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Research Article

Autonomous Upgraded Herbicide Sprayer Using Basic Concepts of Artificial Intelligence

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Abstract: This paper intends to help farmers fight weeds in a better way. This paper is an initiative to design an autonomous upgraded herbicide sprayer to prevent toxic contamination on healthy food crops and ensure herbicide free food for consumption. The paper suggests simple ideas to upgrade existing herbicide sprayers after analyzing advantages and disadvantages of prevailing spraying methods. The aimed working methodology and proposed features of the autonomous upgraded herbicide sprayer are detailed in this paper. Considering the heavy soil compaction that happens due to excess usage of tractors, the overall weight of the proposed herbicide sprayer aims to be of lesser weight and is inspired by the basic design structure of an all-terrain vehicle (ATV). The ATV is proposed to be an autonomous version using navigation sensors, GPS, machine vision, dead- reckoning sensors, laser-based, inertial sensors, and geomagnetic direction sensors. Features like Climate checking technology is also suggested in the proposed herbicide sprayer. The concept of smart spraying technology is marginally altered and inculcated to the proposed herbicide sprayer. To differentiate between a weed and a healthy crop, a smart weed identifier along with an advanced camera is proposed to be used. To fix the challenge of herbicide being possibly sprayed on nearby healthy crops, a fast-adaptive herbicide sprayer is being included to the proposed sprayer.

Index Terms—Autonomous upgraded herbicide sprayer, All- terrain vehicle, Climate Checking Technology, Machine Learning Algorithm, Deep Learning Algorithm, Smart weed identifier, Fast adaptive herbicide sprayer

1. INTRODUCTION:

Agriculture is the most dynamic and contributing sector to world economy. With growing population around the world, the need for more food is also increasing year over year. Whereas agricultural production is facing many challenges to meet the growing demand for more food. The principal problem of the agricultural sector in many developing nations is the low yield. Poor Infrastructure, low usage of farm technologies, improper irrigation management and continuous and excess usage of herbicide are the foremost reasons for the low yield. Owing to low yield, in the long run, most farmers are not able to invest in their farms for improving their land fertility. They become incapable to invest more on latest technologies that could help them improve their agricultural productivity. A weed is an unwanted plant grown in the wrong place at the wrong time. Weeds are one of the major threats faced by farmers. Weeds absorb all nutrients, sunlight and water belonging to the nearby crops and this is costing the farming industry billions in agricultural yield. Weeds causes the deteriorating quantity and quality of agricultural productivity. Many farmers are facing major financial losses due to weeds in their crops producing food products. A proper weed management alone can bring down these losses. Farmers widely use conservative strategies to handle weeds. Farmers mostly use chemical herbicides as a familiar and effective solution for controlling weeds. Excessive use of herbicides over crops to handle weeds has a damaging impact on environment and its influence on the good crop also. Heavy use of herbicides also impacts the food products produced for consumption. A smart spraying technology will secure overall crop production and yields and will ensure safe food production that are being consumed by the entire world population. The agricultural sector has been quite slow in taking advantage of the various emerging technologies.

There is enormous scope for enhancing farmer’s income by lowering cost on weed control and by achieving higher productivity. Timely weeding and raising a healthy crop are critical in our fight against the onslaught of weeds. Herbicides will be an important component of Integrated Weed Management. With clever integration of weed management, herbicides will enable farmers to achieve better weed control at reduced cost with enhanced crop productivity. Since integrated weed management is a knowledge intensive activity, it requires the support of weed researchers and technology experts. Farmer’s need to realize the value of using advanced technology.

1.1 Herbicide Industry –A Glance:

Growing food demand because of rising population is the major reason behind the demand of herbicides. To satisfy the ever-growing food demand, there is a rise in producing of food across the world. Since herbicides protect crops from attack of weeds, the global herbicide market is increasing its production. To improve agricultural productivity, herbicides are used for averting the crops from weeds such as insects, fungi, weeds etc. Farmers have started using herbicides abundantly to improve production. Herbicide usage has become inevitable to secure availability of food for the ever-increasing population in our nation. The herbicides industry is expected to secure a major market share in the coming years. As per the market overview report shared in [Crossref 11] the global herbicide market is expected to grow at a CAGR of 6.5% during the forecasting period (2020-2027). Since herbicides provide more economic means of controlling weeds, herbicide usage is high in major agricultural producing nations. With an approximated volume share of 48% in global pesticide market, herbicides have evolved as the largest consumed crop protection pesticide across the globe. The herbicide global market overview report [Crossref 11], states the below global herbicide market value share between 2018 to2026.

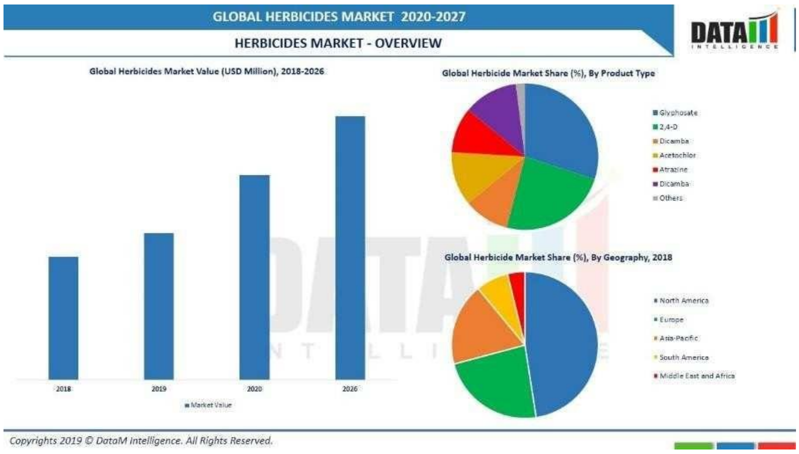

Fig. 1: Global Market Value of Herbicides

Courtesy Source: [Crossref 11] datamintelligence.com/research-report/herbicides-market

1.2 Herbicide Spraying –Challenge Faced:

A farmer must have thorough awareness on the weeds, herbicides, and relevant herbicide application technique to effectively manage weeds. Herbicides are poisonous and toxic and so farmers must be cautious in usage of herbicides. Herbicide application techniques should accurately target the weed alone. If farmers can map the exact location of weeds in their farms, they need not spray herbicides over the entire field. Instead, they can precisely target the exact crop that is affected by weed and spray herbicide to the affected crop. Increased usage of herbicides can significantly increase environmental damage. It may result in retention of herbicide remnants in soil. Over usage of herbicide reduces biodiversity and even poisoning of humans, farm animals and even aquatic life because these chemicals mix with rainwater which later joins river water.

Physical Health Hazard to The Farmers Involved in Spraying Herbicide: Physical exposure to the harmful chemical found in herbicide is a major health hazard faced by the farmer involved in herbicide spraying. Majority of farmers suffer from skin disorders, nausea, and digestive problems because they inhale herbicide while spraying.

Herbicide Drift: Drift is the accidental movement of herbicide through air to the nearby non targeted healthy crop. **Physical drift** of herbicide is caused when the small herbicide droplets are accidentally dropped on the nearby healthy crops. Small droplets usually get dripped through the spray nozzle tip to the nearby crop during spraying. The height above the ground, from where the herbicide is released may also increase physical herbicide drift. High wind speed may cause the herbicide droplets to even travel a few feet from the targeted area. **Vapor drift** is the capability of an herbicide to vaporize and mix easily in air. The quantity of vapor drift depends on the herbicide, its formulation and the weather and soil conditions. Vapor drift mainly results in air contamination. **Herbicide-Contaminated Soil drift** is the contamination of soil caused because of the herbicide. Herbicide may contaminate soil when it is drifted on the soil or when herbicide is washed off by rain or overhead irrigation. Drifted herbicide residues may remain in soil and affect vulnerable crops. So, the main challenge in herbicide spraying is drifting of herbicide. There exists a significant need for an effective technological solution to evade herbicide drift.

Water Contamination:

As mentioned in article [Crossref 12] Leaching is indicated as the major reason of ground water pollution by herbicides. While leaching is essential for the incorporation of herbicides into soil, negatively, herbicides can also reach to deeper layers of the soil until they reach deep down the ground and contaminates the ground water. The article further states that water can be contaminated by run off herbicides. Herbicides can reach surface water through runoff from treated plants and soil. Contamination of water by herbicides and chemicals has become widespread. It takes many years for the hazardous chemicals in polluted ground water to dissolve or cleared.

Soil Contamination:

As cited in article [Crossref 13] effect of four triazinyl-sulfonylurea herbicides (cinosulfuron, prosulfuron, thifensulfuron methyl, triasulfuron) on soil microbial biomass, soil respiration, metabolic activity, metabolic quotient, and some enzymatic activities (acid and alkaline phosphatase, β-glucosidase, arylsulphatase, and fluorescein diacetate hydrolysis) were monitored under controlled conditions over 30 days. Herbicides applied at ten-fold field dose, created a long-term toxic effect. The soil microbial parameters showed that the normal field dose had minor effects on soil microflora, while at ten-fold field dose, the tested herbicides exercised a stronger poisonous effect on soil microbial biomass and its biochemical activities.

Effects on the Fertility of Soil:

Heavy deposition of herbicides in soil may destroy beneficial microorganisms found in soil. Plants rely on a species of soil microorganisms to change atmospheric nitrogen to nitrates, which plants can use. Whereas herbicides disrupt this process.

Air Contamination:

Due to drifting and heavy wind speed, herbicides mix with air and results in air contamination. Inhalation of contaminated air by human, animals, birds all shall have a toxic effect. Certain chemical ingredients in herbicides stay in air for a short while, whereas some herbicide ingredients stay for a long period of time and dissolve into the surrounding air.

Ecological Effects of Herbicides:

The article published in [Crossref 12] states that ecological effects of herbicides are diverse and are often interconnected. Several effects caused by herbicides are, Death of the organism, Cancers, tumors and lesions in fish and animals, inhibition or reproduction failure, suppression of the immune system, endocrine (hormonal) disturbance, cell and DNA damage, teratogenic effects(physical deformities, example curved beaks in birds), weakened health of fish marked by a low production of red to white blood cells, excessive slime in fish scales and gills, other physiological effects like thinning of eggshell, etc., The vital point to be concerned is, many of these effects are chronic and have consequences on the entire food chain. The article further states that the ecological effects caused by herbicides extend beyond individual organisms and can extend to ecosystems, affecting biodiversity.

2 VARIOUS METHODOLOGIES USED FOR HERBICIDESPRAYINGS:

The foremost aim of any herbicide application method is to cover the target (weed) most effectively and to take out the weed affected crop alone with minimum contamination to nearby healthy crops.

2.1 Conventional Herbicide Spraying:

Conventional herbicide spraying techniques include usage of Knapsack Sprayer. In this method, the sprayer stands mounted on the back of the human operator and he sprays herbicide manually using the hand pumps. Foot Sprayer is another method of herbicide spraying. In this method, the pump of t h e sprayer is functioned by operating the pedal lever by the foot of the human operator. This method requires two persons to work and is mostly used for orchard crops and trees. Conventional spraying method requires more manpower and is also time consuming. Conventional procedures of herbicide spraying causes excess application of chemicals, inferior spray uniformity, heavy water, soil, and air pollution.

2.2 Electrostatic Sprayers:

Electrostatic spraying is a method used to drizzle herbicides with less drift potential. Electrostatic spraying method has a better coverage on difficult weed targets than the conventional spraying method. The electrostatic guns used in this method have excessive transfer efficiency. Electrostatic sprayers can save water, fuel, and herbicide. But Electrostatic sprayer is also a manual method risking the farmer being exposed to herbicides and in this method also there is high possibility of contamination of adjacent healthy crops.

2.3 Drones for Herbicide Spraying:

Drone spraying significantly reduces the quantity of herbicide sprayed on farms because they can spray evenly to all layers of the crop. The drone spraying can cover around fifty acres of land on a single day of operation. There are three of types of Drones, namely Fixed Wing Drone, Single rotor drone and Multi rotor drone. Fixed Wing Drone requires a separate launcher to launch the drone into air. It can only move forward and cannot hover over a place. Single rotor drone is exhausting to operate and is high-priced and complex. Multi rotor drone can be operated within a limited flying time and possess a limited payload capacity. Since Drone spraying does the job of a man spraying herbicides, it protects labor from getting poisoned during spraying. But drones shall be used for spraying natural, organic fertilizer uniformly on all over the crop. Drones shall be used for spraying crop vaccines on the entire crop to boost the immunity of the overall crop field. But spraying herbicide all over the crop will contaminate the overall crop field and is hazardous to the surroundings too.

2.4 See and Spray Method:

A company in California called Blue River Technology has designed and innovated See and Spray Method. They have integrated this method to reduce herbicides by spraying only where weeds and weeds are present. They use "See and Spray" equipment that uses machine learning and deep learning concept to improve detection of weeds and weeds in a field. "See and spray" technology used by Blue River is a case of precision farming, where the spraying machine is fixed with a camera that detects every weed or weed in a crop within a noticeably short time and aims at providing plant by plant care. Moreover, an additional camera is attached to the spraying machine, which checks the action made and shall ensure that spraying action is performed accurately. By this, the machine operator has a micro level accuracy across the entire crop as the spraying machine is operated through the crop land. Blue Rivers technology claims that farmers use 90% lesser herbicide by using see and spray method. The company used cameras with graphics processing units (GPUs) and they are electronic circuits designed to swiftly operate and adjust memory to speed up the formation of images in a frame buffer. High value control systems are currently used in this technology to help perform operations effectively. But the See and Spray technology is expensive and is hard to understand. Since the See and Spray method is used with tractors, it may not be feasible for small farm lands. Continuous usage of heavy tractors also causes soil compaction. Tractors are unavoidable for farming purposes whereas usage of tractors for a herbicide spraying can be eluded [Crossref 10]

3 KEY DISADVANTAGES OBSERVED FROM ABOVE METHODS:

In conventional and electrostatic methods, contamination of the healthy crops because of herbicides spraying. Exposure of farmers with the herbicide chemicals can cause harmful effects and has been fatal too in worse cases.

In See & Spray method too, human intervention is required during its operation. The heavy weight tractor used here may cause soil compaction and may also damage the crop. See and Spray method may not be feasible for small farms on account of the large size of tractor being used in this method.

Drones are basically extremely hard to operate and are over- priced and complicated for a farmer to use. Some type of Drone requires separate launcher and can only more in forward direction. Whereas some other type of Drones has a limited flying time and possess a minuscule payload capacity. The main disadvantage is contamination of healthy crops due to spraying of herbicide from a certain aerial height.

4 PROPOSEDMETHODOLOGY:

Considering the necessity of having an efficient herbicide spraying technology and the detriments and setbacks of the current methods, a new herbicide spraying method is proposed and discussed below. An Autonomous Upgraded Herbicide Sprayer can be de- signed with the basic structural idea of an All-terrain vehicle and we shall inculcate Smart Weed Identifying Technology.

4.1 Features of Autonomous Upgraded Herbicide Sprayer:

With due concern on the impairments, and impediments observed in the existing herbicide sprayers discussed above, the following features are deliberated for the proposed Autonomous upgraded herbicide sprayer.

4.1.1 All-Terrain Vehicle:
The All-terrain vehicle used here is aimed to be a solar powered one. It is aimed to decrease the overall usage of fossil fuels and to minimize the harmful emissions and pollution. The overall ATVs design is an association of electric, mechanical systems along with a numerous computational method. [Crossref 1], [Crossref 2]. The proposed ATV has seven basic components, Solar panel, Energy storage, Converter, Engine, Motor, Transmission, Wheels.

Solar panel: The ATV is proposed to be operated by solar energy. The batteries shall be charged with solar energy with the help of a solar cell. Solar cells transform the energy of sunlight explicitly into electricity using the photo- voltaic effect [Crossref 9]. The solar panels shall be designed by combining solar cells in series / parallel manner. It is proposed to use Photo Voltaic panels in a parallel manner to overcome shading effect [Crossref 4].

Energy storage: The design shall be in accordance with the estimated power demand required by the all-terrain vehicle, so that it makes a particular speed profile trip, responding to requests of drive cycles, for maximum speed, acceleration, breaking and gradeability [Crossref 3]

Energy converter: The proposed ATV is aimed to be a dc machine and the power converters used for controlling dc machines are much simpler than ac machines. They are required only to generate a varying dc voltage. Depending on the dc source, a converter may be required to either step up or step down the voltage or a converter to perform both [Crossref 1]

Engine: The engine of an ATV uses strokes to power the engine which in turn powers the wheels. A single stroke is one movement of the piston from the top dead center position to bottom dead center position. In one power cycle, the fuel is compressed and ignited, and the exhaust gases are expelled from the combustion chamber [Crossref 5]

Motor: The motors usually used in solar powered cars are three phase brushless DC permanent magnet motor used for converting the electrical energy to mechanical torque. The same is intended to be used as it has high power to weight ratio, high rate of efficiency [Crossref 4]

Transmissions: As of now a lot of such vehicles use conventional transmissions, but it is suggested to use multi-speed transmission system which is designed specifically for the ATV. The usage of multi speed transmission helps the ATV to be powered by lesser sized batteries and motors and still have a long range and be energy efficient. [Crossref 6]

Wheels: Wheel assembly mostly called as Hub assembly is the major automotive assembly in an automotive vehicle. The design of the wheel assembly controls the dynamics and control behavior of any vehicle.

Autonomous Guidance: The ATV is proposed to be an autonomous version and does not require human involvement during its operation. The autonomous ATV is considered to have a guidance system which uses navigation sensors, computational methods, navigation planners and steering controllers. Sensors comprise global positioning systems (GPS), machine vision, dead-reckoning sensors, laser-based sensors, inertial sensors, and geomagnetic direction sensors. Computational techniques for sensor information are inclined to extract features and fuse data. Planners generate movement information to supply control algorithms. Actuators transform guidance information into changes in position and direction. Several prototype guidance systems have been developed but have not yet proceeded to commercialization. GPS and machine vision fused conjointly or one fused with another one auxiliary technology is becoming the trend development for agricultural vehicle guidance systems. [Crossref 2], [Crossref 14]

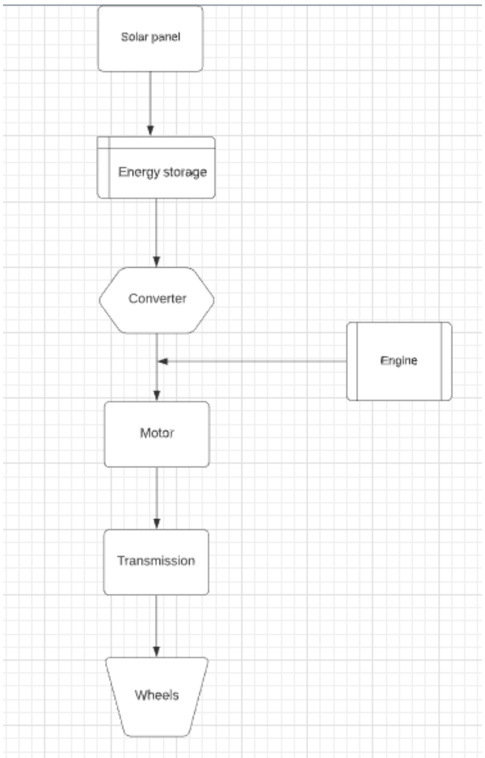

Fig. 2. Basic Topology of the ATV

In-built weather checking technology: An in-built weather checking technology shall be added. Weather factors also directly affect the spraying of herbicides. For example, when the weather at a particular point of time is windy and if the herbicides are twigged during this time, there are high chances so that the herbicide gets drifted across and falls on a perfectly healthy crop rather than on the weed due to high drift potential. Hence such weather-crop relations analysis is important. To minimize this effect, it is intended to collect test cases of different climatic conditions and perform big data analysis and by using machine learning algorithms, a model shall be trained and deployed. This model will help the proposed herbicide sprayer to determine the existence of above - mentioned climatic condition and to stop the functioning of the autonomous upgraded herbicide sprayer. Studies can be conducted using Fisherian regression integral, curvilinear technique. Linear regression can be performed on the Time series data [Crossref 7]

4.1.2 Swart Weed Identifier:

This function is basically inspired from the See and Spray Method [Crossref 10]. In See and Spray Method, deep learning algorithms shall be used a n d by using cameras, weeds are identified, and herbicide is sprayed from a tractor vehicle. In this project, we propose to use a section of the see and spray method and use camera and differentiate between a weed and a crop. Also, by using a modified algorithm, we intend to accurately differentiate a weed and a crop even when they grow on each other. When a weed is identified, it shall send an alert to fast adaptive herbicide sprayer.

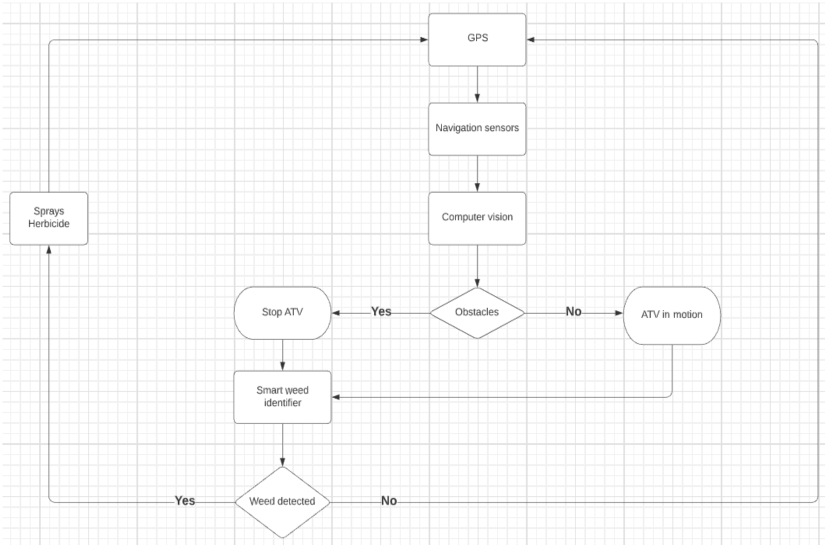

Fig. 3. Basic flowchart of the upgraded herbicide sprayer

4.1.3 Fast Adaptive Herbicide Sprayer:

Once the weed identifier finds a weed and alerts the sprayer, the tubes affixed to the sides of the ATV acting like a hand in turn points out the machine's robotic nozzles [Crossref 8] acting as a finger. The smart weed identifier identifies the weed and notes the location and makes the nozzles to perform targeted spraying of the herbicide on the weed. The precise application enables farmers to bring down the chemical usage by an order of magnitude and unlocks the ability to use herbicide alternatives to competently control weeds that would otherwise be resistant.

4.2 Variants of Autonomous Upgraded Herbicide Sprayers:

Autonomous Upgraded Herbicide Sprayers is also proposed to be built of different variants. Diverse crops may require different soils and all kinds of soil has a varied weight carrying capacity. Each soil and its weight carrying capacity should be studied and analyzed using big data skills. After the analysis, customized variants of autonomous upgraded herbicide sprayer can be launched be fitting diverse soil types.

5 CONCLUSION:

To conclude with, futuristic technology will help to resolve the "chemical treadmill" that the farmers are trapped in. With an in-depth research and along with the help of machine learning technologies and data analysis, a systematic herbicide spraying model can be developed based on the weed type, crop type, soil type and climate condition.

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