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Application of GIS and Distance Monitoring Technologies in the Study of the Bioecology of Tomato Pests (On the Example of Andijan Region)

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Abstract: The article provides an in-depth analysis of the bioecological characteristics, life cycles, and distribution factors of the main pests affecting tomato crops - Tuta absoluta, aphids, and thrips - in the conditions of Andijan region. Specifically, it highlights the potential use of modern GIS (Geographic Information Systems) and remote sensing technologies (drones, multispectral cameras, satellite imagery) for timely detection of these harmful organisms and planning effective control measures against them. Additionally, the article explains pest monitoring forecasting models based on AI (artificial intelligence), Random Forest, YOLO, NDVI indices, and early warning systems with practical examples. Based on real conditions in Andijan region, the article reveals ways to implement innovative approaches in tomato agroecosystems.

Keywords: Tomato pests, Tuta absoluta, GIS technologies, Remote sensing, Drone monitoring, NDVI index, Satellite imagery, Artificial intelligence (AI), Random Forest, YOLO, Andijan region, Bioecology, Early warning system, Pheromone traps, Tomato agroecosystem.

Introduction. Tomato (Solanum lycopersicum) is one of the most important vegetable crops in the world, and its product plays an important role in human nutrition. However, tomato cultivation is seriously threatened by various pests - on a global scale, it is noted that insect pests damage an average of 13-14% of the yield of agricultural crops. In regions with a warm climate, such as the Andijan region, the most harmful pests to tomato crops are the tomato moth (Tuta absoluta), various aphids, and thrips. It is known that in the conditions of the Fergana Valley (including Andijan), the tomato moth has become one of the five most dangerous pests of vegetable and melon crops in recent years. In this article, using the example of the Andijan region, the bioecological characteristics of tomato pests and the use of modern geoinformation systems (GIS) and remote sensing technologies (drones, satellite imagery, etc.) in monitoring their distribution are analyzed. Attention will also be paid to the issues of introducing artificial intelligence (AI) and algorithms into the observation process, increasing the effectiveness of monitoring, and forming early warning systems.

Main tomato pests and their bioecology

In the Andijan region, among the main insects damaging tomato yields in open fields and greenhouses are the Tuta absoluta (tomato moth), aphids, and thrips. Below, these pests and their bioecological characteristics (life cycle, reproduction and distribution factors) are described.

Tuta absoluta (tomato moth)

The tomato moth is a small moth (butterfly) that originated in South America and has rapidly spread throughout Europe, the Middle East, Asia, and Africa since 2006. In Uzbekistan, this invasive pest was first identified in 2016 and is currently found in many tomato-growing regions of the country. Tuta absoluta is an oligophagous plant, mainly characteristic of tomatoes, and can also damage other nightshade crops (potatoes, eggplants, tobacco, etc.). Its eggs are small (0.35 mm) and are laid one by one on the leaf surface; each female butterfly can lay up to 250-300 eggs during its lifetime. The hatched larvae feed by forming shafts inside leaves and fruits - this shaft-like damage is a characteristic feature of tomato moths, manifesting as large wounds in leaves and small holes in fruits. The larva develops in four stages, completing development in 13-15 days; then pupates in the soil or in plant debris. Adults (imago) are small grayish-brown butterflies, with a body length of only ~6 mm, narrow wings, and black spots on top. The life cycle is very short - under optimal conditions (25-27°C), it takes only 30-35 days for the egg to hatch and reproduce. Therefore, in warm regions, this pest can develop up to 10-12 generations throughout the year (even in greenhouse conditions). For example, in observations conducted in the central part of the Fergana Valley, it was noted that Tuta absoluta produces 5-6 generations during the season (even up to 6 generations, including those in the warehouse), the development period of each generation lasted about a month.

Reproduction conditions are very suitable for sunny and warm climates, and larval development accelerates when the daily temperature is around 25-30°C. In this case, the pest continues to multiply in the open field until the end of autumn; with the arrival of winter, it can partially survive in the pupal or adult moth stage. Studies have shown that in the Fergana Valley, the tomato moth can overwinter in the egg, pupa, and adult moth stages. In particular, in the Andijan region and adjacent territories, larvae and pupae are found in open areas before the onset of autumn cold, and in winter, the adult stage of the live moth is observed in greenhouses (for example, in the Tashlak district). This pest flies actively during hot days (mainly at night) and can spread itself over short distances, but the factors of its spread are mainly related to human activity: it quickly penetrates new territories through the sale of infected tomato seedlings or fruits, packaging material, and other products. The influence of absolute mustard on local crops can be extremely destructive - if effective control measures are not taken, it is noted in scientific sources that it can potentially destroy 80-100% of tomato yield. For example, in the conditions of Uzbekistan, during the first invasion in 2016, it was observed that the tomato moth spread to almost 100% of the field in some farms within a few weeks (on the example of the Zangiata district of the Tashkent region). Therefore, the tomato moth is currently recognized as a pest that poses a serious threat to the agricultural sector of the region and requires early detection and control.

Tissues aphids:

Among the juicy pests that pose a threat to tomato plants, the most common are the green peach aphid (Myzus persicae) and related species, which form colonies on tomatoes and other vegetables and feed by sucking plant sap. Insects are very small, soft-bodied insects (1-2 mm long), often living in clusters on the underside of leaves or at the tips of branches. Their color can be greenish-yellow, sometimes pink, dark. aphids have a specific life cycle: female individuals often reproduce directly by live birth without males (through parthenogenesis). This allows them to grow populations very quickly - at the optimal temperature (around 25 °C), the full development of one generation is completed in only 10-12 days. In regions with a warm climate (for example, in the spring-summer months of the Andijan region), aphids are capable of producing 20 or more generations per season. Each female aphid can produce an average of 30-80 offspring, and its lifespan is limited to several weeks. As the aphid colony becomes dense, winged morphs appear in the population, which migrate to new plants and expand the colony. Breeding conditions: mild and warm weather is most favorable for aphids' reproduction; their offspring grow quickly in high humidity and moderate temperature. Several generations alternate before autumn, and at the end of autumn, when the days become shorter, some species develop sexual females and males, laying overwintering eggs (often fruit trees - for example, peaches, apricots of the Prunus genus). Distribution factors: aphids affect many plant species and are found almost everywhere; due to their small size, they can be spread over long distances by wind. Especially when seedlings infected with aphids that have multiplied in greenhouses or nurseries are brought to the field, the pest quickly spreads to new areas. Indeed, aphids that live in the greenhouse year-round and spend the cold season move to open fields and household plots with seedlings in spring. While aphids damage tomatoes directly by inhibiting nutrient competition and assimilation, the sweet "aphid" liquid they secrete leads to the appearance of fungal moths (soy spots) on the leaves. Most importantly, aphids spread dangerous viral diseases through their sucking mouthparts - for example, pathogens such as tomato mosaic virus and potato virus Y common in tomatoes migrate specifically through aphids. Therefore, early control of aphids plays an important role in preventing viral diseases.

Thrips:

Trips (belonging to the order Thysanoptera) are also dangerous pests of tomatoes and other heat-loving crops. The most common species in the Andijan region is the Western Flower Thrips (Frankliniella occidentalis), as well as the Tobacco Thrips (Thrips tabaci). Trips are very small, thin-bodied insects, about 1 mm long, usually yellowish-brown in color, with narrow wings (perpetually flapping). Life cycle: stages of thrips development - egg, 2 larval stages, then immobile prepupa and pupa stages, then imago (adult) stage. In hot conditions, the complete cycle can be completed very quickly - within 7-15 days. For example, if the optimal temperature range is around 20-35°C, a week will be enough for the egg to hatch. Therefore, during the summer months, thrips reproduce by merging several generations, and the population can increase dramatically. Female thrips lay eggs on leaf or flower tissue; larvae feed under the leaf or on the petals. The larval stages are very mobile and feed by sucking plant cell sap, resulting in the appearance of small whitish-dirty (silver-like) spots on the leaves. Affected leaves dry and wrinkle, and flowers and fruits may fall off. Breeding conditions: dry and hot weather contributes to the spread of thrips - if relative humidity is low, they multiply quickly, otherwise, heavy rains can wash them away and reduce the population. Usually, thrips survive the winter in a greenhouse or in the soil in the form of a surviving adult female, as it is difficult to survive in an open field in a cold climate. Distribution factors: although thrips cannot fly actively, they can move passively over considerable distances in the wind due to their light body. Also, the transfer of infected seedlings and products to new locations is a source of spread. These pests cause double damage to tomato plants during the feeding process: firstly, they damage tissues and slow down growth; secondly, they are very dangerous - they transmit viral diseases. In particular, the tomato bronze spot virus (TSWV - Tomato Spotted Wilt Virus) is spread by thrips and causes great damage to tomato growers. This virus is only taken from the plant by thrips larvae, then persists in the imago thrips body throughout its life and continues to infect other plants. As a result, even if there are several infecting thrips in the field, they can quickly spread the virus throughout the field and destroy a significant portion of the harvest. The virus-carrying nature of thrips makes them especially dangerous pests and requires early warning and entomological control measures against them.

Pest distribution mapping using GIS technologies

Modern Geographic Information Systems (GIS) serve as a powerful tool for monitoring and analyzing the distribution of pests in agricultural entomology. With the help of GIS, it is possible to conduct spatial analysis of data collected from sites, to show on accurate maps the areas where the pest is distributed, and to identify risk zones. In the Andijan region, the use of GIS technologies for pest monitoring in horticulture and vegetable growing has also begun. For example, if field inspection data is collected together with coordinates through special GPS devices or mobile applications and entered into ArcGIS or QGIS programs, the points where the pest was encountered are displayed on the map. With the help of this approach, it is possible to determine in which districts and farms the damage was observed in a short period of time, and to create maps of regional distribution. With the help of such maps, it is possible to visually analyze the spatial concentration, directions of distribution, and dynamics of tomato pests.

GIS tools allow not only the creation of static maps, but also real-time monitoring. For example, with the help of special applications, such as ArcGIS Field Maps, inspectors can locally enter the number of pests trapped on each farm or field, the degree of damage. The entered data is transferred to the central server (or cloud) and is constantly updated in the form of a dashboard. Thus, at first glance, it is clear in which territory the pest has appeared and where the risk of its spread is high. Using the example of the ArcGIS Dashboard, responsible specialists can monitor the number of traps, the conditions of their detention, the places where inspection should be carried out, etc. on one screen. Working with such databases obtained using GIS tools significantly simplifies territorial planning of pest control measures.

If we take the example of Tuta absoluta, which poses a threat to tomato crops in the Andijan region, then when this pest first spread in the region in 2016-2018, GIS mapping was used to organize rapid monitoring against it. In particular, field surveys conducted with the support of the World Bank examined tomato fields in dozens of locations across the Fergana Valley, recording the percentage of leaf damage and the degree of fruit damage in each. The maps prepared according to the obtained results showed that, for example, in areas near the border with Tajikistan, up to 15-30% of leaves were damaged by moths from mines, and up to 20% of fruits were damaged in some places. Based on these data, the pest's range was drawn, and its central foci and directions with a high risk of spread were identified. With the help of GIS analysis, the relationship between geographical factors - for example, the climate of certain regions, sowing and harvesting times, transport routes - and pest distribution is also analyzed. This will serve to create risk maps (Risk map) in the future and determine in advance zones with a high probability of infection.

In general, GIS technologies give decision-makers a territorial appearance in controlling tomato pests. Unlike traditional field reporting methods, GIS provides data in a visual and interactive manner, which facilitates problem identification and prompt action planning. For example, if the map indicates the emergence of a pest in several farms in a row in one district, it becomes clear that urgent quarantine and treatment measures need to be organized there. At the same time, with the help of GIS data collected over time, trends in the growth of pest populations and seasonal dynamics are also tracked. In the future, if such a database is created in the Andijan region, it will be possible to predict pest recurrence cycles in advance by analyzing data over several years.

Remote Sensing: Drones and Multispectral Monitoring:

Traditional manual field surveys and trap setting methods are labor-intensive and may be slow to quickly monitor large areas. Therefore, in recent years, remote sensing technologies, in particular, unmanned aerial vehicles (drones) and multispectral imaging methods, have been widely implemented in agriculture. With the help of drones, it became possible to quickly and in detail observe the crops of farms from above.

Drones equipped with multispectral cameras can simultaneously photograph several wavelengths of light reflected from plants (for example, the near infrasarkylic (NIR) range with visible red, green, and blue rays). Vegetation indices can be calculated from the images obtained, in particular, NDVI (Normalized Difference Vegetation Index) maps. The NDVI index reflects the degree of greenness of plant leaves, that is, the activity of photosynthesis, and serves to distinguish between healthy (green) vegetation and damaged (or stressed) vegetation. Experiments show that disproportions in the state of plants across the field can be detected at an early stage using NDVI maps - for example, if leaves begin to be damaged by pests in part of a tomato row, the NDVI value there decreases significantly compared to surrounding healthy rows. In agricultural technology, methods for early detection of stress caused by pests or diseases using NDVI and other spectral indicators are already being successfully applied. For example, AgroScout tracks NDVI in the fields using special drones and satellite monitoring systems, creates a map of plant health, and on this basis warns farmers about the first signs of disease or pest spread.

Experiments on the use of drones in dehkan farms are also beginning in the Andijan region. Small and medium-sized drones are capable of flying over tomato fields at an altitude of ~10-50 m and taking complete orthophotographs of the entire area in a short time. Using special programs, these images are combined to create high-precision maps (with measurement accuracy sometimes up to 3-5 cm). Then, multispectral images are analyzed, and NDVI and other indices are calculated at each point. As a result, a color map shows how healthy the vegetation is in each part of the farm's field. For example, green can indicate healthy rows of thick-leaved tomatoes, while yellow-dark reddish colors can indicate areas with damaged or thinned leaves. If yellowish-reddish spots with a clear contour appear on the map, this often indicates the presence of a pest or disease focus in that area. Drone monitoring is especially helpful in early detection of leaf-mining pests, such as tomato moths - because as the leaves begin to be infected, photosynthesis slows down and NDVI decreases. Also, when a high-resolution camera on a drone directly captures the state of leaves from above, an experienced agronomist or automated software can see mine traces or color changes on the leaves. This makes it possible to determine the location of the pest as soon as clear signs appear.

Another important advantage of remote sensing is the rapid coverage of large areas and non-invasive (without damaging the plant) observation. For example, it is difficult for a few inspectors, who are usually observers of a 50-hectare tomato field, to fully inspect it in a few days. However, a single drone can perform this task in a matter of hours and transmit or record information in real time. Although the use of drones in Uzbekistan is still at a new stage, these methods are proving effective in many countries around the world. For example, in the USA, observation of insect distribution on large farms using drones has been established; In Italy, the state of pests and irrigation in tomato fields is jointly analyzed, and differential irrigation plans are being developed based on NDVI maps.

Work is also underway to implement not only detection but also direct combat measures using drones. For example, some developed farms are testing technologies that accurately spray insecticides only on damaged areas of the field using a drone-mounted sprayer. This brings ecological and economic benefits by targeting specific hotspots rather than poisoning the entire area. Of course, the success of such approaches also depends on early pest detection - the aforementioned GIS and drone monitoring play an important role in accurately identifying affected points.

In conclusion, drones and multispectral remote sensing technologies will raise the quality of tomato pest monitoring in agricultural areas such as the Andijan region to a new level. These technologies provide faster, more comprehensive, and more accurate information than conventional methods, resulting in timely and targeted pest control measures.

Detection of contaminated areas based on satellite imagery:

Drones provide high local accuracy, while satellite monitoring covers entire regions and large areas. Currently, data from Sentinel-2 (European Space Agency) and Landsat 8 (US NASA) are widely used as high-resolution open-source satellite images. These satellites take multispectral images: for example, images of Sentinel-2 are taken in several spectral channels (blue, green, red, red-boundary, NIR, etc.) in a spatial dimension of up to 10 meters and are updated every 5 days. Landsat 8 transmits images in ~30 m in 11 channels (15 m panchromatic), passing over the area every ~16 days. With the help of these satellite images, the condition, development, and signs of stress of agricultural crops are assessed remotely.

The use of a satellite in pest monitoring is of particular importance, as it allows you to see large areas in an instant. For example, Sentinel-2 footage can simultaneously cover all tomato fields in the Andijan region. If we analyze such images weekly, we will notice in which areas the vegetation index has sharply decreased from normal or stopped growing. These symptoms can be due to various reasons (water shortage, lack of fertilizers, or diseases, pests). If other factors are excluded, such abnormally low NDVI areas may be designated as suspected pest damage. Especially when leaf and fruit-destroying insects like Tuta absoluta are rampant, uneven "rain-like" spots can appear on satellite imagery across the field - indicating that plant leaves have completely perished and the earth's surface has become visible. Indeed, scientific research has shown that the combination of red and NIR channels in satellite images demonstrates high sensitivity to identifying plants weakened by pests. For example, scientists successfully mapped the infestation of cochineal in citrus orchards using Sentinel-2 - in which affected trees were clearly distinguished in the indices due to changes in their absorption capacity in the red spectrum. The same approach can be applied to tomato fields: if a pest appears in a field, within a few weeks its field begins to become "pale" from the satellite (the green color disappears). These signs can be automatically tracked through platforms such as Google Earth Engine and dangerous points can be marked across a large area. According to the researchers, the possibility of detecting a large-scale pest attack at an early stage and immediately taking agronomic measures using satellite monitoring has been confirmed.

Another advantage of satellite imagery is the observation of the temporal sequence, that is, the analysis of the dynamics of changes by photographing each area several times during the season. For example, in the Andijan region, in June, tomato fields have maximum green vegetative mass, and the NDVI index averages ~0.8 (on a scale from 0 to 1). If some areas of the rows begin to be damaged by Tuta absoluta in mid-July, NDVI may decrease to 0.5-0.6. In the next Sentinel-2 shots, this change is clearly visible - the corresponding part of the field appears as a yellowed spot. If measures are not taken in a timely manner, after 2-3 weeks, it can be observed that the spot has enlarged and spread throughout the field. Thus, satellite observation also serves to assess the speed of pest spread: for example, by concluding that an area of 10 hectares increased to 30 hectares in a week, one can draw conclusions about the rate of infestation. This is important when planning control measures (for example, determining when to release beneficial entomofauna for biological control in which area or in which direction to expand insecticide spraying).

Of course, satellite imagery in some cases cannot directly identify the pest, showing only indirect signs. Therefore, they must be confirmed by ground observations. However, satellite monitoring is very useful for primary screening in large areas. For example, at the level of the phytosanitary service of the republic, based on Sentinel-2 data, a system for monitoring vegetation anomalies can be established throughout the Andijan region. Then inspectors are sent to the points where the anomaly was detected, where the presence of a pest is verified. This approach will be much more economical and faster than taking conventional measures, since resources are used purposefully.

For example, Canadian scientists, using satellite imagery and deep learning algorithms, segmented the areas of damage caused by the bark beetle pest in forests - combining 13 Sentinel-2 spectral channels and 13 vegetation indices derived from it, the affected areas were classified with an accuracy of over 85% using the UNet++ neural network. This example shows that it can also be applied to agricultural crops: that is, by analyzing images that seem complex from a satellite view using modern algorithms, it is possible to automatically "paint on the map" the areas where the pest is directly distributed.

In general, satellite monitoring is the highest level of remote observation, which provides a wide range of coverage, regularity, and the possibility of historical analysis. Drones sometimes cannot reach many places simultaneously or fly long distances. The satellite covers an unlimited area and creates a sequence. This technology is especially useful in densely populated agricultural areas, such as the Andijan region, because it simultaneously creates a general picture of where the situation is worse in the region. At the same time, it is possible to observe long-term processes using satellite imagery - for example, to see whether the pest's range is expanding year by year, to analyze the impact of climate change on pest populations, and so on.

Use AI and algorithms in pest monitoring:

Artificial intelligence (AI) and machine learning methods are revolutionizing the analysis of various complex data in agriculture. In particular, many studies have confirmed the effectiveness of using AI algorithms in monitoring and predicting tomato pests. Among the widely used models are classification algorithms such as Random Forest and artificial neural networks (including a convolutional neural network - CNN, and YOLO for object recognition).

Random Forest is an ensemble model consisting of a large number of decision trees, demonstrating high accuracy in the selection and classification of the most important among a large number of features and factors. For example, if we have data on dozens of variables for a certain area - soil type, temperature regime, humidity, time strictness of NDVI values, etc. - and the appearance or absence of Tuta absoluta in that area, Random Forest models allow us to predict where pests will appear based on these factors. According to the scientific literature, for example, Bárta et al. (2022) analyzed the change in seasonal vegetation indices in satellite images using the random forest algorithm and managed to distinguish beetle-infected areas in forests from healthy areas with 78% overall accuracy. The same approach can be applied to tomato fields: the random forest model can combine data such as NDVI, temperatures, and ground observations to show which field has the highest pest probability. Moreover, using this model, it is possible to determine which factors (for example, very high temperature or thick crop cover) play the most important role in pest infestation.

Artificial neural networks (CNN and others) are showing incomparable results, especially in image analysis. Photographs or videos taken from drones and satellites are a huge source of information, which is difficult to fully "read" with a simple statistical method. CNN-type deep learning models can adapt to complex patterns in images and recognize necessary features and objects. The success of models based on the YOLO (You Only Look Once) architecture in work on tomato pests deserves special recognition. For example, in the study of Shehu et al. (2025), using the YOLOv8 model, it was possible to determine the symptoms of the disease caused by Tuta absoluta in tomato leaves at the level of 0.73 mAP (average accuracy), which is significantly higher than other methods in real field conditions. Similarly, in the experiment of Şahin et al. (2023), the YOLOv5 model was trained based on 1,200 images of infected leaves, as a result of which the task of automatic detection of Tuta absoluta larvae and mine damage in tomato leaves was solved with an average accuracy of ~80% (mAP) - the accuracy for some categories even approached 90%. This means that now it is possible to analyze a picture of a tomato leaf taken with a simple smartphone camera and conclude with the help of an AI model that "There is a Tuta absoluta larva on it" or "no." Such tools are also being developed in the form of easy-to-understand mobile applications for farmers.

AI technologies help to work not only with images, but also with data in the time layer, or to integrate interconnected multidimensional datasets. For example, to predict the dynamics of pest populations in the coming weeks, recurrent neural network (RNN) or lSTM models can be used - this includes the current entomological state, weather forecast, agrotechnical measures, and the model predicts the next trend. In some experiments, it was noted that such a predictive model, synthesized on the basis of AI, correctly predicted pest development up to three months in advance with an accuracy of about 90% (in this regard, AI technologies are considered a powerful tool in making agronomic decisions).

For the implementation of AI models in regions such as the Andijan region, it is first necessary to collect sufficient data in local conditions. In the future, for example, creating a database of tomato fields in each district, the number of pests observed in each district, the number of moths caught, and the current weather and agricultural practices will open the door to enormous analytical opportunities with the help of AI. Models can also determine where and when Tuta absoluta is most abundant, or which farming methods (such as irrigation type or planting sequence) affect pest outbreaks. Additionally, early warning systems can be automated using artificial intelligence: for example, if the number of butterfly catches from pheromone traps placed around a certain fog increases sharply at a certain time, and the model assesses that this is likely to turn into an epidemic, the system immediately sends a message. This message will reach all farmers in the cluster via SMS or application, and they will start spraying pesticides or taking other necessary measures.

Another useful aspect of AI and machine learning models is the identification of hidden data patterns. For example, in a simple observation, we might wonder why the autumn tomato harvest is damaged more in some years and less in others. The models can identify the most impressive among dozens of variables and draw conclusions such as "if the average spring temperature is such-and-such, Tuta absoluta will flourish early in summer." This is also useful in determining adaptation measures in the context of climate change. Indeed, there is information that with climate warming, the life cycle of many pests accelerates and their range expands - therefore, with the help of artificial intelligence, it is possible to predict the potential spread of pests based on regional climate forecasts.

Monitoring Efficiency and Early Warning Systems:

As a result of the integrated application of the above-mentioned technologies and methods, it is possible to significantly increase the effectiveness of controlling tomato pests and, most importantly, prevent damage. In traditional control measures, farmers often resorted to chemical treatment only after the pest covered the field and the harvest was at risk. In this case, due to the delay, part of the harvest would have already been lost. The early warning system warns farmers and officials to take urgent measures even before the pest reaches its peak.

To create such a system, monitoring itself must be continuous and comprehensive. GIS, remote sensing, and AI tools will be integrated in a complementary way. For example, the Invasive Pest Management (ArcGIS) solution combines the ability to properly distribute traps in the area, collect data from them online, monitor the results on the dashboard, and even share them with the public. This approach is called proactive monitoring - it is aimed at preventing damage rather than treating the affected areas. For example, if an increase in tomato moths is recorded in one district of Andijan, the early warning system immediately sends a message to neighboring districts and other regions where tomatoes are ripening around the same time. This message provides information about the potential attack of the pest and possible recommendations (e.g., rapid bioinsecticide spraying or increasing pheromone traps).

In early warning systems, not only public services, but also the participation of farmers themselves and the population plays a large role. Through special mobile applications or web platforms, ordinary gardeners can report that a strange moth is flying in their garden or that unknown mine spots have appeared on the leaves. For example, if the population sends a message about the detection of a malware using tools such as ArcGIS Survey123, it automatically appears as a dot on the system map. If specialists check and confirm this, a risk zone will be declared around this point, and a warning will be given to neighboring farmers. Establishing operational communication through public engagement is becoming an important part of the fight against invasive pests today.

Another way to improve monitoring effectiveness is the involvement of automation and IoT (Internet of Things) elements. For example, smart pheromone traps are being developed: these devices are equipped with a small camera or sensor that automatically detects insects caught in the trap on the spot and sends a signal to the online system. Let's imagine that such a trap is installed in each village of Andijan - as a result, it will be possible to simultaneously find out where and when the first butterfly appeared in the region. This information is analyzed using an AI model, and a forecast is made about where the pest population may increase in the coming weeks. If the forecast is reliable, measures such as releasing biological control agents (parasitic bees or entomopathogenic fungi) to these areas in advance or laying protective nets are taken.

In conclusion, it can be said that the protection of important crops in the national economy, such as tomatoes, from pests today should be based not only on pesticide spraying, but also on integrated monitoring and early warning systems. While GIS helps us in spatial awareness of pests and identification of attack areas, remote sensing allows us to observe them on a large and fast scale. Artificial intelligence, by generating meaningful knowledge from the flow of big data, is able to foresee laws and dangers invisible to the human eye. The introduction of such approaches in the Andijan region serves not only to preserve the harvest, but also to ensure the overall sustainability of the agro-industrial complex. After all, prompt and scientifically based monitoring is the most effective way to "catch" pests and be one step ahead of them.

References used:

1. Shermatov M.R. va boshqalar. Farg‘ona vodiysi tangachaqanotli hasharotlar faunasining agroekotizimlarda taqsimlanish xususiyatlari. – CyberLeninka elektron kutubxonasi (2022).
2. Saidov N. va boshqalar. First report of invasive South American tomato leaf miner Tuta absoluta in Tajikistan. – Florida Entomologist jurnalidagi maqola (2018).
3. EPPO (European Plant Protection Organization) ma’lumotlari. First report of Tuta absoluta in Tajikistan (2018) – EPPO Global Database xabarnomasi.
4. AVRDC (World Vegetable Center) faktlar varag‘i: Tuta absoluta – Tomato Leaf Miner (2016).
5. Shehu H.A. va boshqalar. YOLO for early detection and management of Tuta absoluta-induced tomato leaf diseases. – Frontiers in Plant Science, 16:1524630 (2025).
6. Şahin Y.S. va boshqalar. Detection of Tuta absoluta larvae and their damages in tomatoes with deep learning-based algorithm. – Int. J. of Next-Generation Computing, 14(3): 555-565 (2023).
7. Capinera J. Green Peach Aphid (Myzus persicae) – UF/IFAS Extension, IN379 (2000-y.).
8. AgroScout bilim bazasi: NDVI – monitor crop health to detect stress and pests early (2025).
9. Esri ArcGIS Blog: Finan K. Optimize pest detection operations with the Invasive Pest Management solution (2025).
10. Barta et al. Detecting Pest-Infested Forest Damage through Multispectral Satellite Imagery and Improved UNet++. – Remote Sensing, 14(19): 4823 (2022).
11. UC IPM Guidelines: Thrips on Tomato – University of California IPM (2019).