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Examining the Relationship Between Pesticide Use Levels and Infant Mortality: Correlational and Spatial Analysis by Province (2020–2024)

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Keywords

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Abstract

Numerous studies conducted worldwide have highlighted the harmful effects of excessive pesticide use in weed control on human health. The aim of this study is to examine the relationship between pesticide use levels and infant number of deaths in different provinces of Türkiye. Pesticide use reports from the Ministry of Agriculture and Forestry for the years 2020 and 2024, and infant mortality data by province from the Turkish Statistical Institute (TÜİK) were used. The analysis of the data was conducted utilising SPSS, Jamovi, and Jasp software. Spearman's correlation analysis was employed to ascertain the statistical relationship between the data. A p-value of less than 0.05 was considered to be significant, and the findings were visualised by creating geographic maps using QGIS and GeoDa software to demonstrate spatial overlap. The analyses revealed a moderate, positive, and statistically significant correlation between pesticide use at the provincial level and all infant mortality periods in both years examined. Geographic distribution maps demonstrated that the Aegean, Mediterranean, and Southeastern Anatolia regions, where pesticide use was most intensive, also exhibited the highest infant mortality rates, thereby providing spatial evidence for this correlation. An examination of the four-year period reveals a concurrent increase in pesticide utilisation and a decrease in infant number of deaths. The significant positive correlation obtained indicates that environmental pesticide exposure, along with other determinants such as socioeconomic status, is a potential risk factor contributing to infant mortality.

Cite

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1. INTRODUCTION

The infant mortality rate is widely regarded as a highly sensitive indicator of a nation's public health and socioeconomic development level. Such deaths, which frequently occur in the first year of life, are often deemed to be preventable through the implementation of medical or social interventions. Consequently, they are often used as a metric to evaluate the efficacy of a given society's health policies. The monitoring and recording of stillbirths and neonatal deaths is of crucial importance in order to reduce these losses, improve the quality of care, and identify preventable factors (Kerber et al., 2015). As reported in the 2008 Turkey Demographic and Health Survey (TDHS), the infant mortality rate in the country was recorded at 17.6 per thousand. In this context, the neonatal period, which covers the final stage of pregnancy and the first 28 days

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after birth, is of great importance. Neonatal mortality statistics are fundamental data indicators of the level of development of a country's health system, and neonatal mortality rates are critical for identifying problems in health services and taking measures to address them (Korkmaz et al., 2010). In the context of our nation, there is an observable trend of escalating institutional endeavours in this particular direction, concomitant with a decline in neonatal mortality rates. The factors determining a neonate's probability of survival are not confined to biological predispositions but are predominantly influenced by broader elements, including the region's socioeconomic activities, cultural structure, and the quality of public services. As demonstrated in the study (Ergin & Hassoy, 2011), scientific research has revealed a strong correlation between socioeconomic status and infant health in most countries. In addition to well-documented medical causes of infant mortality, such as genetic disorders and diseases, socioeconomic and cultural factors have also been shown to contribute significantly to infant mortality. These factors include poverty, inadequate health infrastructure, and lack of awareness. This socio-economic background also affects the amount of environmental risks to which the community is exposed.

Chemicals used in modern agricultural practices are considered to be among the primary environmental risk factors. Pesticides, a class of chemical compounds, are defined as substances that are employed to mitigate the detrimental effects of pests (Sataloğlu et al., 2007). The application of agricultural pesticides to farmland has been demonstrated to result in their dispersal into the environment. These pesticides have been observed to enter various ecosystem components, including air, water, and soil. Within these environments, the pesticides undergo a series of biological or chemical transformations. Despite the pervasive utilisation of pesticides across the globe for the purpose of attaining substantial and superior crop yields, these intensive chemical applications have the potential to engender considerable problems and hazards to human, animal, and environmental health (Topuz, 2005). The toxic effects of pesticide exposure, particularly on children, have also been reported by the American Academy of Pediatrics (Roberts et al., 2012).

In this context, the primary objective in the field of public health is to reduce infant mortality (Arslan et al., 2013). These underlying causes of death are closely related to environmental factors to which the mother is exposed (Gökçen & Küşümler, 2023). The study demonstrated that chemical pollutants, including pesticides, dioxins and heavy metals, can be transferred to the infant via breast milk, potentially inducing teratogenic effects. The extensive and excessive utilisation of pesticides has been demonstrated to induce neurological impairments in foetuses and children (Arslantaş, 2025), and a moderate correlation between maternal exposure to pesticides and the risk of premature birth has been substantiated (Lin et al., 2023). Moreover, research is being conducted on the potential link between prenatal and infant exposure to environmental pesticides and autism spectrum disorder (von Ehrenstein et al., 2019). In Turkey, the excessive and prohibited consumption of pesticides in agricultural activities poses a threat to public health by causing serious contamination in water and food sources (Altıkat et al., 2009; Tiryaki, 2016; Atasoy, 2019; Doğan & Karpuzcu, 2019). Moreover, regional studies in Turkey corroborate the hypothesis that prematurity and congenital anomalies account for a

significant proportion of cases. Such studies have been conducted in Kilis by Çam and Karasu (2021), in Kayseri by Yıldız et al. (2020), and in Bingöl by Mete et al. (2018). In this context, although data on pesticide use intensity by province and region is available nationwide (Özercan & Taşcı, 2022), no direct study has been found in the literature that reveals the potential correlation between infant mortality in different provinces of Turkey and pesticide use intensity and environmental exposure risks in those provinces. The primary objective of this study is to conduct a descriptive ecological analysis to examine the potential association between infant mortality and pesticide use in various provinces in 2020 and to support this relationship through the use of maps. Concurrently, these applications are scheduled for execution in 2024, with an interim evaluation of the alterations that have transpired over the preceding four years. The objective of these statistical and spatial analyses is to illuminate the potential relationship between agricultural pesticide use and infant mortality, thereby making a critical contribution to the development of public health policies.

2. MATERIAL AND METHOD

2.1. Sample Data

The pesticide quantities utilized in the provinces of Turkey in this study were obtained from reports by the Ministry of Agriculture and Forestry (URL 1). The data presented herein express the total quantities of pesticides utilized in agricultural areas at the provincial level in kilograms (kg-lt). The number of infant deaths in the neonatal (newborn) and post-neonatal periods by province was obtained from official statistics published by the Turkish Statistical Institute (TÜİK), with a sample size of N=81(URL 2).

All data obtained from different sources were first transferred to Microsoft Excel in order to create the analysis template, after which they were organized so that each province represented a separate observation unit (row). In order to ensure consistency between infant mortality and pesticide use data, the 2020 and 2024 years were examined separately for both data sets. The matched dataset was subjected to a thorough examination for any potential missing data, and no such data was detected. Zero values recorded for pesticide use in certain provinces were confirmed to represent official data report by the relevant authorities for the specified years. It was ascertained that these values were not attributable to data entry errors or missing observations, but rather reflected the actual reported figures.

2.2. Method

The study utilized software packages such as SPSS and Jamovi to analyze the descriptive statistics (normality, mean, kurtosis, skewness, etc.) of neonatal and post-neonatal number of by province, as well as pesticide usage in kilograms by province. For correlation analysis, the normality of the data distribution was checked using Kolmogorov-Siminov and Shapiro-Wilk tests. Since the data did not follow a normal distribution, the analysis continued with Spearman rank correlation analysis (Spearman, 1904). This analysis is a measure used to determine the relationship between two variables. The Spearman rank correlation coefficient, which measures the strength of the linear relationship between two variables, ranges from -1 to +1. In the absence of a relationship, the coefficient approaches zero. Conversely, a strong and positive relationship causes the

coefficient to approach +1. Similarly, if there is a strong negative relationship, the coefficient approaches -1. A positive sign for the correlation coefficient indicates a direct relationship, meaning that when one of our variables increases (decreases), the other also increases (decreases). A negative sign indicates an inverse relationship, meaning that when one variable increases (decreases), the other variable decreases (increases) (Altaş et al., 2012). In order to calculate this coefficient, it is first necessary to sort the values of the variables from smallest to largest, assigning a value of 1 to the smallest value within each variable. Subsequently, the squares of the differences between the ranks of these two variables must be calculated, forming the basis for calculating the correlation coefficientm (Altaş et al., 2012). The formula for the rank correlation coefficient is calculated as follows (Spearman, 1904; El-Hashash & Shiekh, 2022).

$$r_s = 1 - \frac{6 \sum d_i^2}{n(n^2-1)} \quad (1)$$

The heatmap matrix table of the Spearman rank correlation was created and interpreted using the Jasp software package. In order to support this correlation relationship, the pesticide usage data for 2020 and 2024 by province, as well as the number of infant deaths by province, were integrated into a vector file containing Turkey's provincial boundaries and Geographic Information Systems (GIS), which utilize specialized tools to collect, manage, and analyze data associated with specific geographic locations, were employed in this study to integrate provincial data into Turkey’s digital boundaries (HDX, n.d.). This facilitated the visualization of spatial overlaps between pesticide use and the number of infant deaths. This was done using the QGIS software package. Spatial distribution maps by region were created at various levels using the GeoDa software package. Following a thorough evaluation of the available options, a five-tiered approach was selected on the basis that it offered a more suitable framework for interpretation. This decision was subsequently followed by the conduction of the relevant interpretations.

3. RESULTS AND DISCUSSION

An examination of the descriptive statistics for 2020 reveals a substantial discrepancy between the minimum and maximum pesticide usage (kg). Upon examination of values such as the mean and mode, it becomes evident that these also deviate from each other (Table 1). The findings indicate that the utilisation of pesticides in Turkey exhibits significant variations in its distribution, with Ardahan being the province with the lowest pesticide usage, and Antalya being the province with the highest pesticide usage. An examination of the descriptive statistics for infant deaths reveals a substantial disparity between the minimum and maximum values. Furthermore, a clear distinction is observed in our values, including the mode and median, suggesting a deviation from the expected norm. This finding indicates that the number of infant deaths also do not exhibit a homogeneous distribution.

Table 1. *Descriptive statistics on pesticide use and infant mortality in 2020*

	Pesticide use (2020)	Day zero death	Death within 1 to 6 days	Death between 7 and 27 days	Neonatal period death	Post-neonatal period death	Total deaths
Mean	662580	14.9	37.7	24.6	77.1	43.3	121
Median	220193	8	18	13	39	20	59
Mode	62.0	1.00	4.00	4.00	11.0	3.00	20.0
Sum	53669001	1206	3051	1990	6247	3510	9762
Standard deviation	1.01e+6	22.6	57.2	38.0	117	74.3	189
Variance	1.02e+12	513	3275	1441	13610	5526	35828
Range	4349596	172	395	255	819	470	1288
Minimum	62	0	1	0	4	1	6
Maximum	4349658	172	396	255	823	471	1294
Skewness	2.17	4.67	3.90	3.83	4.06	4.18	4.07
Std. error skewness	0.267	0.267	0.267	0.267	0.267	0.267	0.267
Kurtosis	4.15	29.2	20.0	18.4	21.6	20.2	20.7
Std. error kurtosis	0.529	0.529	0.529	0.529	0.529	0.529	0.529

An examination of the descriptive statistics of the 2024 data reveals the presence of values such as maximum, minimum, mode, and average pesticide use. A significant disparity is observed between these values (Table 2). This finding indicates that pesticide utilization in Turkey exhibits a heterogeneous structure. As demonstrated in Figure 1, the provinces of Ardahan, Bayburt, and Hakkari in Turkey have the lowest pesticide use in the country, with a recorded use of 0 kg. As demonstrated in Table 1, it is evident that while Ardahan was the sole province exhibiting low usage, both provinces have now demonstrated a decline in terms of usage. In 2024, the province of Adana was found to have the highest pesticide use in Turkey; however, four years prior, it was Antalya. Consequently, it can be posited that the utilization of Adana has undergone a substantial augmentation during this specific temporal juncture. Moreover, while the maximum pesticide usage in 2020

was 4349658, this figure has increased to 7122395 in 2024. Upon examination of the descriptive statistics of infant deaths, disparities between the minimum and maximum values become evident, thereby indicating the non-homogeneity of the distribution. A decline in the minimum total number of infant deaths was observed from 6 in 2020 to 4 in 2024. An examination of the maximum number of deaths reveals that it was 1294. However, in 2024, this number has decreased to 899.

Table 2. *Descriptive statistics on pesticide use and infant mortality in 2024*

	Pesticide use (2024)	Day zero death	Death within 1 to 6 days	Death between 7 and 27 days	Neonatal period death	Post-neonatal period death	Total deaths
Mean	669562	12.8	31.2	21.3	65.2	39.4	93.0
Median	187003	7	15	10	32	19	45.0
Mode	0.00	1.00	5.00	2.00	25.0	5.00	36.0
Sum	54234550	1035	2526	1722	5283	3192	7440
Standard deviation	1.16e+6	20.7	48.3	34.6	102	69.8	134
Variance	1.34e+12	430	2330	1195	10322	4873	17879
Range	7122395	162	285	219	664	450	895
Minimum	0	0	0	0	2	1	4.00
Maximum	7122395	162	285	219	666	451	899
Skewness	3.32	5.03	3.38	3.85	3.77	4.26	3.75
Std. error skewness	0.267	0.267	0.267	0.267	0.267	0.267	0.269
Kurtosis	13.5	33.7	13.1	17.2	17.4	20.7	18.2
Std. error kurtosis	0.529	0.529	0.529	0.529	0.529	0.529	0.532

We examined whether the variables of pesticide use and infant mortality rate conformed to the assumption of normal distribution using the Shapiro-Wilk or Kolmogorov-Smirnov tests (Table 3). Deciding whether to use the Pearson or Spearman correlation coefficient to determine the direction and strength of the relationship between the variables is a critical step. Depending on whether the data set was normally distributed, a parametric or non-parametric method was chosen to determine the statistical significance, direction and intensity of the relationship between pesticide use and infant number of deaths.

Table 3. *Normality distribution statistics of variables used in the analysis*

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Pesticide use (2020)	0.257	80	0.000	0.671	80	0.000
Day zero death (2020)	0.182	80	0.000	0.790	80	0.000
Death within 1 to 6 days (2020)	0.217	80	0.000	0.718	80	0.000
Death between 7 and 27 days (2020)	0.218	80	0.000	0.684	80	0.000
Neonatal period death (2020)	0.227	80	0.000	0.717	80	0.000
Post neonatal period death (2020)	0.258	80	0.000	0.575	80	0.000
Total deaths (2020)	0.232	80	0.000	0.669	80	0.000
Pesticide use (2024)	0.282	80	0.000	0.598	80	0.000
Day zero death (2024)	0.225	80	0.000	0.792	80	0.000
Death within 1 to 6 days (2024)	0.237	80	0.000	0.632	80	0.000
Death between 7 and 27 days (2024)	0.246	80	0.000	0.607	80	0.000
Neonatal period death (2024)	0.242	80	0.000	0.658	80	0.000
Post neonatal period death (2024)	0.282	80	0.000	0.503	80	0.000
Total deaths (2024)	0.253	80	0.000	0.598	80	0.000

In addition to these tests, we examined the kurtosis and skewness of the data using histograms, Q-Q plots, and kurtosis-skewness coefficients (Table 4 and 5, Figure 1 and 2).

Table 4*. Skewness and Kurtosis Values for the 2020 dataset*

	Pesticide use (2020)	**Day zero death (2020)**	**Death within 1 to 6 days (2020)**	**Death between 7 and 27 days (2020)**	**Neonatal period death (2020)**	**Post neonatal period death (2020)**	**Total deaths (2020)**
Skewness	2.17	4.67	3.90	3.83	4.06	4.18	4.07
Std. error skewness	0.267	0.267	0.267	0.267	0.267	0.267	0.267
Kurtosis	4.15	29.2	20.0	18.4	21.6	20.2	20.7
Std. error kurtosis	0.529	0.529	0.529	0.529	0.529	0.529	0.529

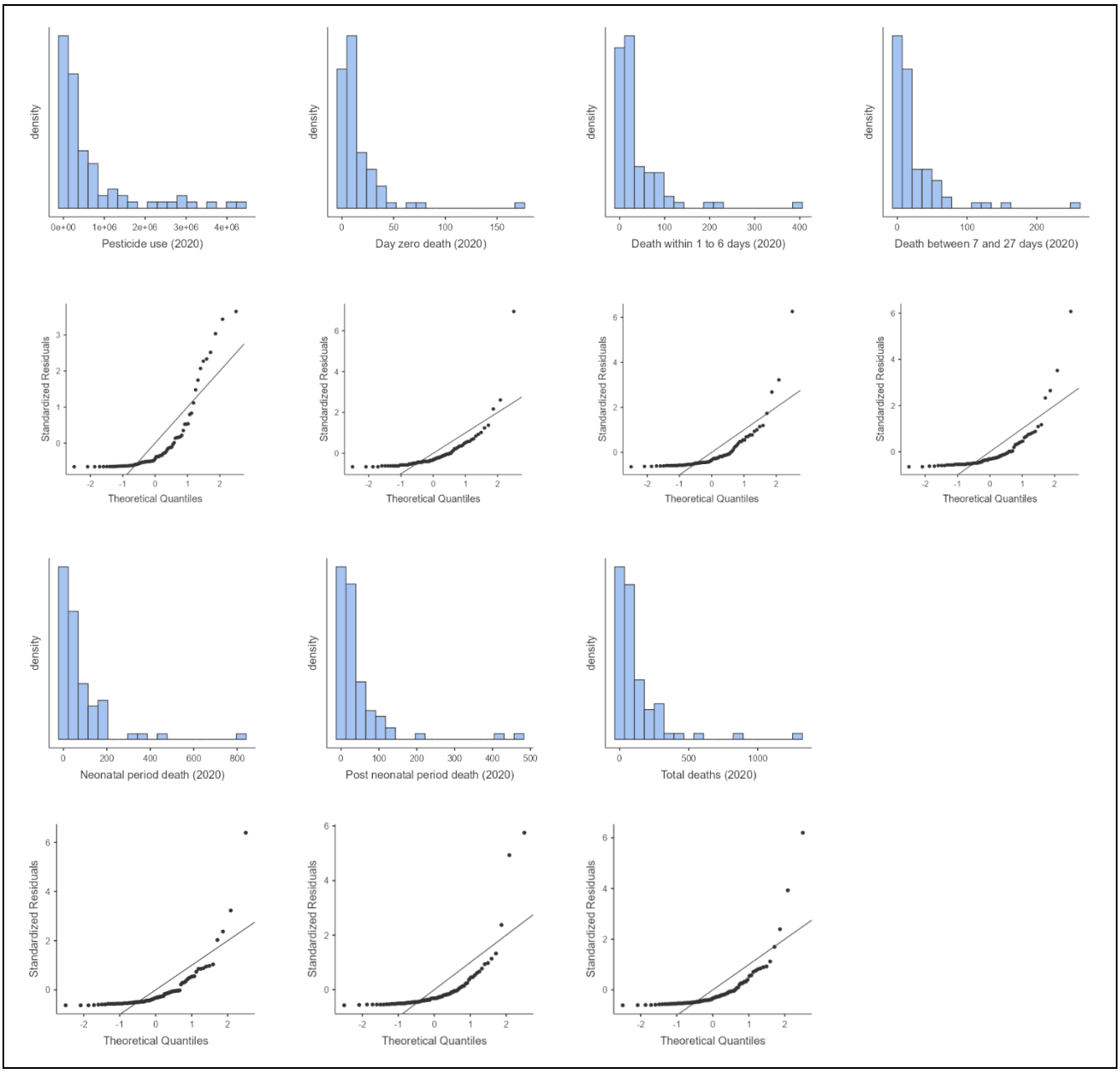


Figure 1. *Histogram and Q-Q plot charts for 2020 data*

Table 5. *Skewness and Kurtosis Values for the 2024 dataset*

	Pesticide use (2024)	Day zero death (2024)	Death within 1 to 6 days (2024)	Death between 7 and 27 days (2024)	Neonatal period death (2024)	Post neonatal period death (2024)	Total deaths (2024)
Skewness	3.32	5.02	3.38	3.85	3.77	4.26	3.83
Std. error skewness	0.267	0.269	0.267	0.267	0.267	0.267	0.267
Kurtosis	13.5	33.4	13.1	17.2	17.4	20.7	16.9
Std. error kurtosis	0.529	0.532	0.529	0.529	0.529	0.529	0.529

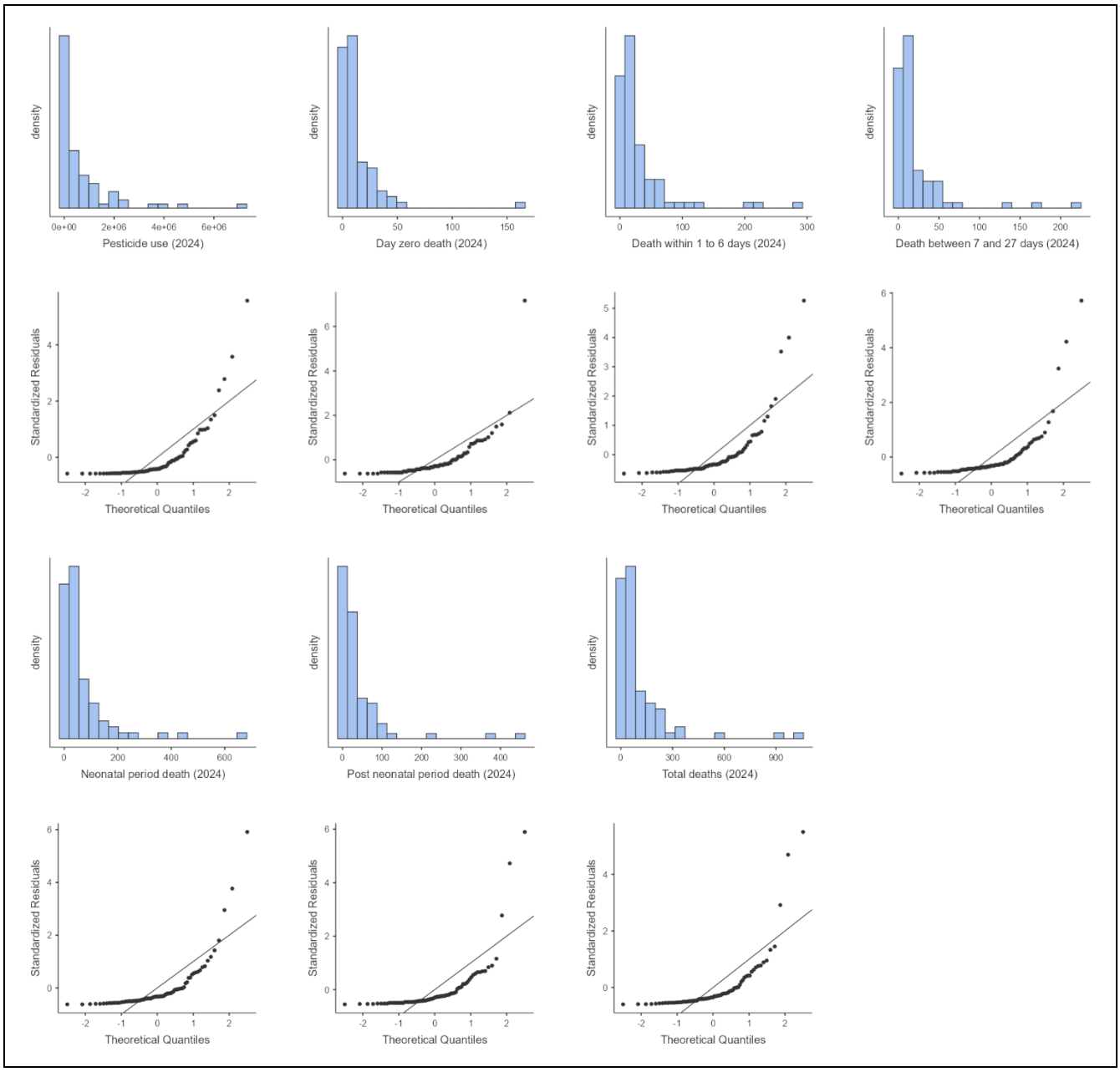


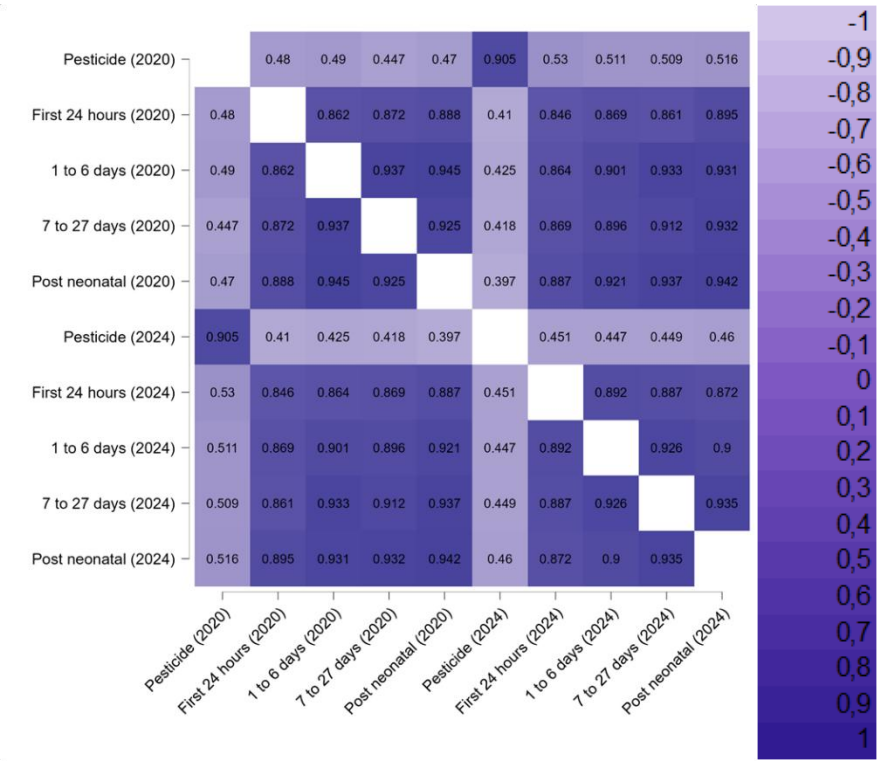
Figure 2. *Histogram and Q-Q plot charts for 2024 data*

When examining the variables for both years, the skewness values range from 2 to 5, while the kurtosis values range from 4 to 33 (Table 4 and 5). These values significantly exceed the recommended thresholds of 2 for skewness and 7 for kurtosis. (Byrne, 2013). These numerical findings have been visually confirmed by the Q-Q plots, indicating that the data do not cluster along a linear line (Figure 1 and 2). Since the Kolmogorov-Smirnov test results ($p < 0.05$) also indicated that these deviations were statistically significant, it was confirmed that the data did not meet the assumptions of parametric tests and the Spearman rank correlation coefficient was preferred for the analyses.

Examining the correlation matrix for 2020 reveals a positive, moderate and statistically significant correlation (indicated by three stars in the superscript) between pesticide use and infant mortality across all groups (Table 6). Similarly, in 2024, there is a significant, positive and moderate relationship between pesticide use and

infant mortality. The correlation coefficients for these two years are very close. For instance, the relationship is 0.493 between pesticide use in 2020 and the total number of infant deaths that year, whereas it is 0.465 between pesticide use in 2024 and the total number of infant deaths that year. Over the past four years, the relationship between pesticide use and total deaths has changed only slightly. The relationship between pesticide use by province and infant deaths has also remained largely unchanged. Looking at infant deaths in 2020 and 2024, we see that the number of infants who died on the first day of life (day 0) was 0.901, compared to 0.912 for infant deaths occurring between days 1–6 and 0.912 for infant deaths occurring between days 7–27.

Table 6. *Spearman rank correlation coefficient matrix*



There is a strong positive correlation (r = 0.947) between the number of infants who died within two years and those who died during the neonatal period (defined as the first 27 days of life). Similarly, there is a strong and significant positive correlation of 0.942 between the number of infants who died in the post-neonatal period (defined as the period from the 28th day of life to 1 year of age) and the number of infants who died within the first two years of life. When we consider total infant deaths (from birth to 1 year of age) in 2020 and 2024, we observe another positive and strong relationship, with a coefficient of 0.969. If the number of infant deaths was high at certain times in 2020, it is likely that they will be high at the same times in 2024.

Examining the geographical distribution maps of pesticide use intensity in Turkish provinces for 2020 and 2024 reveals a decrease in pesticide use from dark to light colours (Figure 3). As can be seen on the 2020 map, the areas with the highest levels of pesticide use are primarily concentrated along the Aegean and Mediterranean coasts, with the Central Anatolian regions experiencing lower levels of use. Looking at the

2024 map, it is evident that the Aegean and Mediterranean regions remain among those with the highest levels of use. This concentration suggests that these regions are characterized by intensive agricultural activities based on greenhouse cultivation. However, in both years, the areas with the lowest intensity are most of the Eastern Anatolia region and part of the Black Sea region. This means that these regions have very low levels of pesticide use. This can be attributed to factors such as lower agricultural production, reliance on grain and livestock farming, and shorter agricultural cycles due to climatic conditions. Transition zones act as a buffer between areas with high and low pesticide use. As observed in both years, these zones are primarily situated in the surrounding provinces of Central Anatolia and the inland regions of the Black Sea area. The reason for the more moderate level of pesticide use in these provinces may be their mixed agricultural structure. This means that while the risk of environmental exposure in these provinces is lower than in areas with high intensity, it is relatively higher than in areas with low intensity.

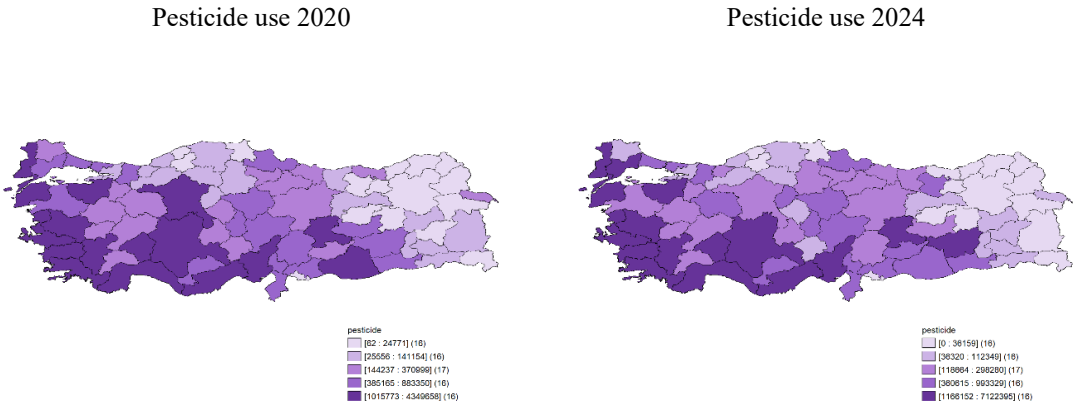


Figure 3. *Spatial distribution maps of pesticide use for the years 2020 and 2024*

Figure 4 shows the geographical distribution of pesticide use and infant deaths on the first day of life in 2020. The colour intensity on the map represents areas with high levels of both pesticide use and infant mortality on the first day of life. Examining both maps simultaneously reveals that both variables are particularly high (dark colours) and co-occur, especially along the Mediterranean coast. This spatial overlap suggests a potential spatial association higher infant mortality counts are observed in areas with high environmental pesticide exposure. Similarly, a correlation between pesticide use and infant mortality is evident in certain provinces along the Aegean coast and in Central Anatolia. However, the high number of infant deaths in Eastern Anatolia despite low levels of pesticide use suggests that deaths in this region may be related to socioeconomic or demographic factors rather than pesticides.

Figure 5 illustrates the geographical distribution of pesticide use and infant number of infant deathsamong newborns aged 1–6 days in 2020. Examining the maps reveals that infant number of infant deaths are concentrated in the Southeastern Anatolia Region and are also high in some provinces in the Marmara, Aegean and Central Anatolia regions. A spatial correlation has been observed between levels of pesticide use and infant mortality in these regions.While infant the number of infant deaths are generally low in the Black Sea and

Eastern Anatolia regions, where pesticide usage is lowest, relatively high mortality have been recorded in some provinces contrary to this general trend.

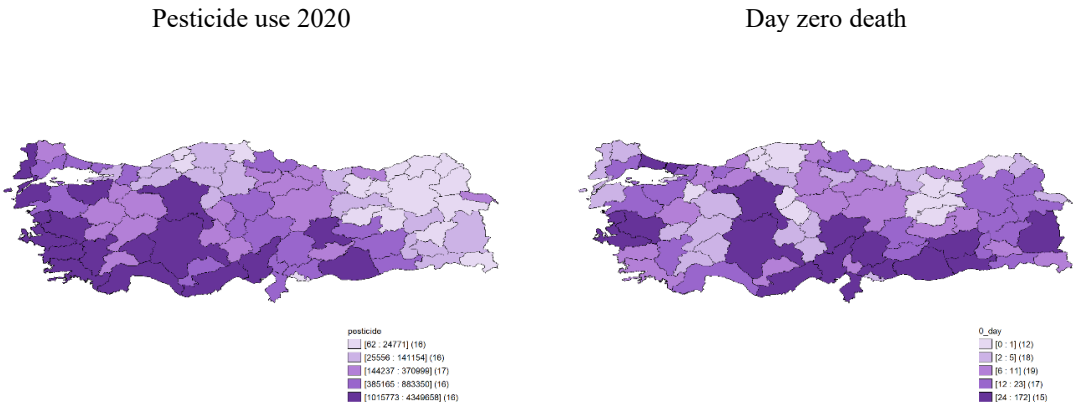


Figure 4. *Spatial distribution maps of pesticide use and zero-day infant number of deaths in 2020*

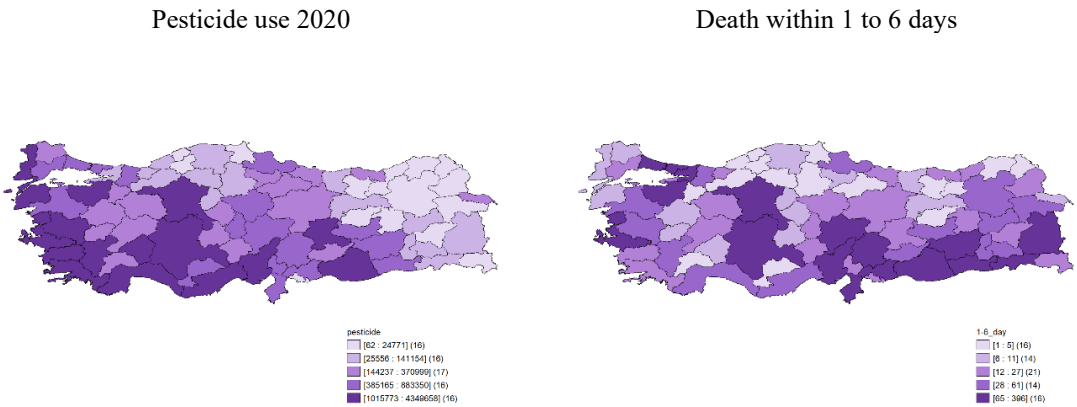


Figure 5. *Spatial distribution maps of pesticide use in 2020 and infant number of deaths between 1 and 6 days of age*

Figure 6 shows a comparison of the geographical distribution of infant deaths within a 7–27 day period and levels of pesticide usage in 2020. The colour scale on the maps shows that the intensity of both variables increases as the colour transitions from light to dark tones. A consistent trend has been observed, indicating that infant number of deaths are also on the rise in the Central Anatolia, Aegean and Marmara regions, where pesticide use is high (though this increase is not as sharp as the intensity of pesticide use). Conversely, within certain provinces encompassing the Black Sea Eastern Anatolia regions, both variables manifest at comparatively diminished levels (indicated by light colours) within these provinces reveals a consistent trend.

Figure 7 shows the geographical distribution of pesticide use and neonatal deaths in 2020. The neonatal period is defined as the first 27 days of a baby's life. It is therefore the sum of the death counts shown in the earlier maps (death count on day zero, death count between days 1 and 6, and death count between days 7 and 27). As can be seen from the two maps, areas with high pesticide use, such as the Mediterranean, Aegean and Marmara regions and parts of Eastern Anatolia, coincide with areas with high and moderately high neonatal

mortality rates. Death rates are also low in the Northeast Anatolia region and in parts of the Black Sea region, where pesticide use is low. However, it is observed that in certain eastern provinces, despite low pesticide use, neonatal number of deaths are significantly higher.

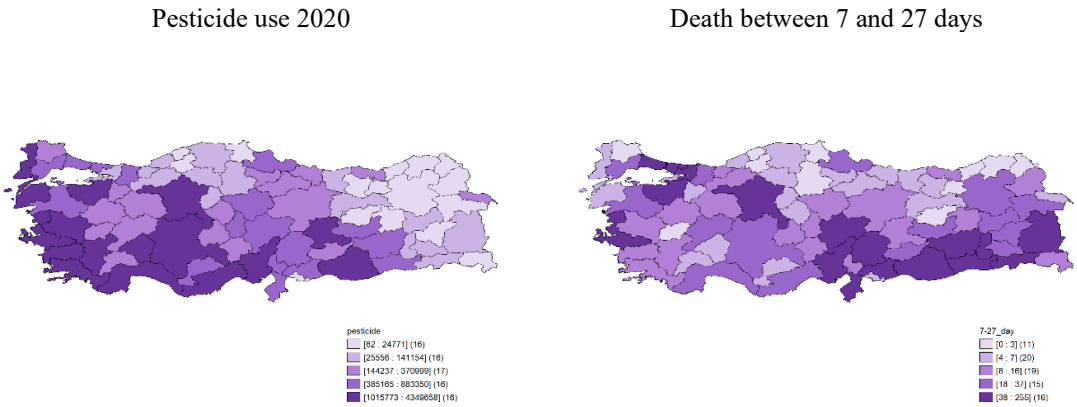


Figure 6. *Spatial distribution maps of pesticide use in 2020 and infant number of deaths between 7 and 27 days of age*

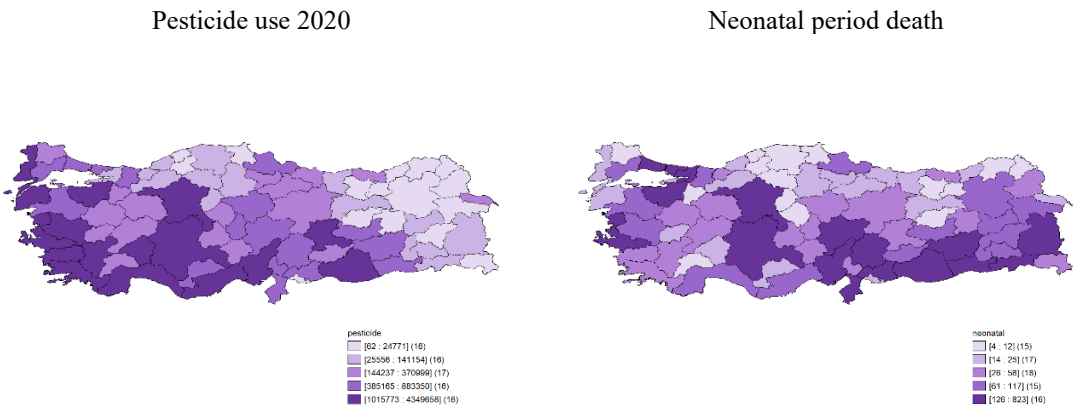


Figure 7. *Spatial distribution maps of pesticide use and neonatal infant number of deaths in 2020*

Figure 8 shows the geographical distribution of pesticide use and the number of post-neonatal deaths in 2020. The post-neonatal period is defined as the period from the 28th day of a baby's life until they reach 1 year of age. The number of babies who die during this period constitutes the total number of deaths in the post-neonatal period. As can be seen from the maps, the use of pesticides and number of deaths show a variable distribution from dark to light. The number of infant deaths are generally high in Central Anatolia, Marmara and parts of Eastern Anatolia and the Aegean regions, where pesticide use is high. However, infant number of deaths in regions with low to moderate pesticide use partially overlap. Nevertheless, when looking specifically at the Eastern region, infant number of deaths are high despite low pesticide intensity. This may be due to factors such as limited access to healthcare and inadequate postnatal hospital care in this region.

Figure 9 shows the geographical distribution of pesticide use and total infant number of deaths (i.e. deaths before the age of one) in 2020. As can be seen from these maps, infant mortality tends to cluster in areas with

intensive pesticide use in the Aegean, Central Anatolia and Southeastern Anatolia regions. This finding suggests the possibility of a link between expectant mothers' exposure to pesticides. As with previous maps, the use of pesticides in the eastern region remains relatively low, yet the number of deaths is high.

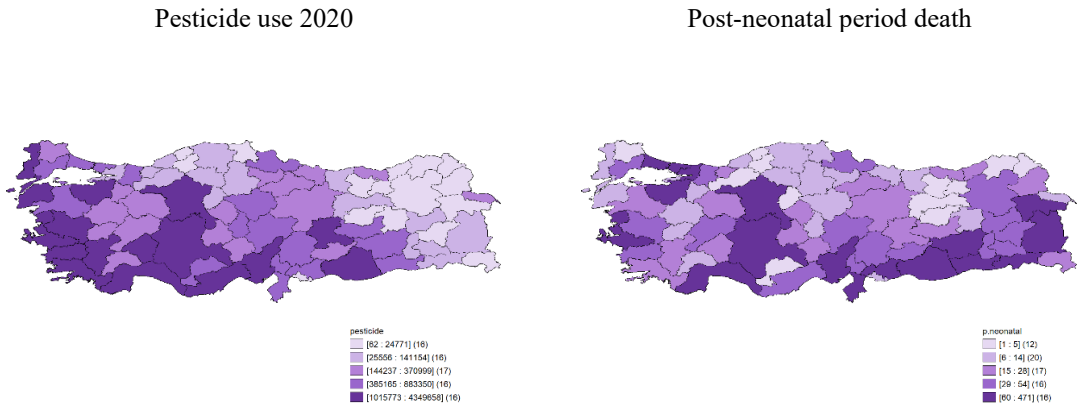


Figure 8. *Spatial distribution maps of pesticide use and infant number of deaths in the post-neonatal period in 2020*

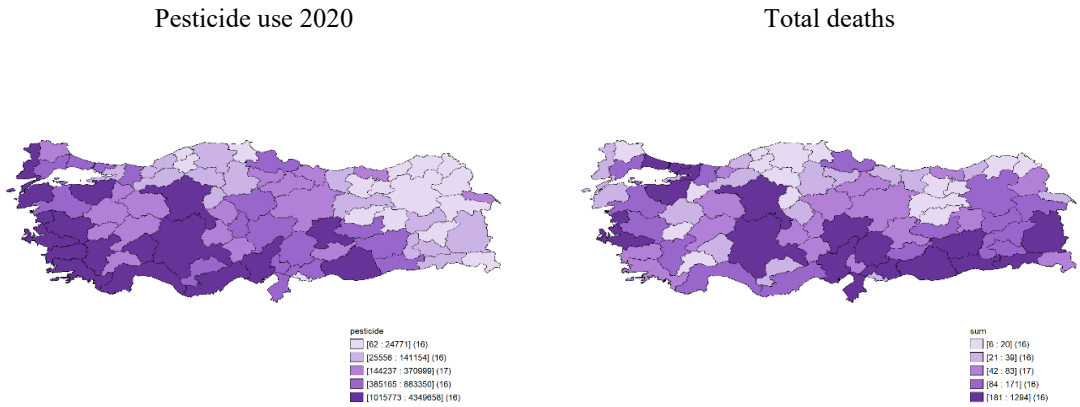


Figure 9. *Spatial distribution maps of pesticide use and total infant number of deaths in 2020*

Figure 10 shows maps of pesticide use in 2024 alongside the geographical distribution of infant deaths on day zero that year. Regions with high pesticide use are shown in dark colours and include parts of Eastern Anatolia, Central Anatolia, the Mediterranean and the Aegean. When we examine the number of infant deaths on the first day of life, we observe spatial overlap in some provinces within these regions. In contrast, although pesticide use is generally low in Eastern Anatolia, the number of infant deaths on day zero is high in this region.

Figure 11 shows the geographical distribution of pesticide use alongside the number of infant deaths occurring within one to six days in 2024. When these two maps are examined together, it can be observed that the areas with high population density particularly along the Mediterranean coast and in the interior regions of Central Anatolia overlap spatially. The Black Sea coast, where pesticide use is low, and the coastal areas of Northeast

Anatolia coincide with high infant mortality rates. However, in other regions, infant deaths can be high in areas where pesticide use is low.

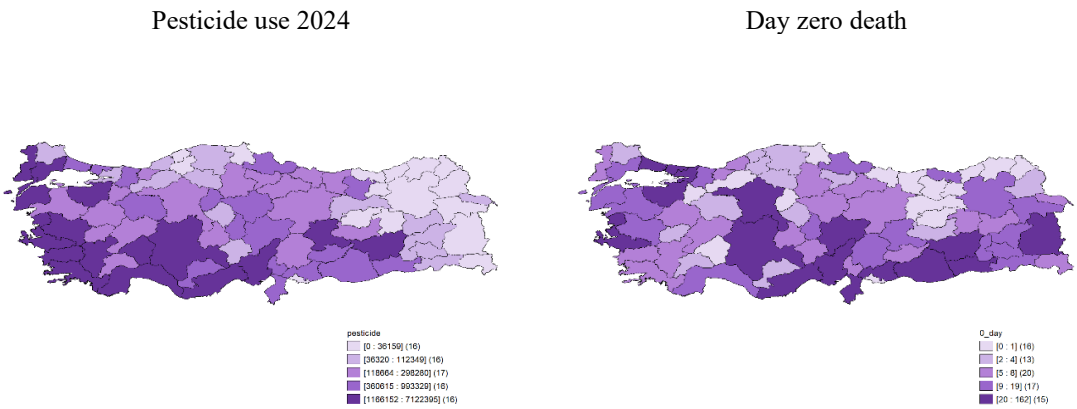


Figure 10. *Spatial distribution maps of pesticide use and zero-day infant number of deaths in 2024*

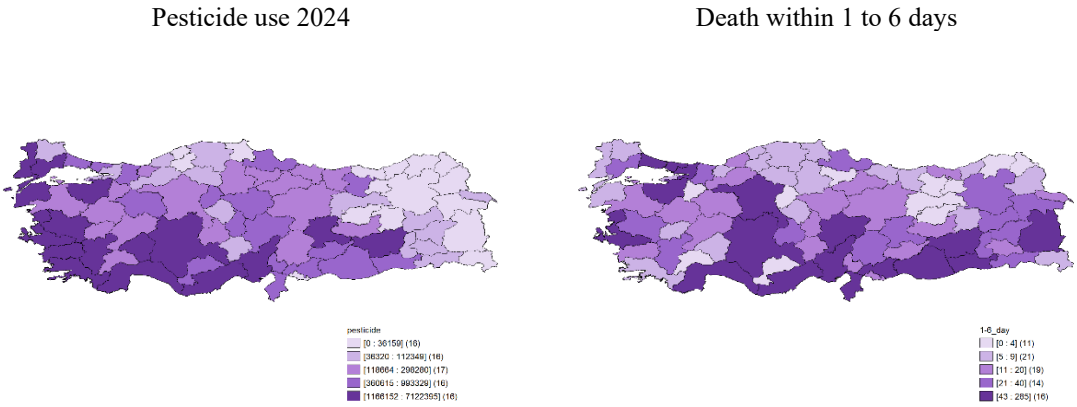


Figure 11. *Spatial distribution maps of pesticide use in 2024 and infant number of deaths between 1 and 6 days of age*

Figure 12 shows the geographical distribution of pesticide use and infant deaths in the 7 to 27 days in 2024. It can be seen that infant mortality is high in the heavily pesticide-affected Mediterranean coastal regions. By contrast, although pesticide use is high in the Marmara region, the number of infant deaths is quite low in some of its provinces.

Figure 13 illustrates the geographical distribution of pesticide use in 2024 alongside the number of infant deaths during the neonatal period. As the neonatal period covers the first 27 days of life, the number of infant deaths shown here is the sum of the deaths in Figure 10, 11 and 12. For this reason, the overlaps seen in the previous maps can also be observed here.

Figure 14 illustrates the geographical distribution of pesticide use and post-neonatal deaths (defined as deaths occurring from the 27th day of life to 1 year of age) in 2024. As can be seen from these two maps, pesticide use is particularly high in the Southeast Anatolia region, where number of deaths are also high.

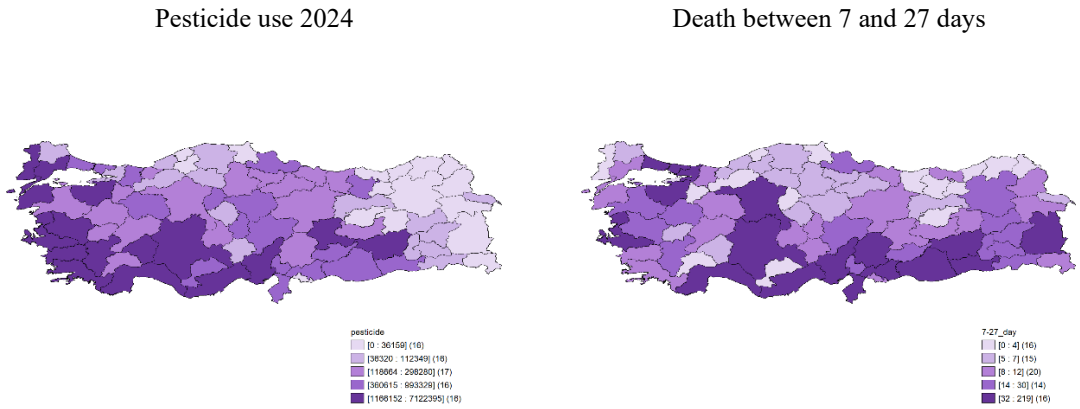


Figure 12. *Spatial distribution maps of pesticide use in 2024 and infant number of deaths between 7 and 27 days of age*

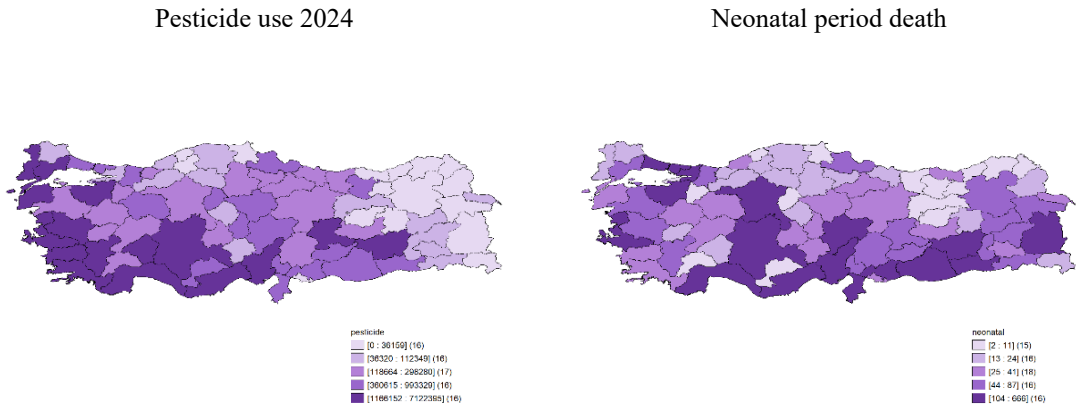


Figure 13. *Spatial distribution maps of pesticide use and neonatal infant number of deaths in 2024*

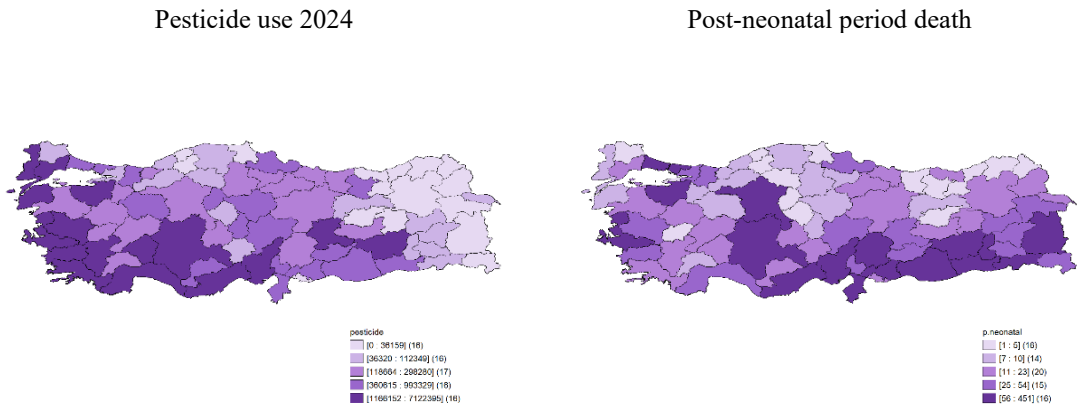


Figure 14. *Spatial distribution maps of pesticide use and infant number of deaths in the post-neonatal period in 2024*

Figure 15 shows geographical maps of the distribution of pesticide use and total deaths (the sum of the neonatal and post-neonatal periods) in 2024. Areas with high pesticide use generally coincide with areas with high total deaths. When we look at the map of total death counts, Istanbul is shown in black. This is because, when the number of deaths was divided into groups of five, Istanbul's number of deaths was so high compared to all

other provinces that it did not fit into any colour scale. One of the main reasons for the high number of infant deaths in Istanbul is that the population exposed to such conditions is larger than in other cities.

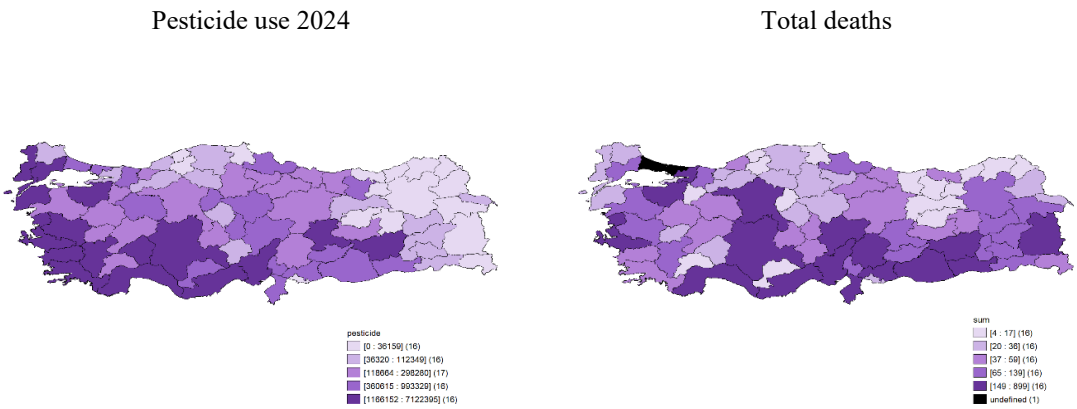


Figure 15. *Spatial distribution maps of pesticide use and total infant number of deaths in 2024*

Figure 16 illustrates the geographical distribution of infant deaths in 2020 and 2024. As can be seen from these two maps, the number of deaths was quite high in the Mediterranean coast, Central Anatolia and Marmara regions. As indicated in the correlation table (Table 6), regions with high number of deaths in 2020 are likely to have high number of deaths in 2024 too. These two maps confirm this spatial overlap. Indeed, while Istanbul had high rates in 2020, these increased even further in 2024, exceeding the scale and being marked in black.

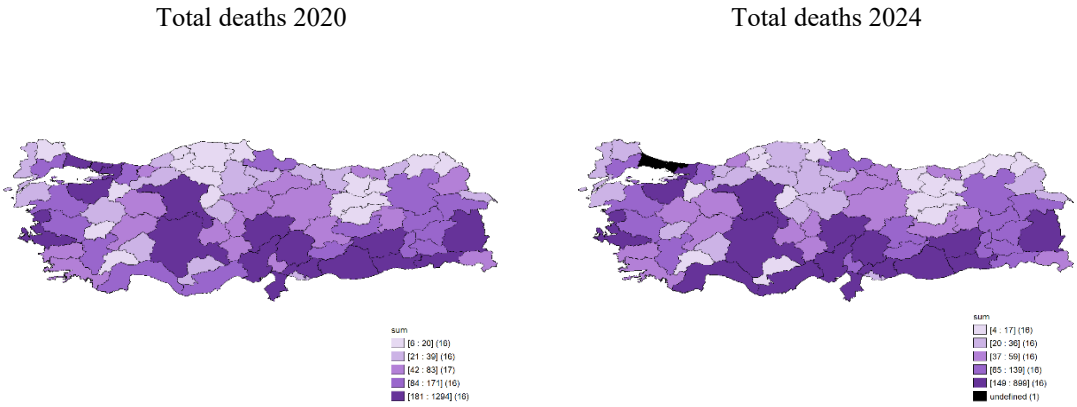


Figure 16. *Spatial distribution maps of the total number of infant deaths in 2020 and 2024*

4. CONCLUSION

This study analyzed the relationship between the intensity of pesticide usage and the number of infant deaths at provincial level across Turkey in 2020 and 2024. Spearman's correlation analysis revealed a moderate and statistically significant positive relationship between pesticide usage levels and all stages of infant mortality for both years studied ($p < 0.05$). Maps created using geographic information systems (GIS) confirmed this correlation spatially, revealing that the Aegean, Mediterranean and Southeastern Anatolia regions, which have intensive agricultural activity, have the highest levels of both pesticide use and the number of infant deaths.

These findings support the existing literature on environmental pesticide exposure as a critical risk factor for infant health. Given the study by Stillerman et al. (2008), which showed that pesticides are associated with adverse outcomes such as fetal growth retardation and shortened gestation period, and the study by Engel et al. (2015), which showed a link between prenatal exposure to organophosphates (OPs) and neurodevelopmental disorders, the positive correlation in the results of this article can be considered reasonable.

However, this study was conducted using an ecological analysis design. While this design allows us to observe general trends at the provincial level, it is insufficient for establishing a cause and effect relationship at the individual level. Infant mortality is influenced by multifactorial variables such as socioeconomic status, access to healthcare, maternal education level, and genetic disorders. Since these variables could not be controlled for in the current study, the correlations found should not be interpreted as a cause and effect relationship; however, the findings presented in this study carry statistical significance that cannot be ignored and offer a critical perspective for public health policies and future research. In this context, it is recommended that future studies examine these factors using spatial regression, taking into account other factors influencing mortality.

In conclusion, the potential risks of pesticide use to infant health should be considered alongside socioeconomic status, access to healthcare and other social determinants (Kim & Saada, 2013). To overcome these limitations and obtain more specific data, future studies should design prospective cohort studies covering expectant mothers in specific regions, measuring personal exposure levels using biomonitoring methods. In light of the current findings, urgent public health interventions to reduce pesticide exposure are clearly needed, particularly in agricultural areas. This could involve promoting the use of personal protective equipment among expectant mothers who are agricultural workers, encouraging organic farming practices, and improving the quality of postnatal healthcare services in high-risk areas.

AUTHOR CONTRIBUTIONS

All authors contributed equally to this work.

AI Exclusion: AI tools are strictly prohibited from being listed as authors.

Legal Consent: All human authors confirm they have reviewed and legally accepted the final version under the **CC BY-SA 4.0** framework.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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