates, Semi Parametric GWR

On the average, at district level, as the proportion of household members having secondary and above education increases, the food insecurity incidence decreases. This result is in accordance with the fact that education has a positive impact on the food security status of households. As, it is shown in the Fig.6.7 that for all of the districts, the sign of the local parameter estimate is negative.

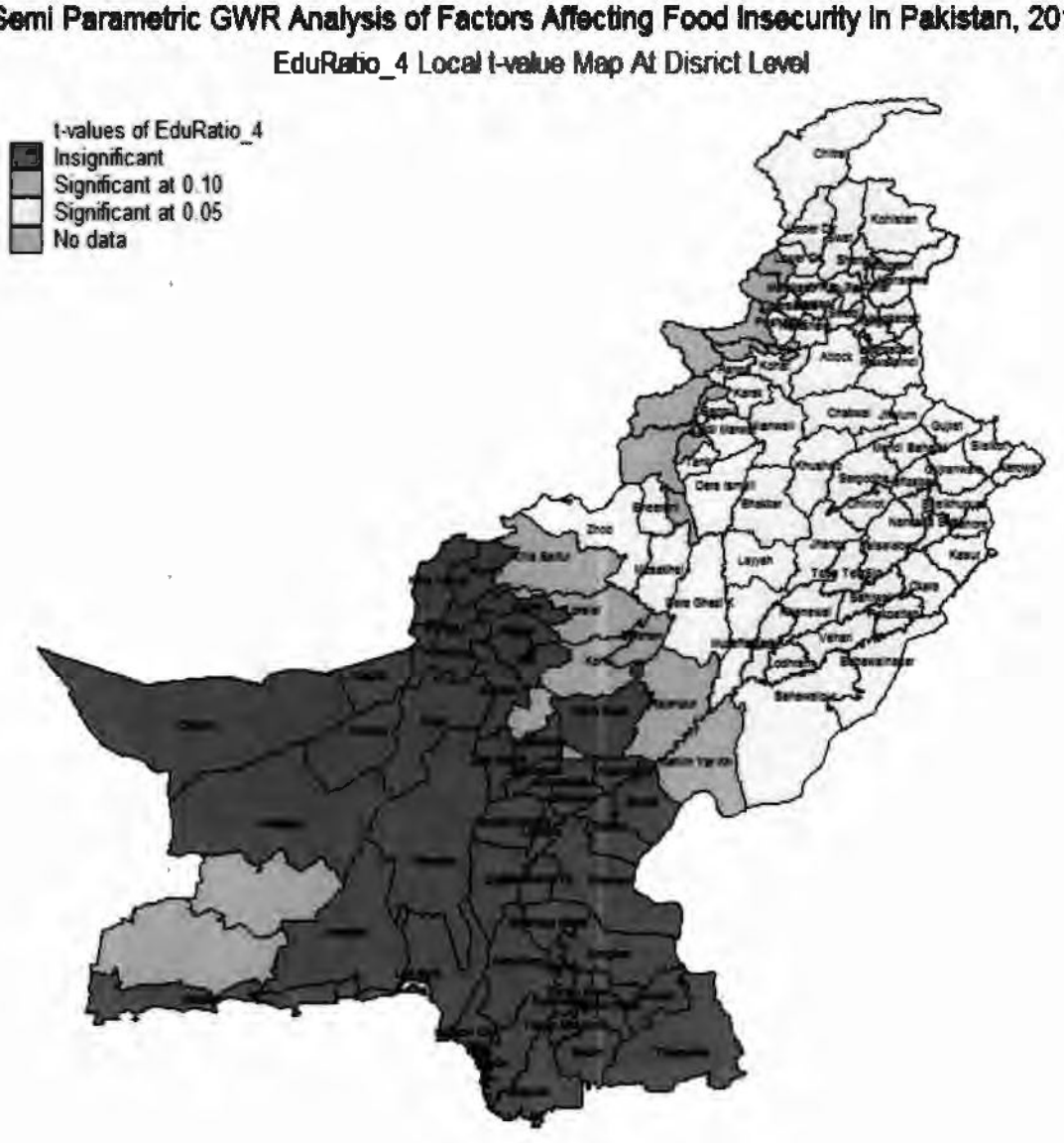


**Figure 6.8 Edu Ratio-4** Local t-value Estimates, Semi Parametric GWR

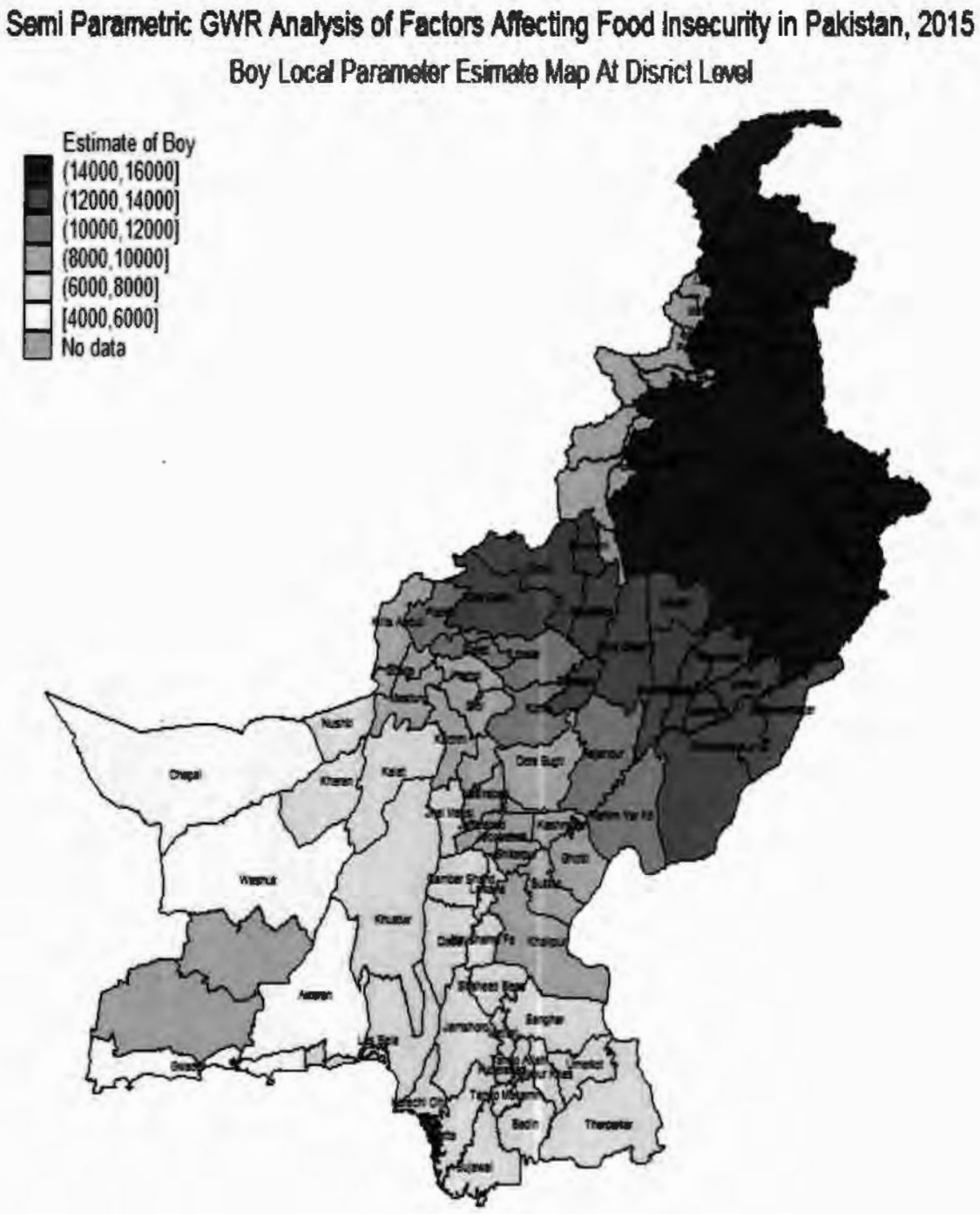


**Figure 6.9** Boy Local Parameter Estimates, Semi Parametric GWR

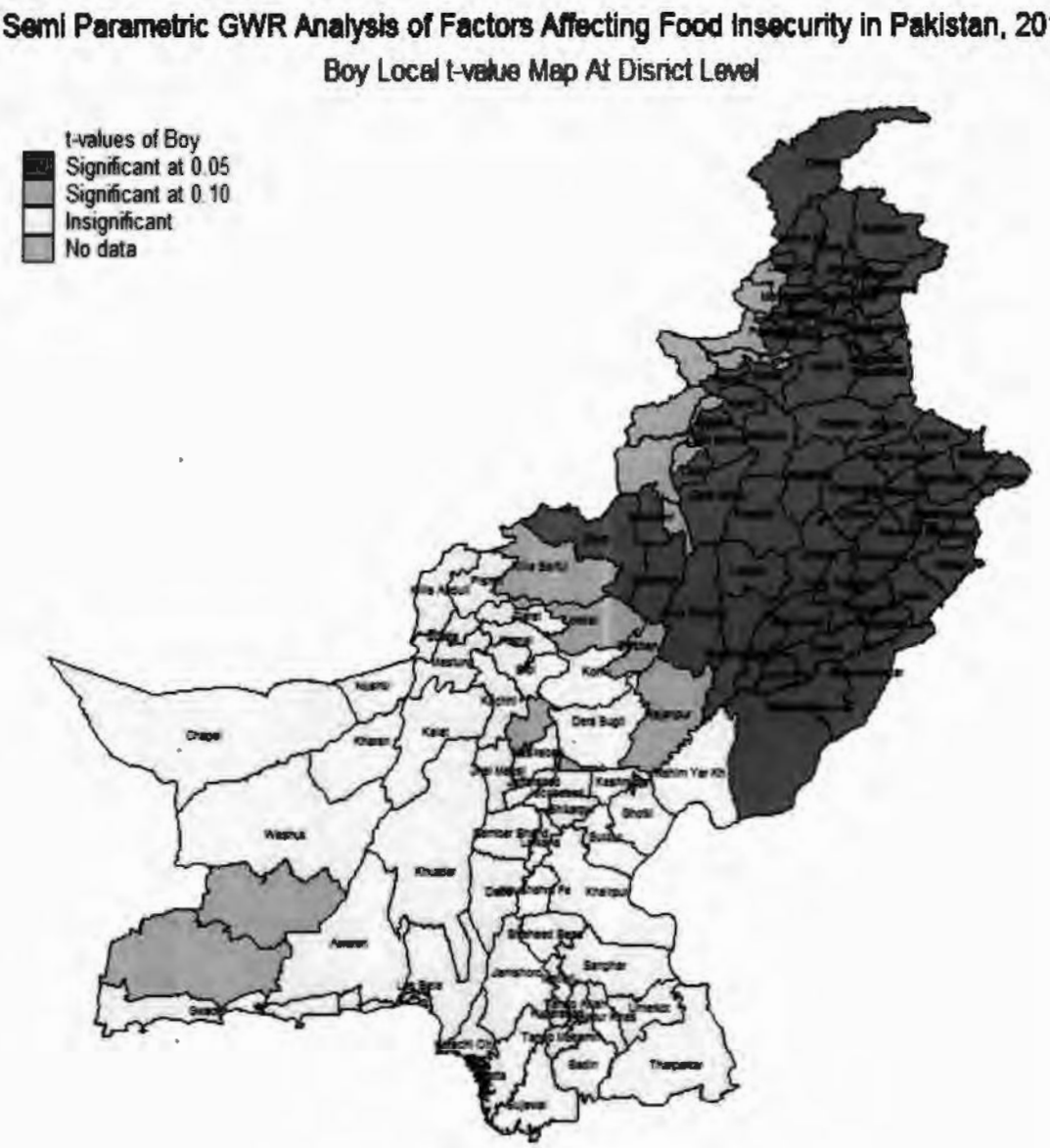


**Figure 6.10 Boy** Local t-value Estimates, Semi Parametric GWR

### 6.1.6 Girl

The variable Girl represents no. of female children < 15 year of age in a household. For GWR analysis, it is averaged at district level. According to the results, the local parameter estimates have positive sign, as depicted in Fig.6.11. It shows a direct relationship between food insecurity incidence and average number of girls per household at district level.

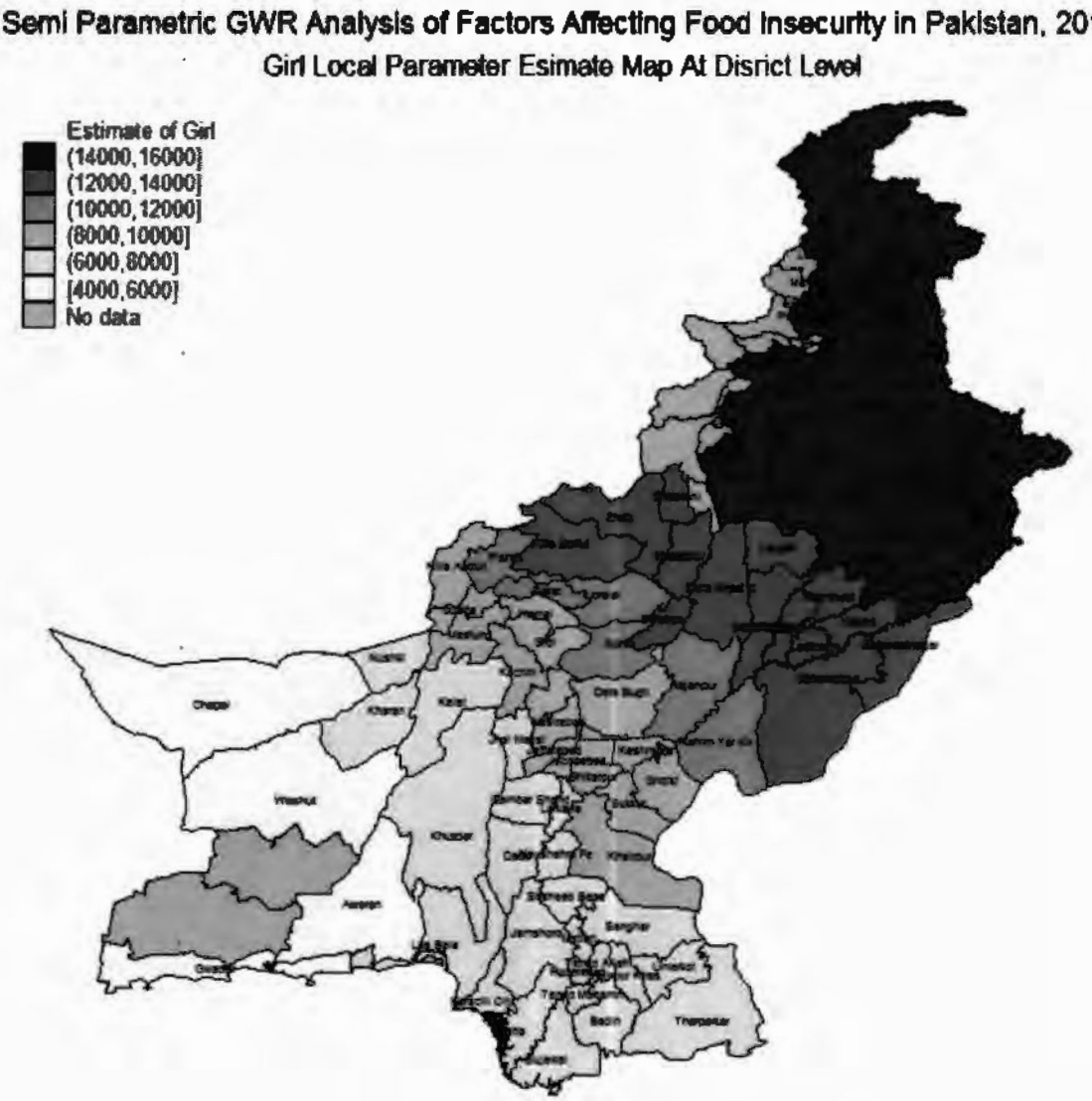


**Figure 6.11** Girl Local Parameter Estimates, Semi Parametric GWR

The significance of the variable Girl is spatially variant across the Pakistani districts as shown in Fig.6.12. It is insignificant in all of the districts of KPK and Punjab except for Rajanpur and Rahim Yar Khan. For Rajanpur it is less significant and for Rahim Yar Khan it is more significant. In case of Sindh and Baluchistan, it is highly significant for all districts except for Loralai, Barkhan and Killa Saifullah, for which it is less significant determinant of food insecurity incidence.

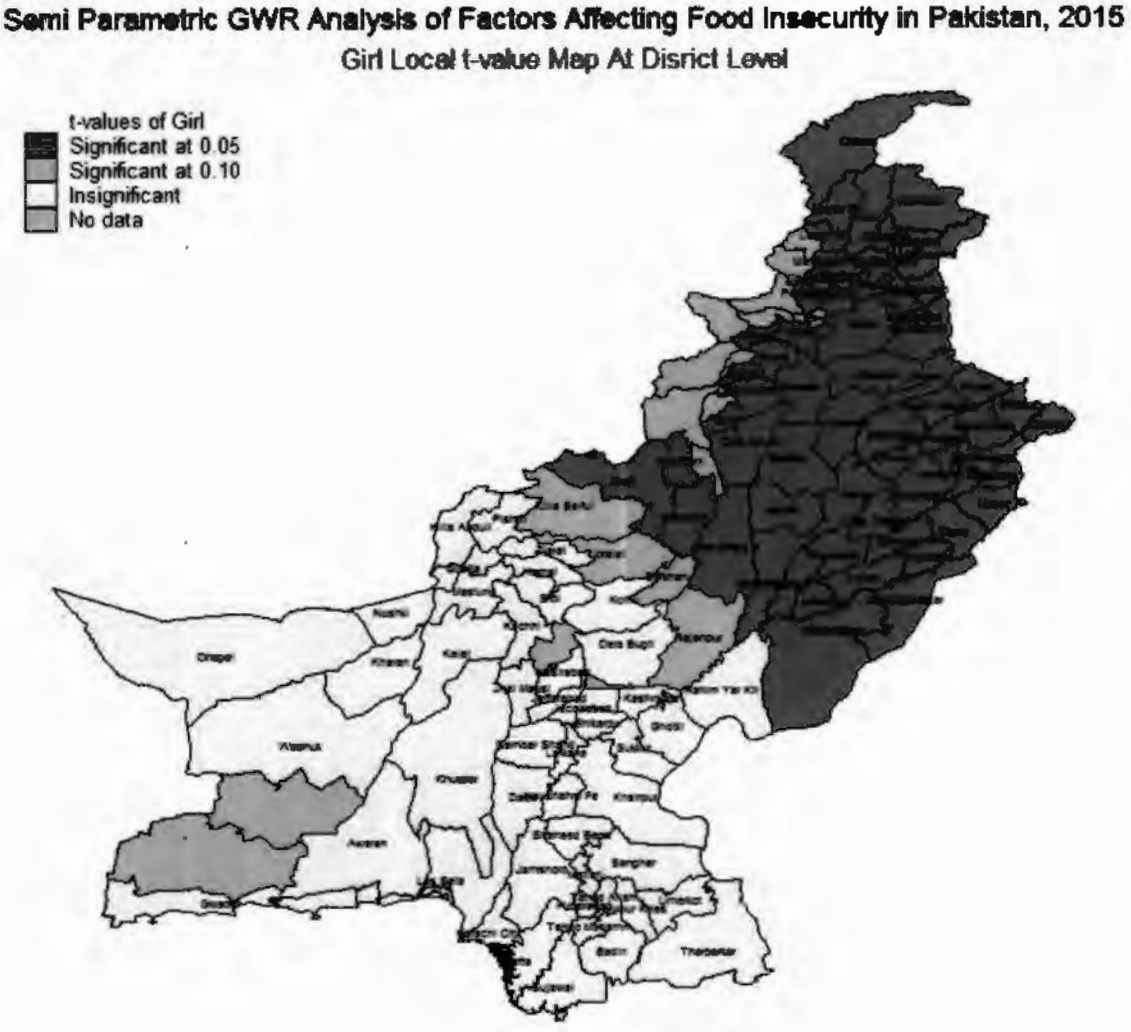


**Figure 6.12** Girl Local t-value Estimates, Semi Parametric GWR

### 6.1.7 Kid

The variable Kid represents no. of children < 15 year of age in a household. For GWR analysis, it is averaged at district level. According to the results, the local parameter estimates have negative sign, as depicted in Fig.6.13. It shows an indirect relationship between food insecurity incidence and average number of children per household at district level. Which might be due to the fact that the caloric requirement or food requirement is less for children as compared with adults. Also, the child labor might result in more income available to be spent on food.

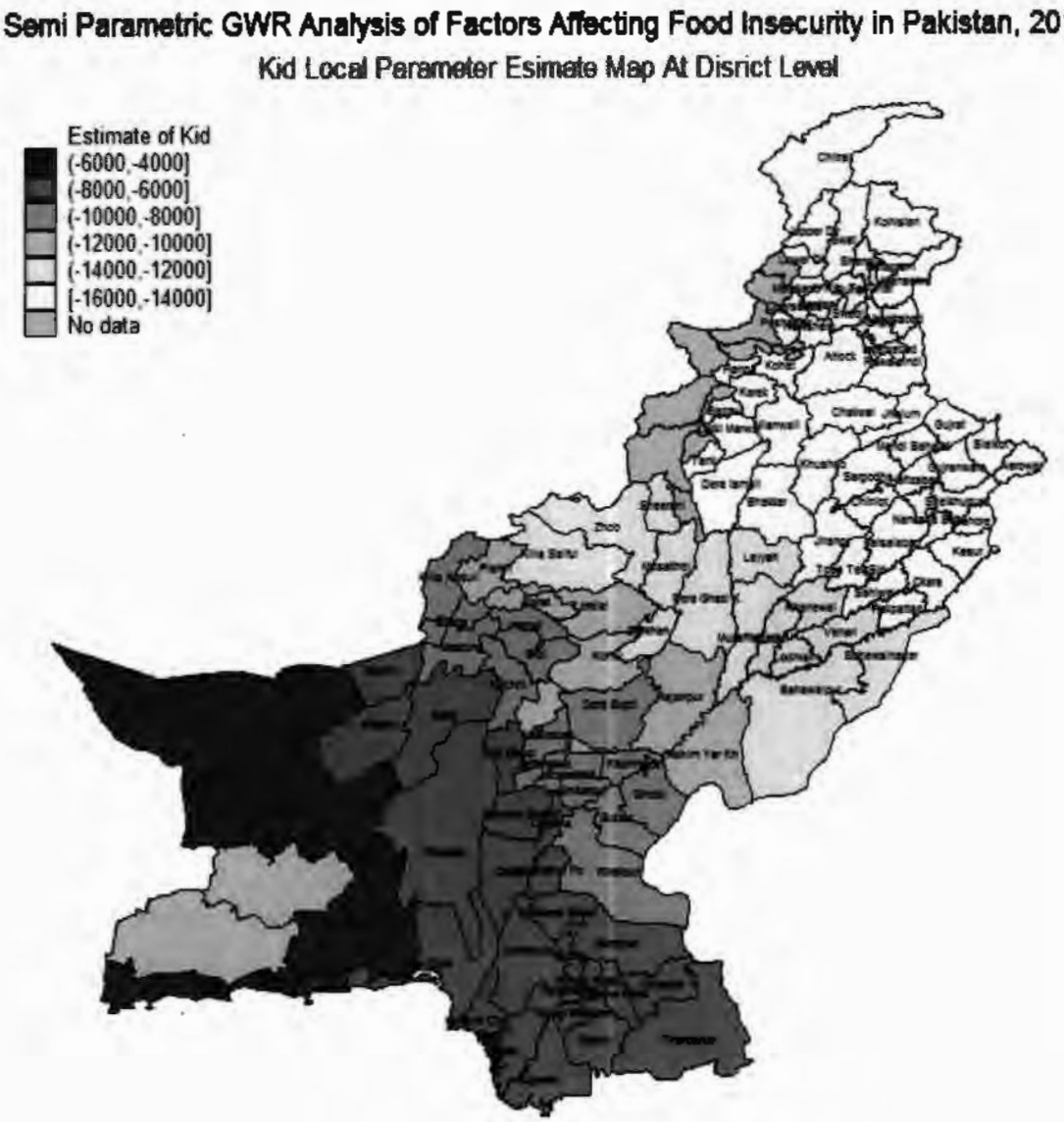


**Figure 6.13** Kid Local Parameter Estimates, Semi Parametric GWR

The variable kid is insignificant in all districts of Sindh and Baluchistan except for Loralai, Barkhan and Killa Saifullah, for which it is less significant determinant of food insecurity incidence. It is highly significant for all districts of KPK and Punjab, except for Rajanpur and Rahim Yar Khan. For Rajanpur it is less significant and for Rahim Yar Khan it is insignificant in determining the food insecurity incidence, as shown in the Fig.6.14.

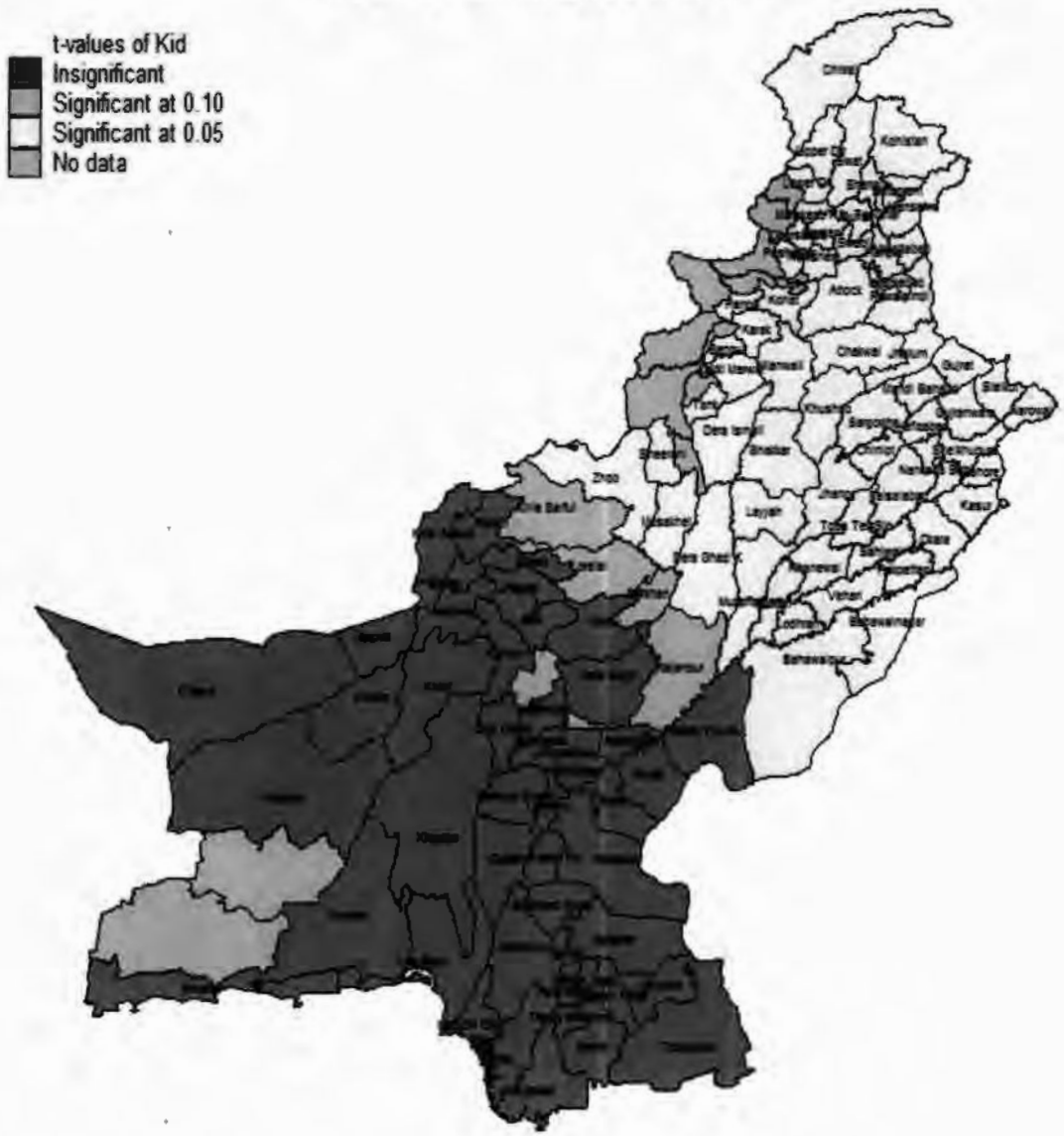


**Figure 6.14** Kid Local t-value Estimates, Semi Parametric GWR

### 6.1.8 No Girl

The variable No Girl is a binary variable, where its value equal 1 means no girl and 0 otherwise. For the GWR analysis, its proportion is taken at district level. The negative sign of the local parameter estimates as shown in Fig.6.15, indicate that lower the proportion of no girl at district level, higher will be the food insecurity incidence.

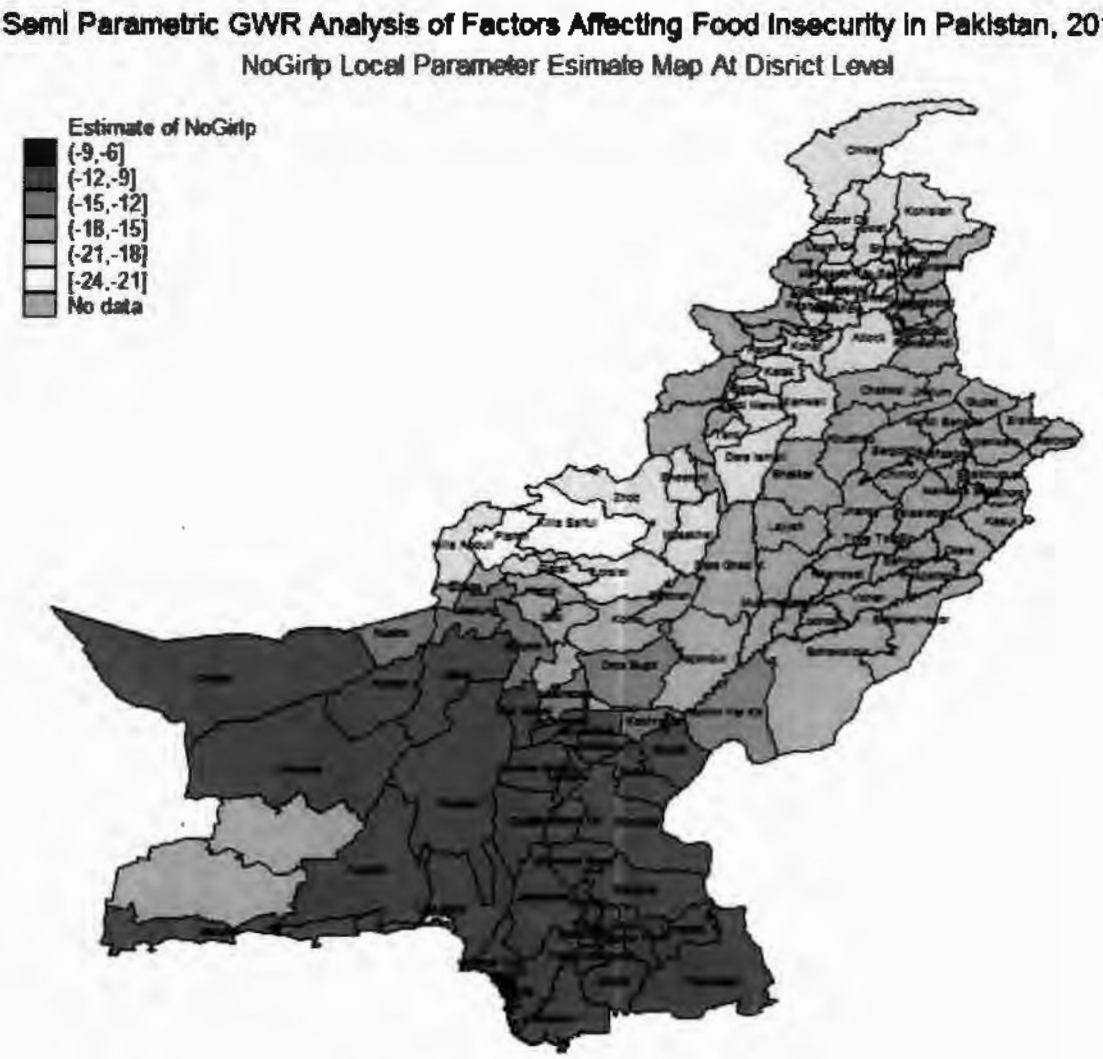


**Figure 6.15** No Girl Local Parameter Estimates, Semi Parametric GWR

The variable No Girl has spatially varying relationship with the food insecurity incidence across the districts in Pakistan, as visualized in Fig.6.16. It is significant (at 10%) for all the districts of Punjab including Islamabad, and highly significant (at 5%) for Rahim Yar Khan. It is significant (at 10%) for all of the districts of KPK. Conversely, in case of Sindh, it is insignificant for all the districts. For Baluchistan, it is insignificant for most of the districts, less significant for some districts and highly significant for Pishin, Killa Saifullah and Zhob districts.

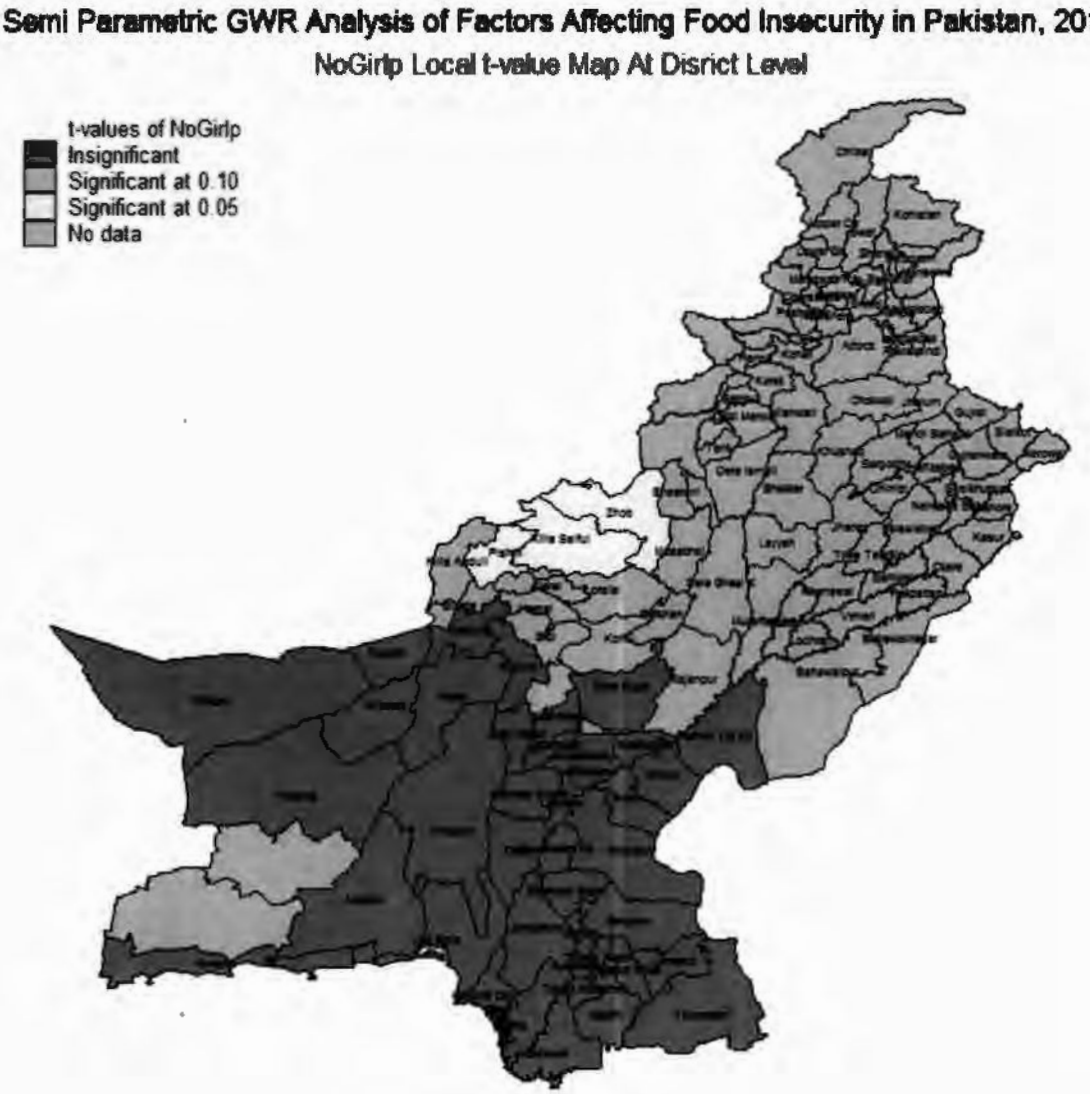


**Figure 6.16** No Girl t-value Estimates, Semi Parametric GWR

### 6.1.9 No Kid

The variable No Kid is a binary variable, where its value equal 1 means no Kid and 0 otherwise. For the GWR analysis, its proportion is taken at district level. The positive sign of the local parameter estimates as shown in Fig.6.17, indicate that lower the proportion of households with no kid at district level, lower will be the food insecurity incidence. As the households with all adult members will require more food expenditures.

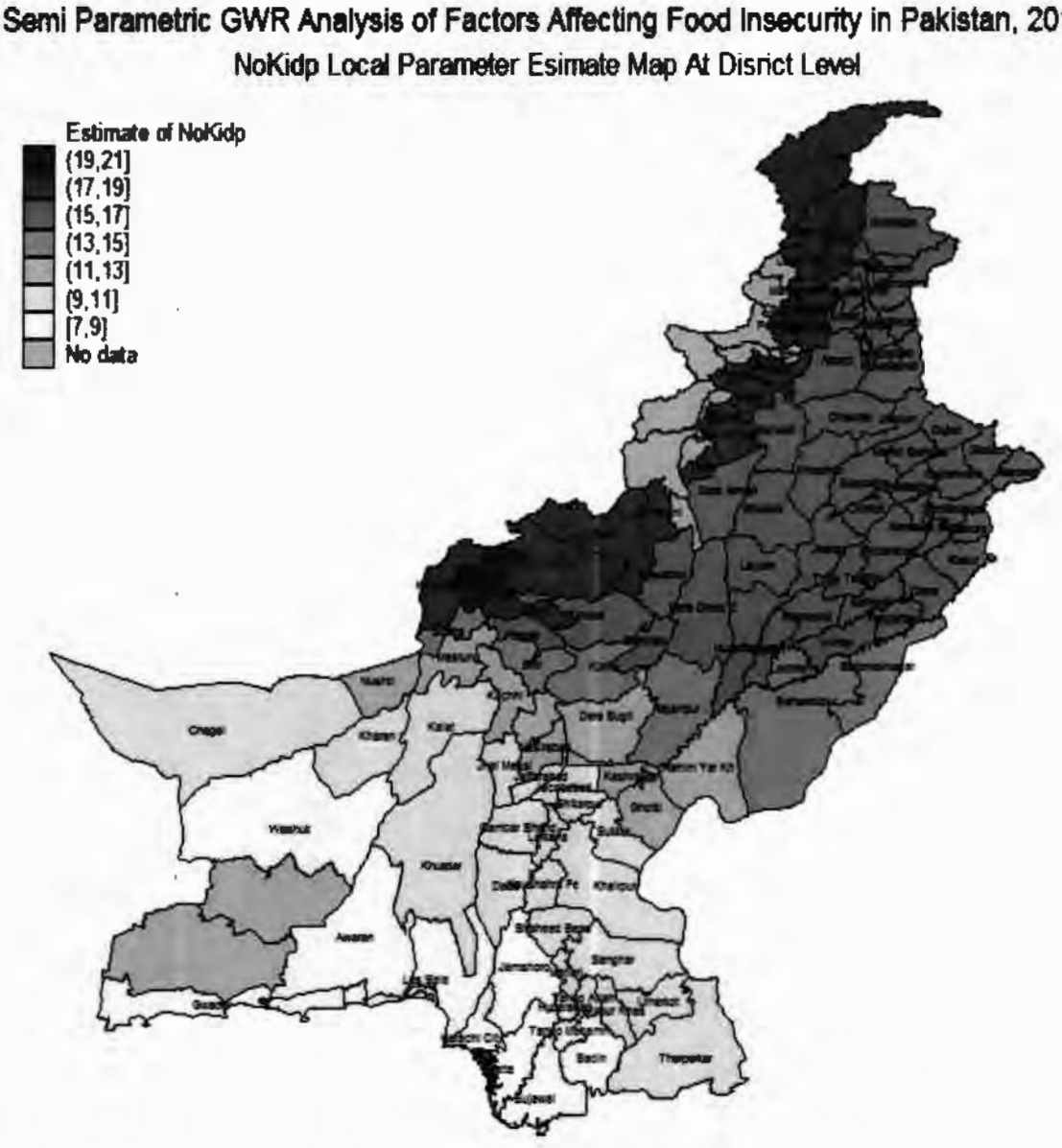


**Figure 6.17** No Kid Local Parameter Estimates, Semi Parametric GWR

The variable No Kid is highly significant in all the districts of Punjab and KPK including Islamabad. On the other hand, in case of Sindh, it is highly significant for Kashmor, while, it is less significant for some of the districts and insignificant for some districts. However, in Baluchistan, it is insignificant for Gawadar, Awaran, Las Bela, Khuzdar, Washuk and Chaghi. While, it is less significant for some districts and highly significant for the rest of the districts, as depicted in the Fig.6.18.

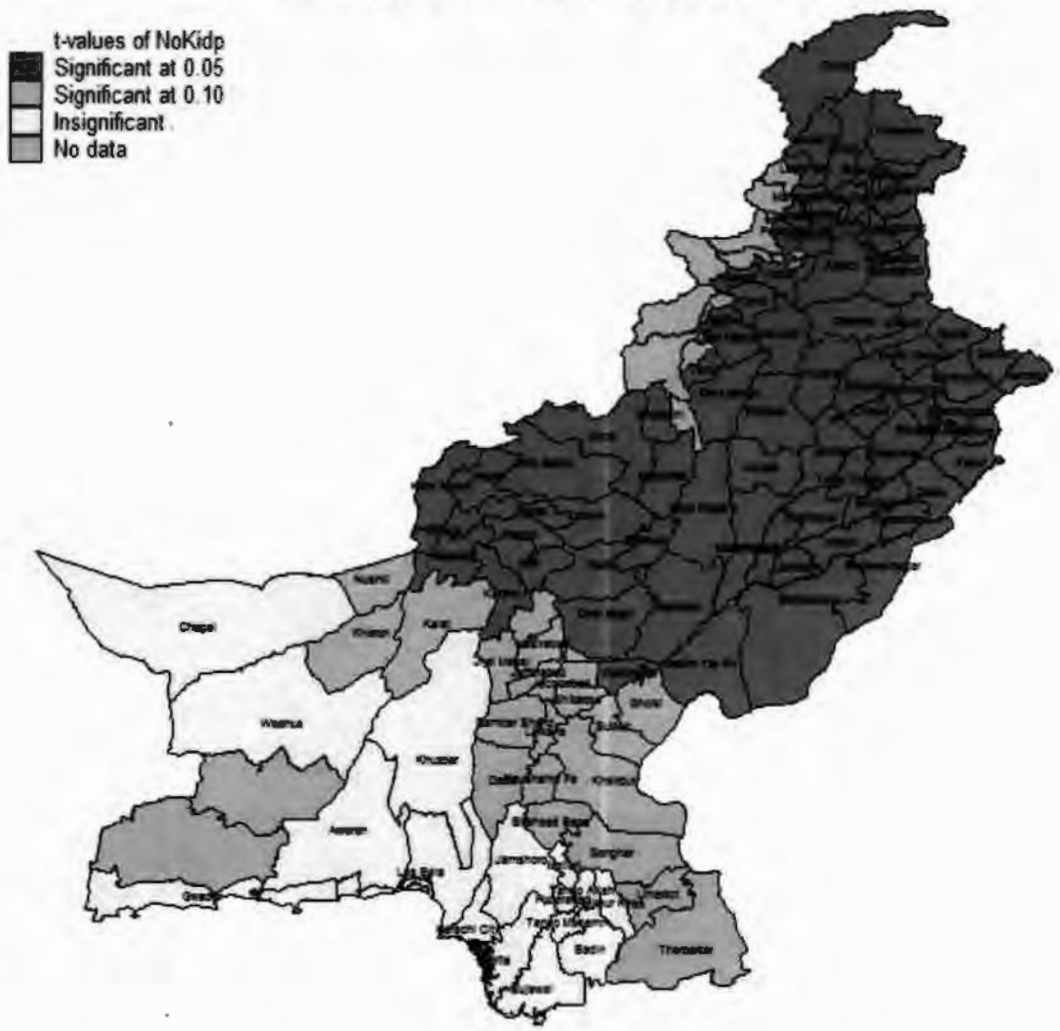


**Figure 6.18** No Kid t-value Estimates, Semi Parametric GWR

### 6.1.10 Girl Ratio

The variable Girl Ratio is the proportion of girls out of total number of children in a household. For GWR analysis, it is averaged at district level. As shown in the Fig.6.19, the sign of the local parameter estimate is positive. The coefficient estimate is larger in districts from KPK and Baluchistan. As, if there are more girls than boys, due to customs girls do not work outside. So, the income available for food expenditure will be less and there will

be high food insecurity incidence. Or due to customs households in such districts do not spend much on the food requirement of girls as much as they spend for boys.

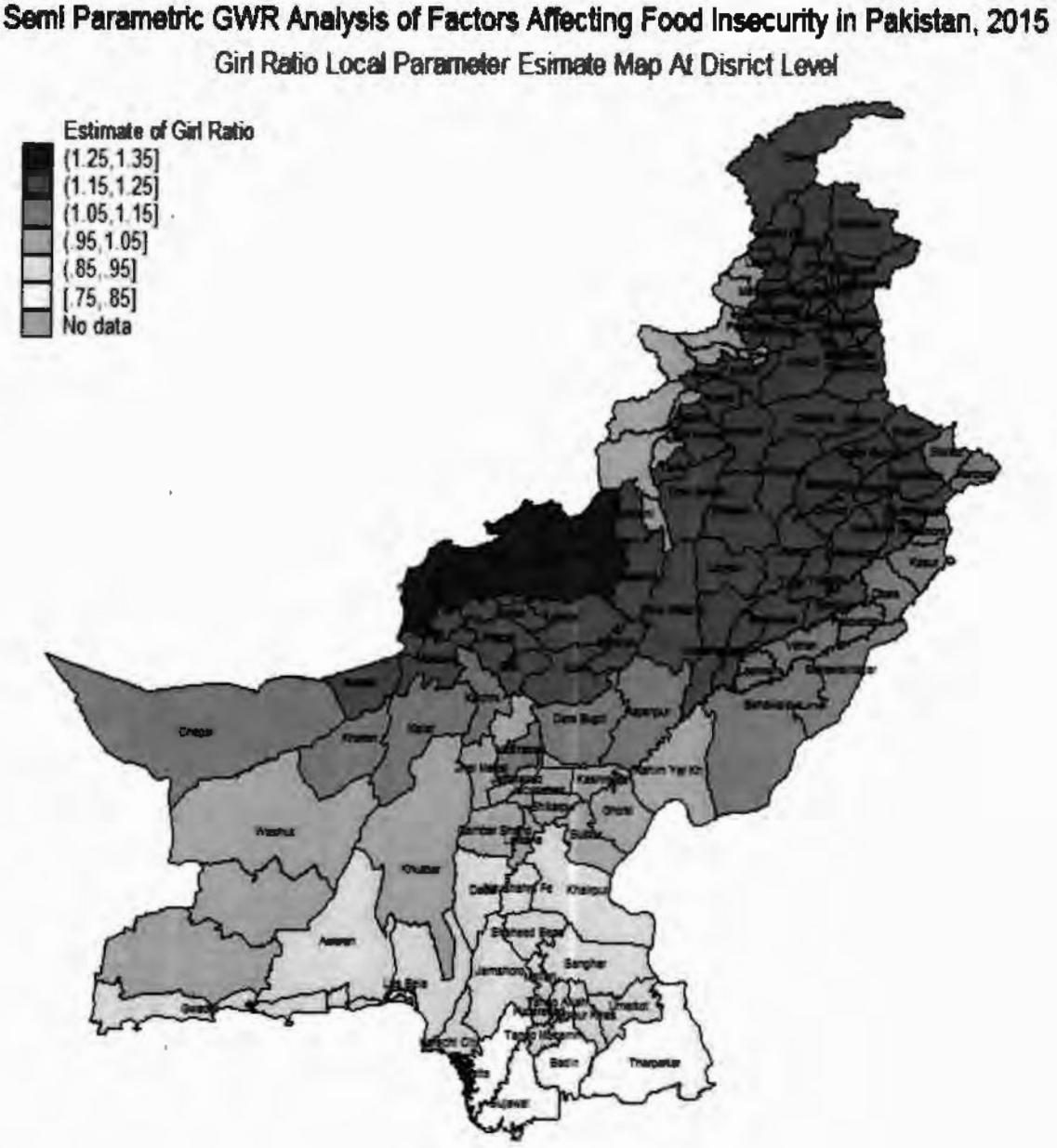


**Figure 6.19** Girl Ratio Local Parameter Estimates, Semi Parametric GWR

According to the results shown in Fig.6.20, the variable Girl Ratio is highly significant in all of the districts in Pakistan except for few districts. The variable is less significant in Gawadar district of Baluchistan, and Karachi, Thatta and Sujawal district of Sindh.

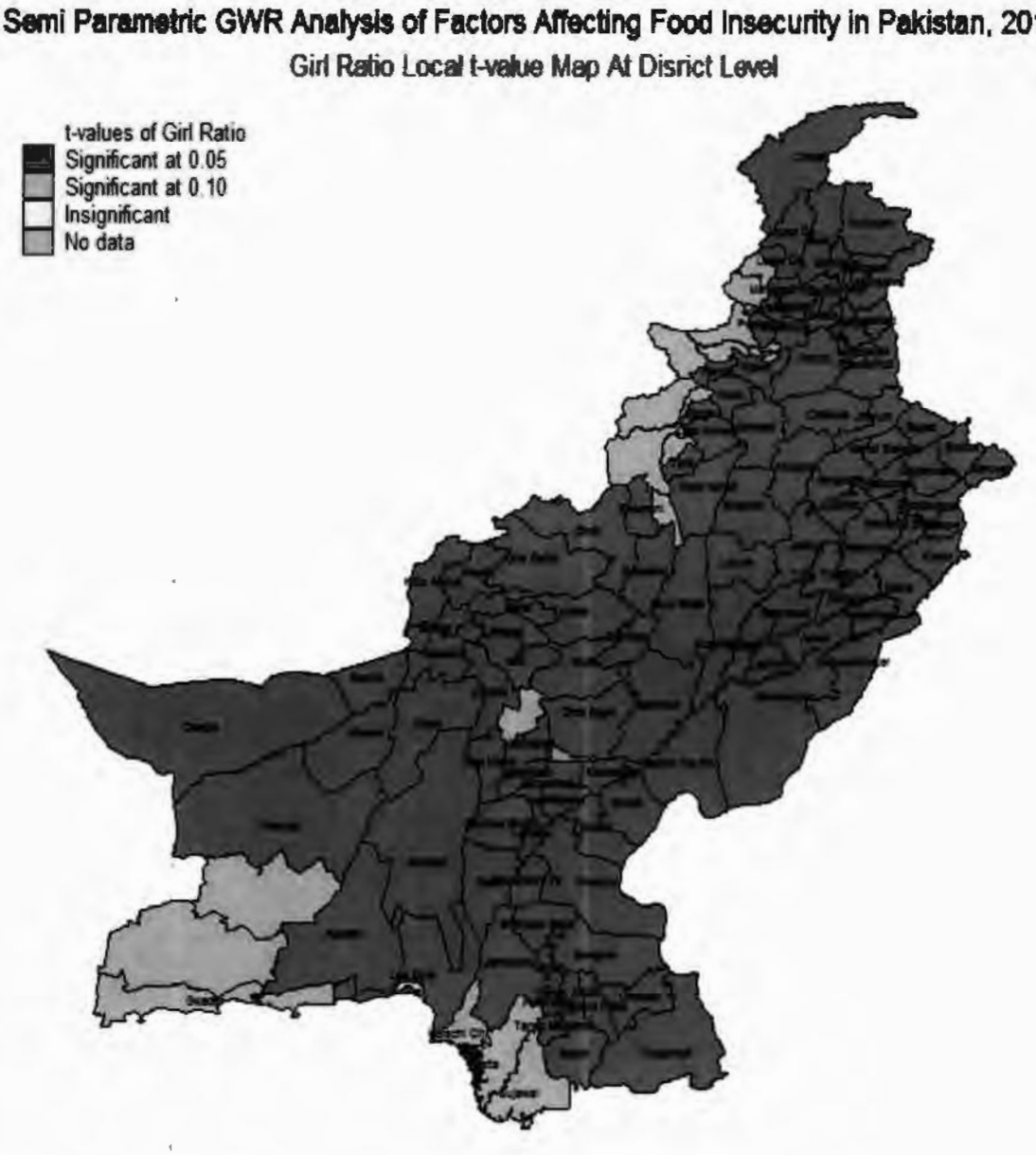


**Figure 6.20** Girl Ratio Local t-value Estimates, Semi Parametric GWR

### 6.1.11 Sex Ratio

The variable Sex Ratio is the proportion of females in a household. For the GWR analysis it is averaged at district level. For almost all of the districts, the sign of the local parameter estimate is positive, as shown in the Fig.6.21. It means on the average, the more is the proportion of female members in a household, the more is the food insecurity incidence at district level.

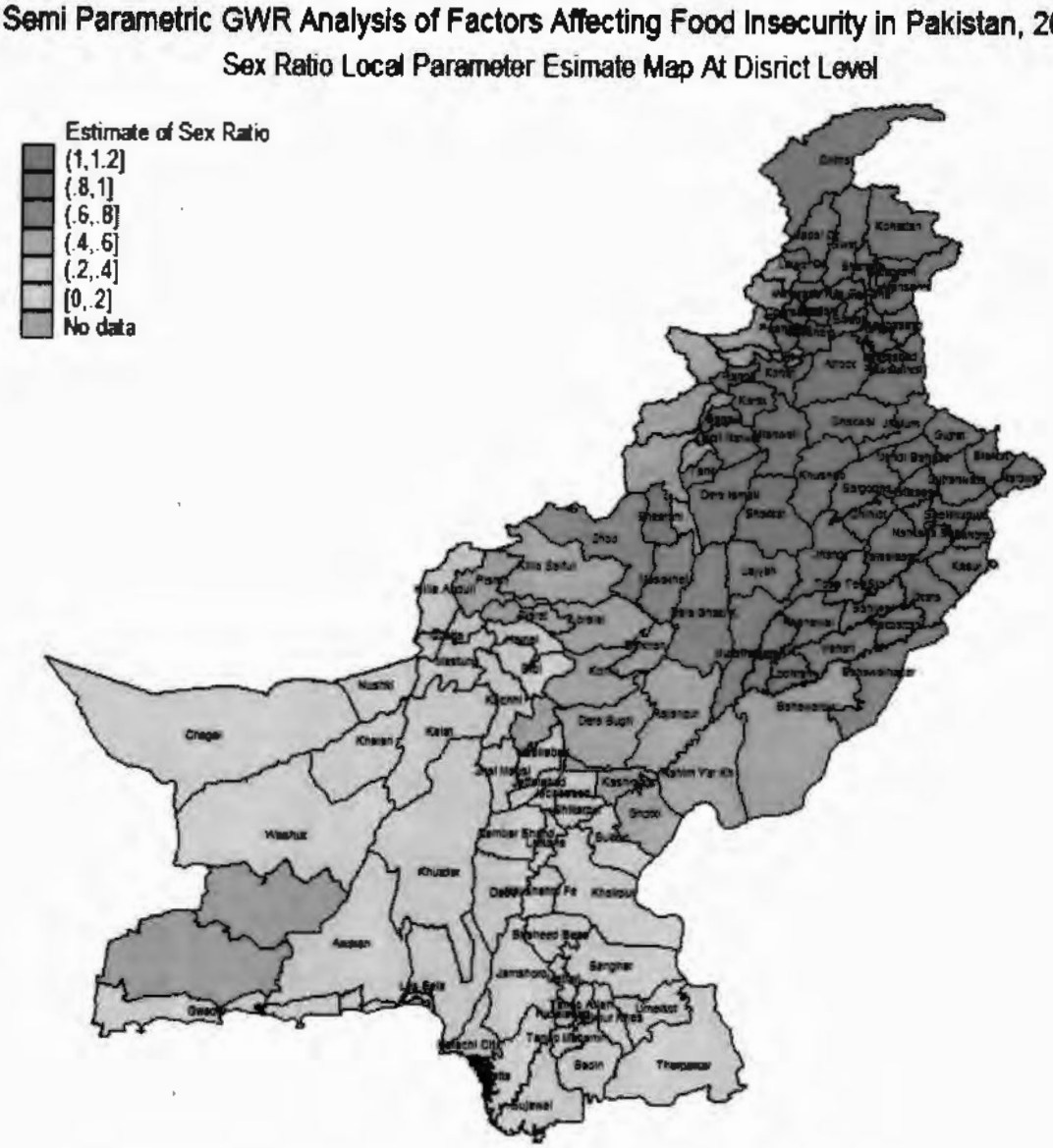


**Figure 6.21** Sex Ratio Local Parameter Estimates, Semi Parametric GWR

The significance of variable Sex Ratio is spatially varying in determining the food insecurity incidence across the districts in Pakistan. It is insignificant in all the districts of Punjab, Sindh and Baluchistan. However, in KPK, it is significant in Kohistan, Chitral, Upper Dir, Lower Dir and Swat District, while, it is insignificant in all other districts, as indicated by in the Fig.6.22.

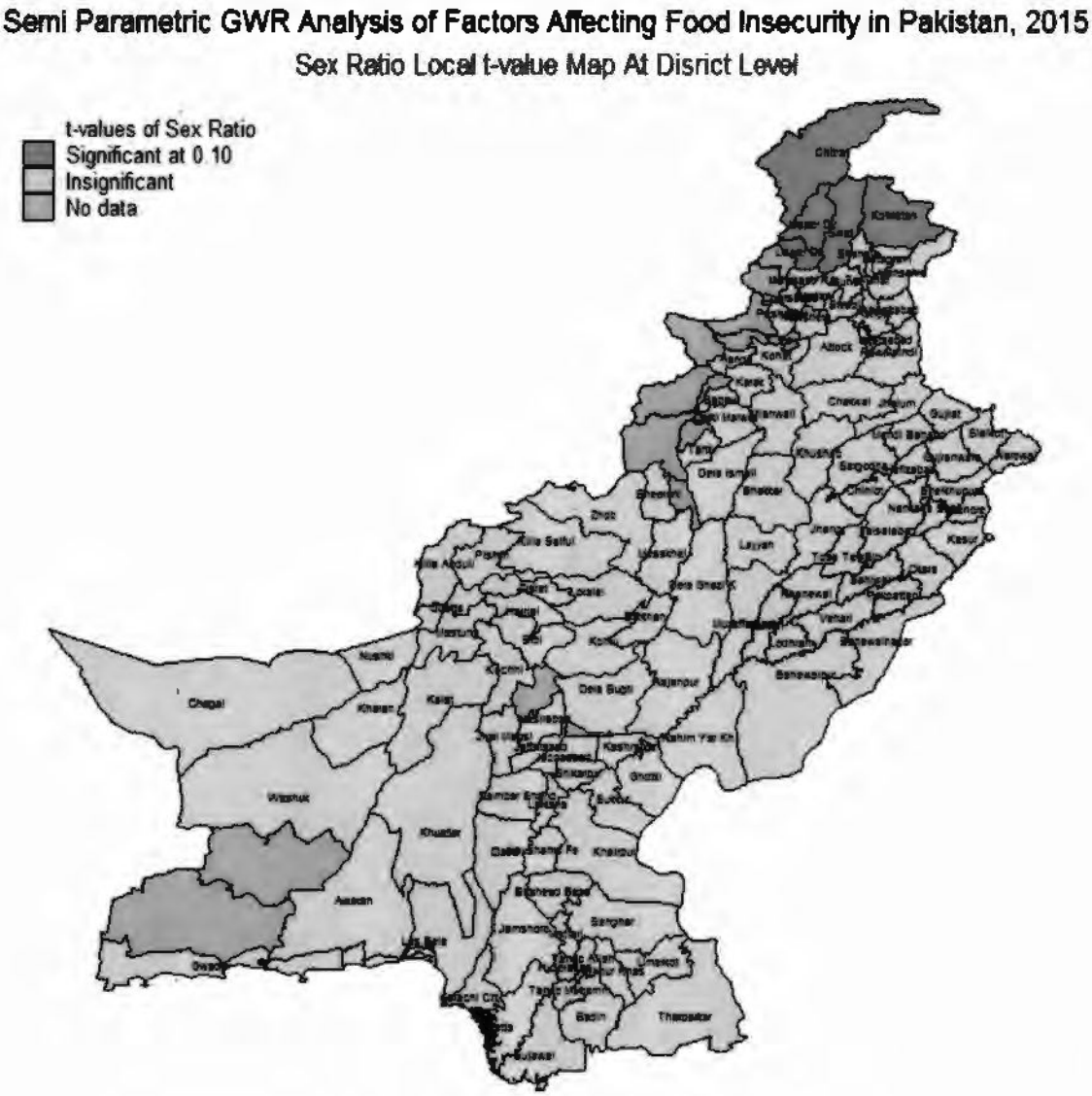


**Figure 6.22** Sex Ratio Local t-value Estimates, Semi Parametric GWR

### 6.1.12 Sex Ratio Adult Men

The variable Sex Ratio Adult Men is the proportion of adult men (15<age<65) in a household. Its average is taken at district level, for the GWR analysis. The sign of the local parameter estimate is positive, as shown in the Fig.6.23. As the caloric requirement of Adult men is more, the higher is the proportion of adult men on the average at district level, the more will be the food insecurity incidence.

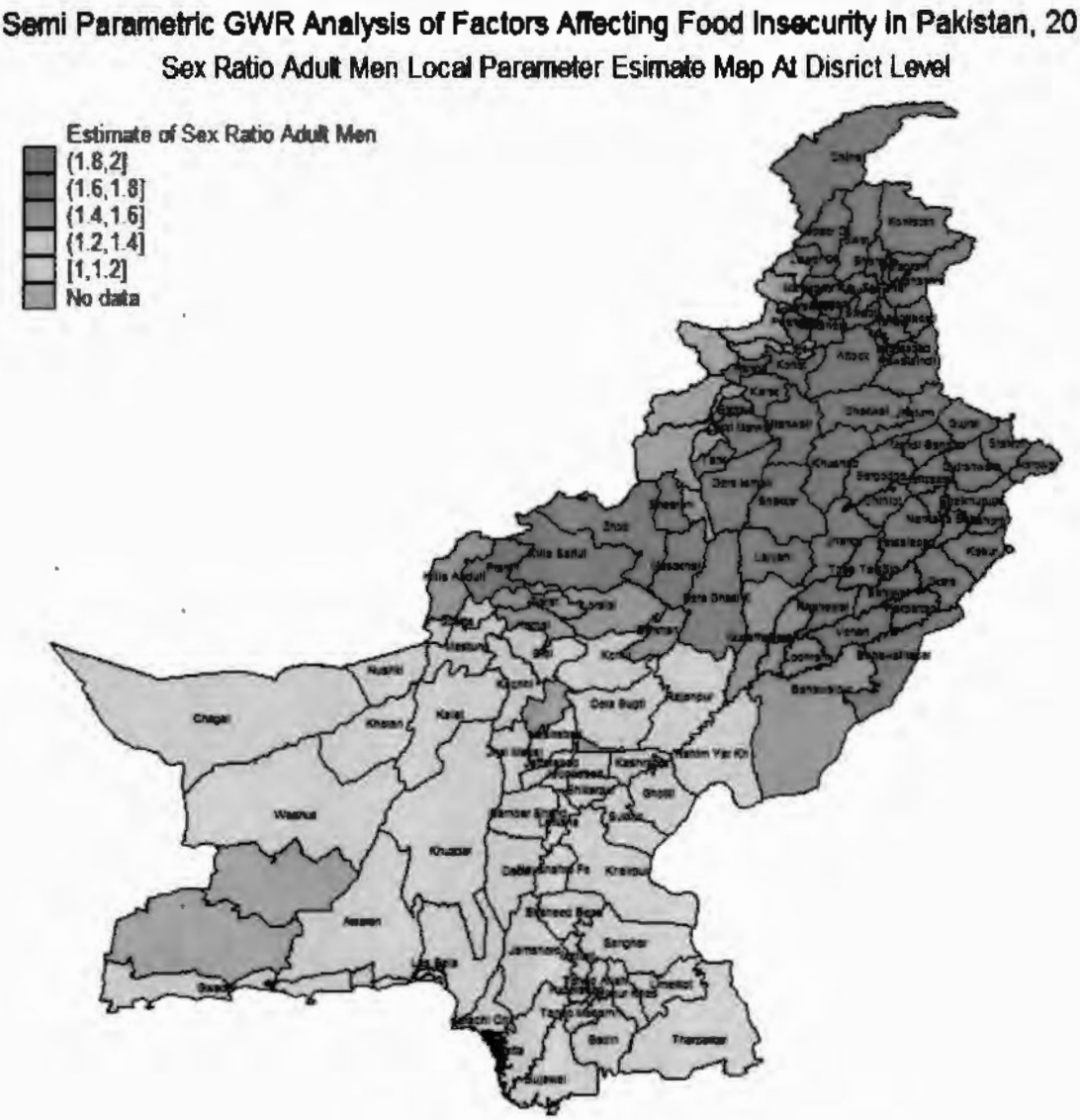


**Figure 6.23** Sex Ratio Adult Men Local Parameter Estimates, Semi Parametric GWR

The variable Sex Ratio adult Men has spatially varying significance in determining the food insecurity incidence across the districts in Pakistan as sbown in Fig.6.24. It is highly significant in all districts of KPK. Similarly, in Punjab, it is highly significant for all the districts except for Rahim Yar Khan, whereas, it is insignificant. Conversely, in Sindh, it is insignificant in all the districts. However, in Baluchistan, it is significant in Killa Abdullah, Killa Saifullah, Pishin, Ziarat, Lora Lai, Zhob, Sheerani, Musakhail, Barkhan, Kohlu and Harnai. While, it is insignificant for rest of the districts in Baluchistan.

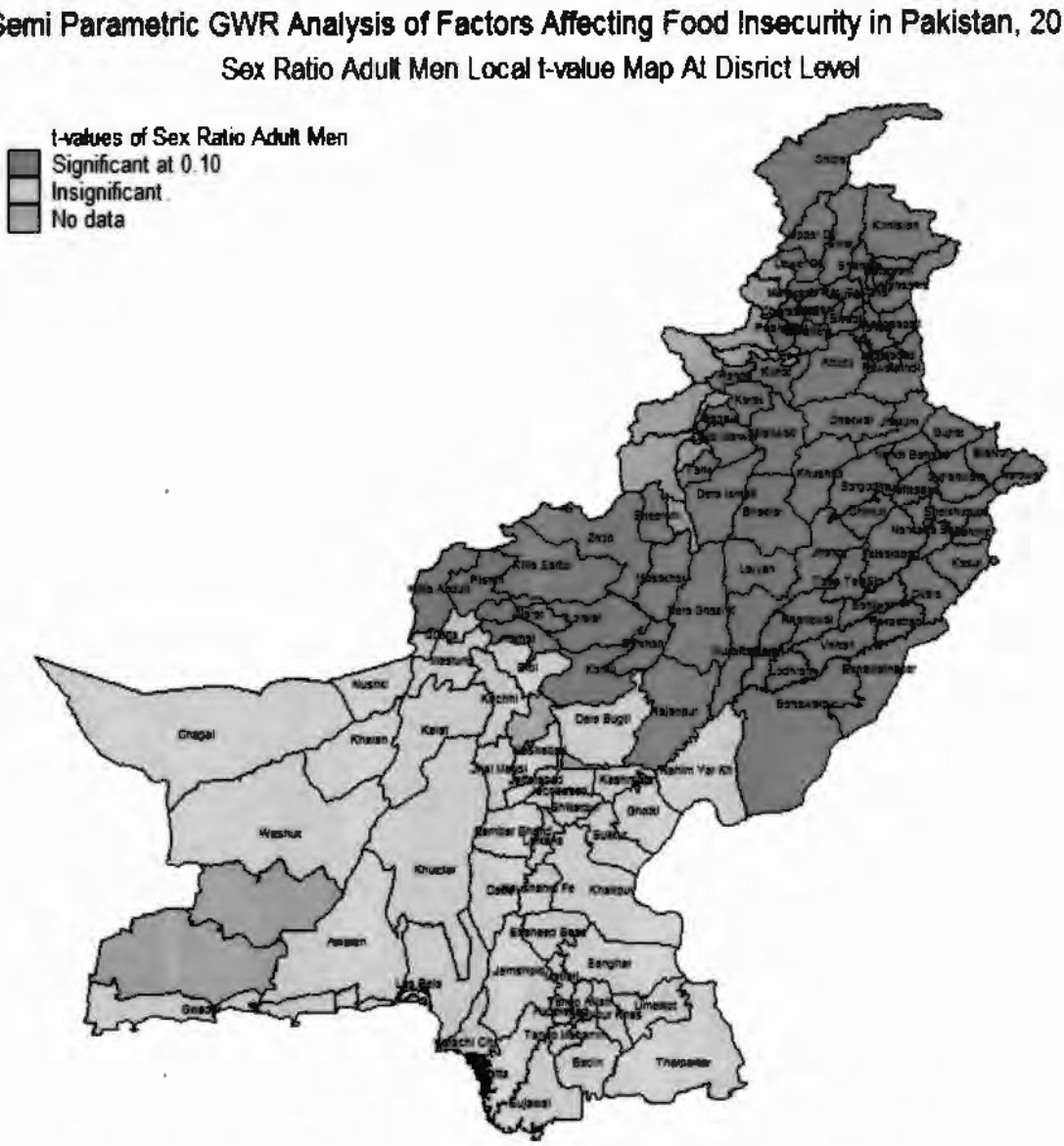


**Figure 6.24** Sex Ratio Adult Men Local t-value Estimates, Semi Parametric GWR

### 6.1.13 Marital-2

The variable Marital-2 represents the marital status of a household member as married. It is a binary variable with 1 equal married and 0 otherwise. Its proportion is taken at district level. The sign of the local parameter estimate is positive for all the districts, representing its direct relationship with the food insecurity incidence as depicted in Fig.6.25.

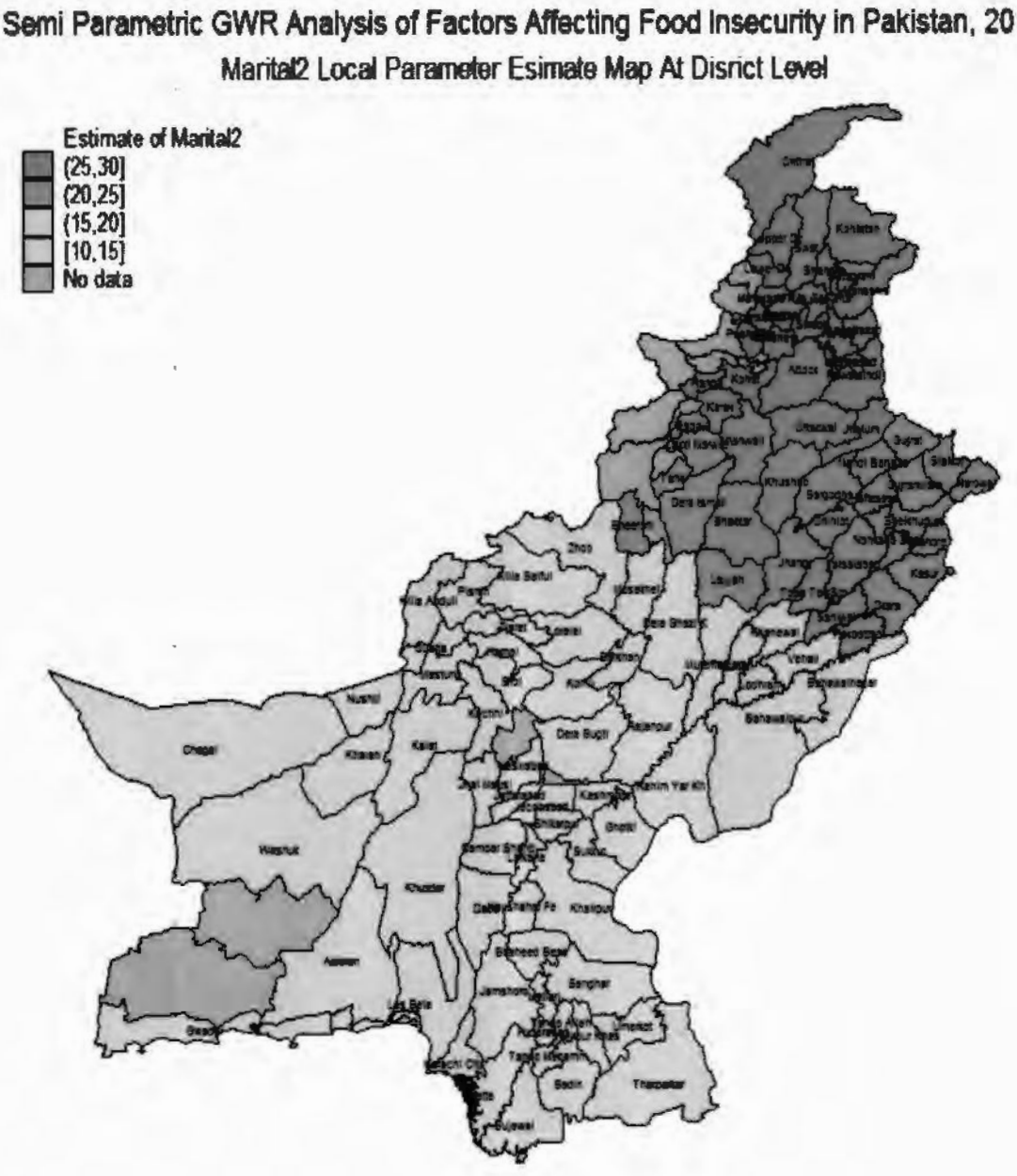


**Figure 6.25** Marital-2 Local Parameter Estimates, Semi Parametric GWR

The significance of the variable Marital-2 is spatially varying across the districts in Pakistan, as depicted in the Fig.6.26. The variable is significant in only one district of KPK i.e. Chitral, while, it is insignificant in all districts of KPK. Moreover, it is insignificant in all other districts of Pakistan.

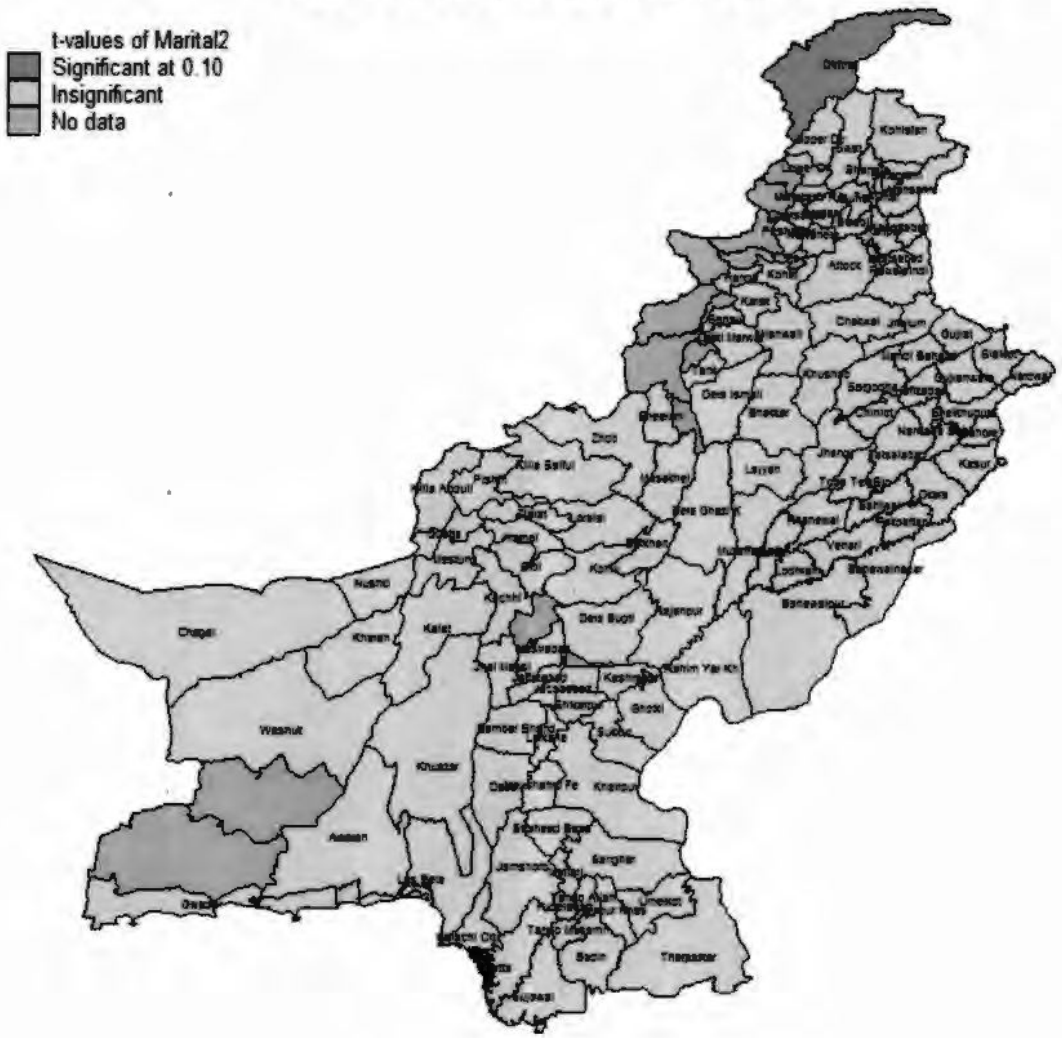


**Figure 6.26** Marital-2 Local t-value Estimates, Semi Parametric GWR

### 6.1.14 Residential Building

The variable Residential Building represents property status of a household. It is a binary variable with 1 equal own residential building and 0 otherwise. For the GWR analysis, its proportion is taken at district level. As shown in the Fig.6.27, the sign of the local parameter estimates is negative. It indicates that higher is the proportion of owned residential building, lower is the food insecurity incidence.

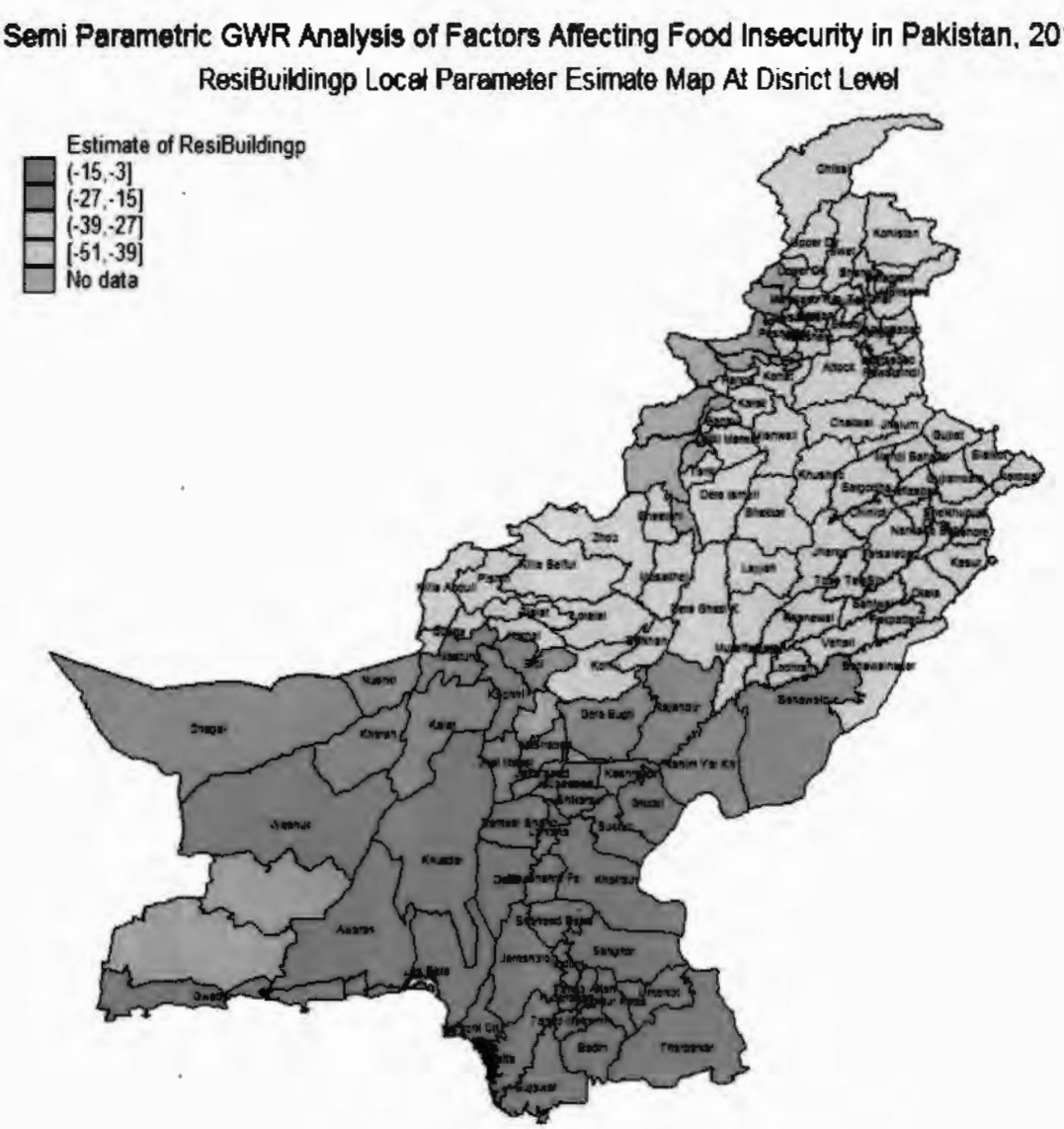


**Figure 6.27** Residential Building Local Parameter Estimates, Semi Parametric GWR

The variable Residential Building has spatially varying relation to the food insecurity incidence across districts in Pakistan. As visualized in Fig.6.28, the variable is insignificant in all the districts of Sindh and Punjab including Islamabad. Moreover, it is insignificant across all the districts of Baluchistan except for Killa Saifullah and Zhob. Similarly, it is significant in few districts of KPK such as Chitral, Upper Dir, Lower Dir, Bannu and Hangu, but insignificant in all other districts.

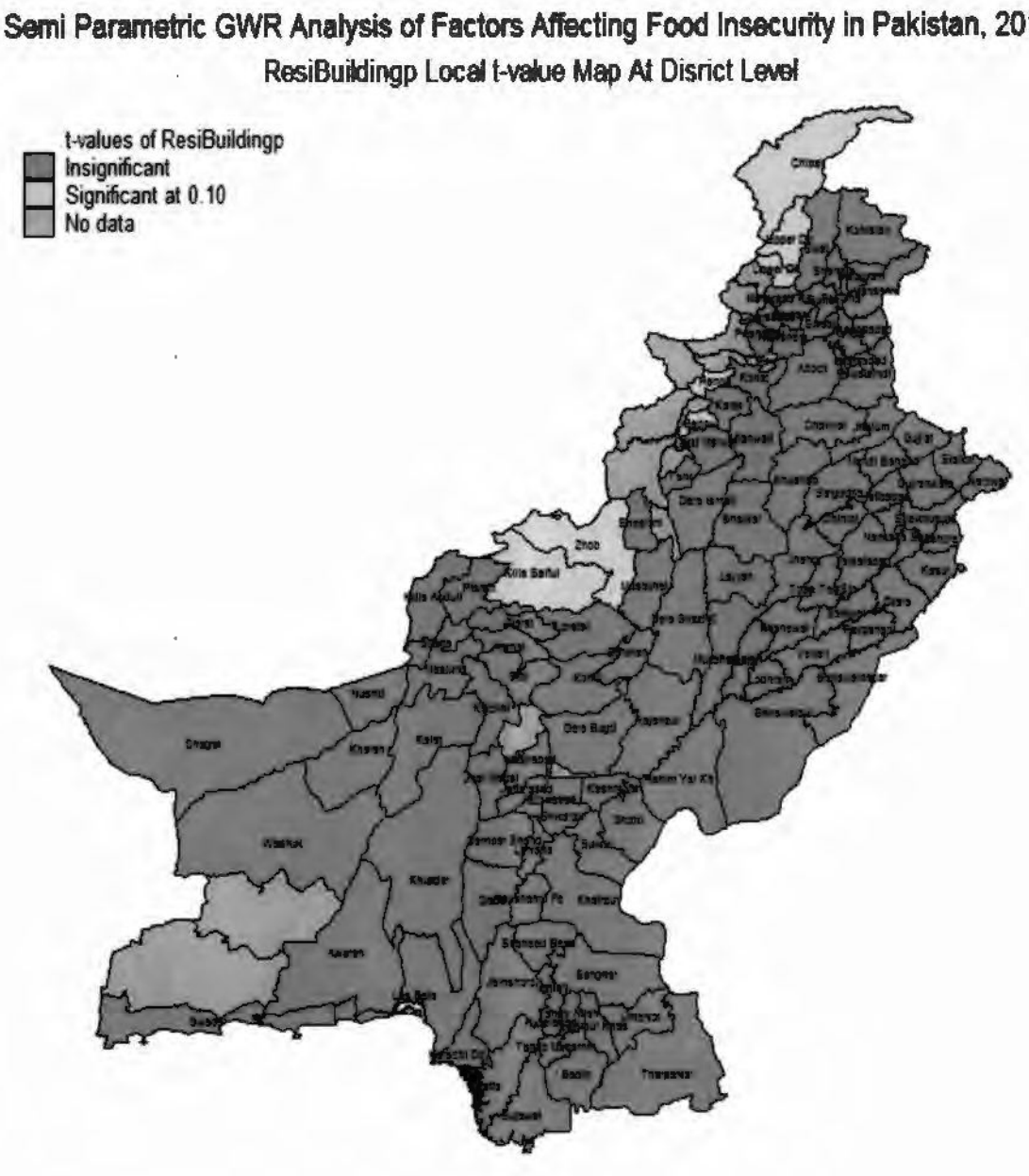


**Figure 6.28** Residential Building Local t-value Estimates, Semi Parametric GWR

# CHAPTER 7

# CONCLUSION and RECOMMENDATIONS

This chapter provides the conclusions, based on SAE analysis of food insecurity, Parametric and Semi Parametric GWR analysis of the spatially varying determinants of food insecurity, as well as the comparison of the Parametric and Semi Parametric GWR estimation results at district level in Pakistan. Finally, recommendations are made on the basis of conclusions drawn from SAE and GWR analysis of food insecurity at district level in Pakistan.

## 7.1 Conclusion

This study primarily analyzed the Food Insecurity at District level in Pakistan. For this purpose two data sets HIES 2015-16 and PSLM 2014-15 were used. The Food Insecurity Analysis is based mainly on two research domains, which were not explored in the field of Food Security in Pakistan. The first one is, the estimation and mapping of District Level Food Insecurity Incidence and District Level Food insecurity Density in Pakistan, employing SAE technique. The second one is, the estimation and mapping of Spatially Varying Determinants of Food Insecurity at District Level in Pakistan, employing GWR technique.

The SAE analysis revealed that overall, food insecurity situation in Pakistan has not gone better. As, according to the estimates the food insecurity incidence in Pakistan is 67.84 %. It points out that about $2/3^{rd}$ of the households in Pakistan fail to make the subsistence food expenditures, thus experiencing food insecurity. At provincial level, Baluchistan is found to be the most food insecure province with 87% households experiencing food insecurity,

followed by Sindh and Punjab. While, KPK is the least food insecure with 63.16 % food insecure households.

According to the District Level Food Insecurity Incidence estimates, Washuk district of Baluchistan is found to be the most food insecure district with almost 93% food insecure households, failing to spend subsistence monthly per adult equivalent food expenditures. The ranking describes that first 20 most food insecure districts belong to Baluchistan province with food insecurity incidence falling between 85%- 93%. On the other hand, the least food insecure district is Abbottabad from KPK with 44.27% food insecure households. Additionally, 4 out of 5 least food insecure districts belong to KPK with food insecurity incidence ranging from 53% to 44%.

The SAE District Food Insecurity Density estimates turned the situation upside down. As, Karachi city from Sindh province, which is the second least food insecure with respect to food insecurity incidence estimates, became the most food insecure in terms of food insecure people (6.4 million). Washuk district from Baluchistan, which was the most food insecure district according to the food insecurity incidence, is the 13$^{th}$ least food insecure district with only 0.17 million food insecure people. Similarly, the top 20 districts with most food insecure people are from Punjab, except for Karachi and Peshawar. While the 20 most food insecure districts were from Baluchistan with respect to food insecurity incidence. Additionally, most of the districts from Baluchistan, which were under category of 20 most food insecure districts, are now under category of 20 least food insecure districts. Furthermore, Sheerani from Baluchistan is the least food insecure district with only 0.05 million food insecure people, was under high food insecurity incidence category.

The second research domain is the estimation and mapping of Spatially Varying Determinants of Food Insecurity at District Level in Pakistan, employing GWR technique. Two types of GWR analysis are performed in this regard, the Parametric and Semi Parametric GWR analysis.

The Parametric GWR Analysis provided strong evidence of the spatially varying relationship of the factors affecting food insecurity at district level in Pakistan. Some factors were significant in some districts, while insignificant in other districts. The overall analysis had quite high explanatory power. Most of the determinants were significant in at least some districts in the GWR analysis. It was observed that the education related variables representing different levels of educational attainment, have significant negative relationship with the food insecurity at district level in Pakistan. Which points out that the districts with high education are less food insecure. Furthermore, the housing related variables such as average number of rooms per household and residential status as own residence are also significant determinants of food insecurity in different districts, with negative sign. Additionally, the health and sanitation related variables such as access to piped water and flush toilet connected with sewerage also proved to be significant in various districts with negative sign as expected.

The Semi Paramctric GWR Analysis short listed the variables taken as local via applying Geographical Variability Test. Some of the variables, which were considered as Local, now became Global variables. The Semi Parametric GWR Analysis had explanatory power higher than Parametric GWR Analysis. The Semi Parametric GWR Analysis also provided a strong evidence of spatial variation in the relation of the food insecurity and factors affecting it, at district level in Pakistan. Most of the determinants were significant in at

least some districts in the Semi Parametric GWR analysis. It was observed that the education related variables representing different levels of educational attainment, have negative relationship with the food insecurity at district level in Pakistan. Which points out that the districts with high education are less food insecure. Furthermore, the housing related variables such as residential status as own residence is also significant determinant of food insecurity in different districts, with negative sign.

## 7.2 Policy Recommendations and Future Research

The conclusions drawn on the basis of estimation results have strong policy implication for the estimation of food insecurity at disaggregated level in Pakistan. Since, the SAE based food insecurity incidence and food insecurity density estimates provided a completely different picture of the prevalence of food insecurity at district level in Pakistan. Similarly, the evidence of the spatially varying determinants of food insecurity across districts in Pakistan based on GWR analysis, also highlight important policy implications. The following policy recommendations are made on the basis above analysis:

1. As, the two ways used to analyse the food insecurity, provided a huge difference in results. Therefore, it is suggested that for targeted policy interventions to reduce food insecurity at district level in Pakistan, the policy makers may consider the food insecurity density in addition to the food insecurity incidence. As, it is evident from the analysis that there are many districts with low food insecurity incidence and a lot of food insecure people residing over there. The policy interventions based on only food insecurity incidence estimates might result in depriving the real beneficiaries.

2. For the successful targeted interventions, it matters a lot, how the food insecurity is estimated. Furthermore, the untargeted programs for food insecurity alleviation such as; health facilities, improved roads and the financial support to local administrative units might be more effective in areas with high food insecurity incidence. Whereas, the targeted programs for improving poor households' condition including income transfers, food for work and free social services may be more favourable in the high food insecurity density areas.
3. The evidences of spatially varying determinants of food insecurity at district level in Pakistan, highlight the requirement of targeting the district specific factors for food insecurity reduction in Pakistan. It may help in optimal utilization of resources in the district specific fields of action, leading to the positive impact on geographically disaggregated food security situation in Pakistan.
4. The results of the analysis might be employed in order to guide local actions for reducing food insecurity. The analysis implies that food insecurity reduction efforts in Pakistan require to be targeted at district level. A relatively inflexible national approach for food insecurity reduction might not be much successful.
5. Our research on food insecurity at district level in Pakistan reveals that there are bleak inter-provincial as well as inter district differences in food insecurity incidence. Food insecurity incidence is the highest in Baluchistan. At the district level, the concentration of food insecurity is clearly evident that top 20

districts belong to Baluchistan. Moreover, the districts having low population and mostly rural areas are the ones with highest food insecurity incidence. According to the population census 2017 Baluchistan has the lowest population density in Pakistan. Additionally, Baluchistan is a resource rich province and such resources may be utilized to create income generation opportunities.

6. Provision of access to the requisites including health, education, sanitation and safe drinking water to the food insecure districts may result in improving the overall as well as district specific food insecurity situation. Especially in the most food insecure districts such as Washuk in Baluchistan Province. Additionally, micro financing, human resource development through health, education and skill development may also contribute toward improving the accessibility aspect of food insecurity in such districts. Moreover, usefulness of social safety net programs may be enhanced through smooth affectee-government interactions.
7. The findings underscore the vital role of education in mitigating food insecurity. Policymakers may prioritize and increase investment in education, especially in regions with high rates of no schooling. Enhancing access to quality education empowers individuals with knowledge and skills, enabling them to overcome poverty and food insecurity in the long run. The results highlight the significance of education in addressing food insecurity. Policymakers may concentrate on promoting and expanding access to quality education in districts with higher food insecurity rates, achieved through

school infrastructure improvements, adequate teaching resources, and incentives to encourage school attendance. By leveraging the positive correlation between education and food security, policymakers may work towards reducing food insecurity in districts within KPK, Punjab, and Islamabad.

8. The discovery that owning a house is negatively linked to food insecurity in Killa Abdullah district, Baluchistan, holds significant policy implications for the region. Policymakers may consider the following actions based on this result: promoting secure land ownership to enhance stability and food security, implementing affordable housing programs that suit local economic conditions, and safeguarding property rights to encourage homeownership and protect against disputes. Targeted support for marginalized groups, livelihood and income generation initiatives, and community development efforts may also improve homeownership access and overall food security. Investing in housing infrastructure, conducting awareness campaigns, and collaborating with local authorities and stakeholders are vital for culturally appropriate and effective policy implementation. It's crucial to tailor these strategies to Killa Abdullah's unique socio-economic and cultural context, along with continuous monitoring and evaluation to ensure desired outcomes in reducing food insecurity and enhancing housing conditions in the district.
9. The discovery that a higher proportion of piped water as a drinking water source is linked to lower food insecurity in most districts of KPK, Punjab, and Sindh, except for some specific districts in these provinces and Baluchistan,

has significant policy implications for enhancing food security and water access in these regions. To address this, policymakers may prioritize the development and expansion of piped water infrastructure in districts where it currently has less impact. Alongside this, ensuring the quality of piped water through regular testing and monitoring is crucial. For districts with a weaker connection between piped water access and food insecurity, targeted interventions like community engagement and education on water hygiene should be considered. Marginalized districts require additional resources and support to improve water access and food security. Tailored rural water management approaches should be adopted in provinces like Baluchistan, while urban areas like Karachi should focus on upgrading water distribution systems. Policymakers need to take an integrated approach, collaborating across sectors and collecting continuous data for informed decision-making. Involving local communities in planning and implementation is essential for long-term sustainability, and climate resilience measures should be integrated into water and food security programs, given the potential impact of climate change. It's essential to tailor these strategies to the unique context of each district, considering socio-economic, environmental, and cultural factors in KPK, Punjab, Sindh, and Baluchistan. Flexibility and adaptability are vital in addressing the specific challenges and opportunities faced by different regions.

10. The study reveals that a higher proportion of flush toilets connected to sewerage is linked to lower food insecurity incidence in most districts of Sindh and Baluchistan but is insignificant in all districts of KPK, Punjab (including

Islamabad), and a few districts of Baluchistan. This has specific policy implications for addressing food security and sanitation challenges in these regions. To improve sanitation and food security, policymakers may prioritize sanitation infrastructure development in Sindh, address disparities in sanitation access, consider behavioural change interventions, focus on urban sanitation management in specific areas, implement rural sanitation initiatives in provinces like KPK and Punjab, and launch sanitation awareness campaigns across all regions.

11. The study indicates that a higher number of rooms available per household is associated with reduced food insecurity at the district level in Pakistan, leading to specific policy implications for addressing food security and housing challenges in different regions. To tackle these issues, policymakers may prioritize housing infrastructure development in KPK, implement affordable housing programs, and consider urban planning and land use regulations. Targeted rural housing development initiatives may be needed in certain districts, while understanding regional disparities is crucial for tailoring interventions. Exploring innovative housing solutions, encouraging community-based initiatives, and fostering data-driven decision-making and cross-sectoral collaboration are essential. Strengthening capacity and raising awareness may further support the implementation of region-specific approaches across KPK, Punjab, Sindh, and Baluchistan to improve housing and food security.

Finally, the future studies are recommended to use Pakistan population census 2017, which is replaced by the PSLM 2014-15, due to the unavailability of the census data till the completion of this study. It might further improve the results. Additionally, similar analysis could be done with the rural/ urban segregation at district level in Pakistan, in order to highlight the food insecurity differences among the rural and urban parts of the districts in Pakistan.

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# APPENDIX A: Adult Equivalent Scale Based on 2350 Calories per Adult

| AGE/SEX Distribution | Energy per person daily requirement | Equivalent factor |
|---|---|---|
| **Children** | | |
| < 1 Year | 1010 | 0.429787 |
| 01 – 04 Years | 1304 | 0.554894 |
| 05 – 09 Years | 1768 | 0.752340 |
| **Males** | | |
| 10 – 14 Years | 2816 | 1.198298 |
| 15 – 19 Years | 3087 | 1.313617 |
| 20 – 39 Years | 2760 | 1.174468 |
| 40 – 49 Years | 2640 | 1.123404 |
| 50 – 59 Years | 2460 | 1.046809 |
| >=60 Years | 2146 | 0.913191 |
| **Females** | | |
| 10 – 14 Years | 2464 | 1.048511 |
| 15 – 19 Years | 2322 | 0.988085 |
| 20 – 39 Years | 2080 | 0.885106 |
| 40 – 49 Years | 1976 | 0.840851 |
| 50 – 59 Years | 1872 | 0.796596 |
| >=60 Years | 1632 | 0.694468 |

**Source:** Authors' own calculation based on information published by Nutrition Cell Planning Commission of Pakistan (2002)

# APPENDIX B: Distribution of Number of Households by Province, Region and Quintiles

**TABLE 4.1(a) :- DISTRIBUTION OF NUMBER OF HOUSEHOLDS BY PROVINCE, REGION AND QUINTILES**

| Province | Quintiles | | | | | Total |
|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | |
| Punjab | 1115 | 1394 | 1837 | 2445 | 3717 | 10508 |
| Sindh | 882 | 1022 | 1062 | 1260 | 1950 | 6176 |
| KP | 373 | 799 | 1030 | 1341 | 1666 | 5209 |
| Baluchistan | 389 | 543 | 499 | 449 | 465 | 2345 |
| Total | 2759 | 3758 | 4428 | 5495 | 7798 | |

**Source: HIES 2015-16 Report, Pakistan Bureau of Statistics**

# APPENDIX C: GWR Results

## Appendix C.1: Parametric GWR Estimation Results; Significance of District Coefficients of Local Independent Variables

| Variables | Districts with significant Coefficients (%age) | | Districts with insignificant Coefficients (%age) | |
|---|---|---|---|---|
| | Positive | Negative | Positive | Negative |
| Hhsize | 0 | 0 | 100 | 0 |
| Sexratio | 33.33** | 0 | 64.04 | 2.63 |
| Depratio | 0 | 0 | 82.46 | 17.54 |
| sexratio_adultmen | 41.23**and 52.63* | 0 | 6.14 | 0 |
| Girlratio | 100* | 0 | 0 | 0 |
| Room | 0 | 41.23** | 33.33 | 25.44 |
| eduratio_1 | 0 | 44.74** | 6.14 | 49.12 |
| eduratio_2 | 0 | 28.95** | 3.51 | 67.54 |
| eduratio_3 | 0 | 47.37** | 0 | 52.63 |
| eduratio_4 | 0 | 56.14* and 11.40** | 0 | 32.46 |
| Adult | 0 | 0 | 0 | 100 |
| Men | 0 | 0 | 97.37 | 2.63 |
| Kid | 0 | 55.26* and 3.51** | 0 | 41.23 |
| Boy | 3.51** and 55.26* | 0 | 41.23 | 0 |
| Girl | 3.51** and 55.26* | 0 | 41.23 | 0 |
| edu1 | 0 | 14.91** and 82.46* | 0 | 2.63 |
| highestedu1 | 0 | 0 | 100 | 0 |
| highestedu3 | 0 | 0 | 54.39 | 45.61 |
| highestedu6 | 0 | 0 | 80.7 | 19.3 |
| language_new2 | 0 | 0 | 100 | 0 |
| language_new4 | 0 | 100* | 0 | 0 |
| language_new5 | 11.40** and 88.60* | 0 | 0 | 0 |
| nokidp | 26.32** and 73.68* | 0 | 0 | 0 |
| nogirlp | 0 | 13.16* and 78.07** | 0 | 8.77 |
| resibuildingp | 0 | 1.75* and 28.07** | 0 | 70.18 |
| pipedwaterp | 0 | 77.19* and 20.18** | 0 | 1.75 |
| cleanwaterp | 0 | 0 | 55.26 | 44.74 |
| toilettype1 | 0 | 37.72** | 0 | 68.28 |
| urbanp | 0 | 0 | 100 | 0 |
| ownership1 | 0.88** | 0 | 67.54 | 31.58 |
| ownership3 | 0 | 35.09** | 0 | 64.91 |
| water2 | 4.39** | 0 | 95.61 | 0 |
| marital2 | 51.75** | 0 | 48.25 | 0 |
| marital3 | 24.56** | 0 | 75.44 | 0 |

Note: n=114, * 5% level of significance, **10% level of significance

## Appendix.C.2: Semi Parametric GWR Estimation Results; Significance of District Coefficients of Local Independent Variables

| Variables | Districts with significant Coefficients (%age) | | Districts with insignificant Coefficients (%age) | |
|---|---|---|---|---|
| | Positive | Negative | Positive | Negative |
| hhsize | 0 | 0 | 100 | 0 |
| sexratio | 4.39** | 0 | 95.61 | 0 |
| depratio | 0 | 0 | 87.72 | 12.28 |
| sexratio_adultmen | 63.16** | 0 | 36.84 | 0 |
| girlratio | 3.51** and 96.49* | 0 | 0 | 0 |
| room | 0 | 0 | 7.89 | 92.11 |
| eduratio_1 | 0 | 20.18** | 0.88 | 78.95 |
| eduratio_2 | 0 | 0 | 0.88 | 99.12 |
| eduratio_3 | 0 | 38.60** and 55.26* | 0 | 61.4 |
| eduratio_4 | 0 | 5.26** | 0 | 39.48 |
| adult | 0 | 0 | 0 | 100 |
| men | 0 | 0 | 100 | 0 |
| kid | 0 | 3.51** and 55.26* | 0 | 41.23 |
| boy | 0 | 3.51** and 55.26* | 41.23 | 0 |
| girl | 0 | 3.51** and 65.79* | 41.23 | 0 |
| edu1 | 0 | 3.33** and 1.75* | 0 | 0.88 |
| highestedu1 | 0 | 0 | 100 | 0 |
| highestedu3 | 0 | 0 | 89.47 | 10.53 |
| highestedu6 | 0 | 0 | 90.35 | 9.65 |
| nokidp | 17.54** and 68.42* | 0 | 14.04 | 0 |
| nogirlp | 0 | 63.16** and 1.75* | 0 | 35.09 |
| resibuildingp | 0 | 6.14** | 0 | 93.86 |
| ownership1 | 0 | 0 | 79.82 | 20.18 |
| marital2 | 0.88 | 0 | 99.12 | 0 |

**Note:** n=114, * 5% level of significance, **10% level of significance

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