Attacking Agriculture with Radiological Materials—A Possibility?

By SHANNON MICHAEL ALLAN and PETER LEITNER

Agriculture as an important strategic target is not new. Its influence ranges beyond feeding a nation to shaping a population's opinion about its government and providing a source of national pride, independence, and economic self-sufficiency.

In 1998, agriculture's influence in the political realm was demonstrated in the Indian elections when the Bharatiya Janata Party lost its majority in New Delhi, Madhya Pradesh, and Rajasthan due to skyrocketing prices of Northern India's staple diet, onions. "In defeat, the party learned that, although issues such as Ram temple and uniform civil code were issues of some value at a particular moment, basic issues linked to common people's lives would always dominate" and thus gained power in the 2003 elections by addressing the subject of agriculture.[1] The differing focus of the populace and its politicians regarding priority issues cost the party the 1998 elections. Voters misinterpreted the scant attention paid to basic needs such as food as a lack of interest in their welfare.

Agriculture is an important source of revenue to a nation, as well as to the individual in the form of employment. The agricultural sector constitutes 13 percent of the U.S. gross domestic product (GDP). In FY 2004, agriculture accounted for $61.5 billion in exports. Furthermore, 18 percent of domestic employment is directly or indirectly related to agriculture.[2] This translates to approximately 26.37 million jobs in 2003.[3] Thus, directing an attack on agriculture would hurt not only a nation's economy but also individuals in the form of lost jobs. This could create discord between the ruling government and its populace.

In countries where agricultural lands are scarce, they are often regarded as a national symbol of food independence. Japan, having limited amounts of arable land for production, is the world's largest net importer of agriculture and food products. The Japanese import nearly 50 percent of their food requirements annually, which amounts to $30 billion in imports. The term "food security" reflects concern over Japan's food dependency. Its self-sufficiency in growing rice, the staple of the Japanese diet, serves not only important material demands but also psychological and emotional needs.[4]

Furthermore, at the individual level, farmers identify with the land as a way of life and have proven to be protective of it. In 1962, the Japanese government proposed as an alternative to the crowded Tokyo International Airport a new international airport at a site in the village of Tomisato, but its residents refused to relinquish their lands. Thus, the site was moved 5 kilometers northeast to the village of Sanrizuka. However, the government met with the same problem despite its offers to relocate farmers to surrounding areas. Refusing to find another alternative, the government began expropriations in 1971, which resulted in 291 farmers being arrested and more than one thousand villagers and police being injured in fights. Despite these difficulties, the new facility, currently known as Narita International Airport, was eventually built. One last attempt to foil its scheduled opening took place when villagers broke into the control tower and destroyed much of its equipment, thus delaying the opening.[5] This event demonstrates the psychological link between agriculture and farmers, although in some other countries, the more pragmatic loss of income is more important than a mystical or spiritual link.

AGROTERRORISM IS NOT NEW

Throughout the history of war, combatants have conducted attacks on agriculture in an

Shannon Michael Allan is a staff officer of the Chemical and Biological Defense Group of the Singapore armed forces. Peter Leitner heads the Higgins Counter Terrorism Research Center at George Mason University.

attempt to weaken adversaries. In 146 BCE, after sacking the city of Carthage, Roman soldiers salted an area of fifty miles around the city as a means of eliminating agriculture production and causing starvation.[6]

In 1777, during the American Revolution, British troops destroyed agricultural lands in the Mohawk Valley of New York State with the intention of damaging its capacity to supply wheat to the Continental Army and the New England states. This destruction eventually led to farmers "being squeezed between friend and foe; the destruction of their capacity to produce by the British, and the seizure of the fruits of their labor by the government in Albany."[7] It proved to some extent successful in sowing discord among the farmers toward their colonial government.

In 1978, in a bid to sabotage Israel's economy, "oppressed Palestinian workers" injected Jaffa oranges bound for the Netherlands with mercury. At that time, Jaffa oranges accounted for one tenth of Israel's economy, with the United Kingdom alone importing seven hundred million fruits annually. A letter announcing the attack was sent to eighteen countries' health officials and the *Straits Times* newspaper, which published part of the letter on February 2, 1978.[8] The letter indicated clearly that the aim was not indiscriminately to kill people but to sabotage Israel's economy. As a result of the publicity, fruit sales plummeted throughout Europe.[9]

In yet another incident a decade later, the U.S. Embassy in Santiago, Chile, received a call warning of an act of protest against the Pinochet regime involving fruits laced with cyanide bound for the United States. The U.S. Food and Drug Administration (FDA) responded by embargoing two million crates of Chilean grapes for eleven days, in what the Chileans argue was an overreaction to questionable test data concerning two grapes containing low levels of cyanide. Consumers were warned of the incident and the risk of any fruits from Chile—which included peaches, blueberries, blackberries, melons, green apples, pears, and plums—resulting in tons of fruit being removed from supermarket shelves. The incident culminated in over twenty-thousand Chilean workers losing their jobs, an economic loss of $210 million, and the United States being sued for $330 million.[10] It also caused trade relations between Chile and the United States to sour to some extent.

These examples clearly demonstrate the potentially damaging effects of the psychological fear that results from an attack on agriculture. Its influence, evolving from earlier times, ranges from directly starving a population and undermining social stability to hurting a nation's economy and marring trade relations.

THE CURRENT SITUATION AND ITS POSSIBLE CONSEQUENCES

Agroterrorism has been analyzed and recognized as a potential threat by experts who have concluded that it has the potential for hurting an economy. However, despite the recognition that agriculture is a potential target for terrorists, it is "one area that has received very little attention . . . in terms of accurate assessments, response structure, and preparedness initiatives; the sector continues to exist as a glaring exception to the wide-ranging emphasis that has been given to critical infrastructure protection."[11]

This is not, however, the issue that this article intends to address. Compounding this preexisting vulnerability is the myopic confinement of the risk and threat to biological agents only. Numerous articles that discuss agroterrorism are usually confined to the realm of biological pathogens. This limitation could be detrimental to understanding another threat.

In a December 1999 report, the U.S. Advisory Panel to Assess Domestic Response Capabilities for Terrorism Involving Weapons of Mass Destruction discussed various threats and judged the idea of using radiological dispersal devices (RDDs) against food or water as unlikely and impractical.[12] The report argued that radioactive materials were insoluble in water and that large quantities would be required to achieve levels of contamination that would be effectively detrimental to the drinking supply. In addition to these factors, the large amount of required radioactive materials would pose safety risks to the terrorists themselves and also serious difficulties in logistics, such as storage, handling, transportation, and dissemination. The conclusion were that, if agriculture is to be targeted, the attack will involve biological agents, and that, if a radiological attack is conducted, it will be aimed directly at the human population and infrastructure in urban settings. As if to reinforce this myopic approach, the strategic plans of the U.S. Department of Agriculture (USDA) and the FDA, the core agencies for food security and protection, have been formulated on the near absolute belief that the threat is in the form of biological agents.[13,14]

Although focusing on threats and how to counter them is the most logical course of action, it could also result in tunnel vision that

may create or compound vulnerabilities to an unpredictable adversary that constantly tests all types and avenues of attack and that thinks in non-linear, adventurous ways.

"Terrorism's primary objective is to terrify, to fill or to overpower with intense fear, to intimidate to achieve an end."[15] It achieves this objective by the unpredictability of the attack in that it lacks warning, familiarity, and proportionality. The sense of uncertainty that results in the feeling of loss of control over events further leads to fear and anxiety. The lack of familiarity and proportionality—by terrorists using unconventional weapons to cause a large number of casualties and economic disruption in a single attack—fuels the psychological fear. The impact of such terrorism is further amplified when its target holds a symbolic status, spreading the feeling of vulnerability nationwide.

Although terrorists' strategic objectives may remain unchanged, they have proven themselves innovative, and unpredictable in achieving them. The September 11 attacks using hijacked commercial planes to crash into New York's Twin Towers and the Pentagon, which at one time was considered unlikely,[16] demonstrated the terrorists' non-linearity in their operations and their sinister ability to choose richly symbolic targets. This cost the United States an estimated three thousand lives; $163.34 billion in interrupted businesses, human productivity, property, and equipment; and an estimated $27.8 billion for repairs to infrastructure and clean-up operations.[17]

The lesson of this is not to discount any terrorist weapon. The use of RDDs in a terrorist attack has been explored but not in the context of agriculture, which might be its most likely target. It has been deemed a potential threat to only highly populated cities, which is a fair but potentially incorrect conclusion.

SOURCES FOR RADIOLOGICAL MATERIAL

There are more than ten thousand sources of radioactive materials that are designed for radiotherapy and over a million radiation sources used around the world for industrial, medical, and research purposes. However, not all radiological sources pose a security threat. In a study by the International Atomic Energy Agency (IAEA), radiological sources were categorized and ranked using numerous factors that collectively contribute to the overall level of risk in terms of security and human health and safety.[18] Subsequently, the Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC) Interagency Working Group on Radiological Dispersal Devices conducted a study to identify radioactive materials of greatest concern.[19] In this latter study, the methodology "combined insights about relative dose impacts and the relative attractiveness for access." Table 1 shows the radiological materials of greatest concern with their categorization and ranking according to the IAEA.

Despite studies and subsequent improvement in security controls, hundreds of pieces of radiological equipment in the United States continue to be lost, abandoned, or stolen on an annual basis. "In the period of January 1996 through October 2000, the NRC reported a total of 156 thefts of portable gauges."[20] Only 40 percent of the stolen gauges were reported recovered.[21] Since 1999, there have been 215 confirmed cases of illicit trafficking in radiological materials. In addition, the IAEA warns of a potentially higher number of cases of smuggling, "citing reports of a further 344 instances over the past eleven years which have not been confirmed by any of the seventy-five states that monitor illicit trafficking."[22]

Sophisticated terrorists often have a higher level of education than the average person and maintain façade occupations ranging from professional careers as lawyers, doctors, engineers, and university professors to blue-collar positions.[23] Thus, acquisition of this equipment could be facilitated by the nature of the job that they hold. They may be able to cultivate a familiarity with security personnel of a facility during their employment that may result in the lax enforcement of routine checks, thus easing the theft of radiological sources from the facility.

In 1995, David Hahn of Clinton Township, Michigan, demonstrated that scouring junkyards is another avenue in addition to theft in acquiring radiation sources. He managed to amass sufficient quantities from readily available household items, such as smoke detectors and radium clocks,[24] to build a makeshift radium gun and also a small breeder reactor, "which not only generated electricity but also created fissionable material."[25] More recently, investigations of Aum Shrinkyo reported that the group sought "sophisticated equipment from the U.S. such as an industrial laser system and a 'vibration isolation table,' both of which after modification could be used to measure plutonium."[26] Although the transactions were not completed because of suspicions harbored by the companies, the incidents demonstrated

TABLE 1. Radiological Materials of Concern

Material	Practice or application	Equipments (International Atomic Energy Commission Categorization)
Americium-241 (Am-241) 433-year half-life	Residential/commercial/medical	Conveyor gauges (Cat 2) Level gauges (Cat 2, 3) Well logging (Cat 3) Thickness gauges (Cat 4) Moisture/density detector—portable units (Cat 4) Bone densitometry (Cat 4) Static eliminators (Cat 4) Lightning preventors (Cat 4)
Cesium-137 (Cs-137) 30-year half-life	Industrial/medical	Blood irradiator (Cat 1) Industrial radiography (Cat 1) Food sterilization and preservation irradiators (Cat 1) Teletherapy (Cat 1) Brachytherapy—high/medium dose rate (Cat 2) Well logging (Cat 3) Level gauges (Cat 3) Conveyor gauges (Cat 3) Thickness gauges (Cat 4) Moisture/density detector—portable units (Cat 4) Density gauge (Cat 4)
Strontium-90 (Sr-90) 29-year half-life	Industrial/military/medical	Radioisotopic thermoelectric generators (Cat 1) Thickness gauge (Cat 4) Brachytherapy—low dose rate (Cat 5)
Cobalt-60 (Co-60) 5.3-year half-life	Medical/industrial	Teletherapy (Cat 1) Blood/tissue irradiators (Cat 1) Food sterilization and preservation irradiators (Cat 1) Multibeam teletherapy (Cat 1) Brachytherapy—high/medium dose rate (Cat 2) Industrial radiography (Cat 2) Blast furnace gauges (Cat 3) Level gauge (Cat 3) Dredger gauges (Cat 3)
Iridium-192 (Ir-192) 74-day half-life	Industrial/medical	Brachytherapy—high dose rate (Cat 2) Industrial radiography (Cat 2) Brachytherapy—low dose rate (Cat 4)
Californium-252 (Cf-252) 2.7-year half-life	Research/industrial	Well logging (Cat 1) Brachytherapy—low dose rate (Cat 4) Moisture/density gauge—portable units (Cat 4)

Source. "Radiological Dispersal Devices: An Initial Study to Identify Radioactive Materials of Greatest Concern and Approaches to Their Tracking, Tagging and Disposition," May 2003, Report to the Nuclear Regulatory Commission and the Secretary of Energy. The categorization system (Cat) is from the International Atomic Energy Agency, "Categorization of Radiation Sources," IAEA-TECDOC-1344, revision of IAEA-TECDOC-1191, July 2003, http://www.pub.iaea.org/MTCD/publications /PDF/te_1191_prn.pdf (accessed August 20, 2004).

the possibility of fraudulent purchasing of equipment from less vigilant countries. These incidents demonstrate the numerous possibilities or opportunities that are impossible to monitor constantly and that could be used by motivated and persistent terrorists to acquire radiological materials.

MERITS IN USING RADIOLOGICAL MATERIALS VERSUS BIOLOGICAL AGENTS

Facing tightened security in accessing biological agents and increased surveillance for an outbreak in the agriculture sector, terrorists may be

forced to look for an alternative. Similar to any military operation, the alternative would need to have genuine merit to be considered. Chemical agents, due to their limited durability and the large quantities required for effect, may be considered as the last choice in the WMD realm. Radiological materials, however, have a number of advantages from a terrorist's perspective.

First, tunnel vision with respect to the threat against agriculture would grant an advantage to terrorists. One of the essential components of success in any military operation is the element of surprise. If the terrorists were suspected of acquiring radioactive materials, surveillance for attacks would be concentrated around highly populated cities, since conventional wisdom would have us believe that the most effective use of an RDD would be in an urban setting as opposed to a rural setting. This unconscious bias could possibly give the opening the terrorists need to attack the agricultural sector with an unsuspected weapon.

Second, radiation, unlike biological agents, causes damage to any living tissue regardless of species. There are so far no reports of plant pathogens causing diseases in humans and only some animal pathogens being anthrozoonotic.[27] Depending on the type of biological agent used—plant or animal pathogen—the specificity in the pathogen's target host could provide response forces some added "safety," unlike radioactive materials. There would be a strong need for caution and protection during investigation and decontamination operations regardless of the type of radioactive material used. This could consume more time and manpower, adding to the level of frustration of the emergency response force, farmers, and the nation as a whole.

It may be argued that through the various methods of acquisition, terrorists may manage to acquire only small quantities of each radiological material. However, this would not set them back. Because individual radiological sources have similar irradiating effects, they could be pooled to obtain an amount sufficient to cover an area of significant size. Mixing radioactive materials could be no more than a physical task.

Third, radiological material cannot be neutralized or destroyed like a biological agent; it has to be stored and allowed to decay into safe inert materials. Thus, the area denied productive use results in agriculture land abandoned because of costly decontamination operations, fertility lost because of clean-up operations, or the allocation of land for storing collated contaminants that otherwise could be used for more productive purposes. In the Goiânia incident, three thousand 3000 m^3 of soil had to be removed after being contaminated with just 28 g of cesium-137 (Cs-137).[28] All such attack sites would need to be secured so that the soil would not be reused for another attack.

Fourth, the factors governing a radiological material's ability to cause harm are not as complicated as those pertaining to biological agents. Using a biological agent against agriculture would require a certain level of knowledge regarding transmissibility, virulence, infection factors, the minimal amount of bacteria or viral particles needed to initiate a disease in the target, and so forth. The success of an attack is mainly dependent on the survivability[29] of an agent outside a host and its LD_{50}.[30] If the dose is insufficient or a target is not affected within the short life span of the pathogen, the operation will be a failure. Therefore, even though the impact is devastating once the disease is successfully initiated, its success is largely based on probability and a small time window. Radioactive materials of concern, on the other hand, have half-lives spanning years and are not adversely affected by weather conditions.

The solubility of some radiological materials, such as Cs-137, with a solubility rating of 1.87kg/L, adds to their value. This gives terrorists an additional form of the contaminant to plan with rather than just the commonly accepted powdered form. Radioactive liquid contamination could result in the contaminant seeping into the soil and adhering to it more strongly than the powdered form. This would increase the need to remove the cornerstone of agriculture, which is the fertile soil, rather than the transient crops.

Finally, the psychological impact may be greater than that of a biological attack. Human diseases caused by biological agents have a great psychological impact because of the delayed symptoms brought about by the incubation periods of the pathogens. Comparing the effects of radiation along these lines, an RDD attack could prove to have a greater impact. A person would be allowed relief after weeks or months if no symptoms are manifested after exposure, depending on the biological agent. The effects of low-level radiation, however, are stochastic, manifesting themselves decades after exposure in the form of cancer, if the initial received doses are not immediately lethal. Furthermore, radiation is believed to have the

potential to cause hereditary effects in the offspring of exposed persons.[31] Although there is controversy over the effects of low-level radiation, this stigma still remains until disproved with strong scientific evidence that does not yet exist.[32] Almost twenty years after the Chernobyl accident, the stochastic effects of radiation are still not clear. Exacerbating this psychological impact is the nonexistent preventive treatment or therapy for the stochastic effects of radiation.

DISPERSION METHOD

There are many ways that radiological material could be dispersed; the methods include pneumatic, thermal, natural, and explosive means. The pneumatic method would include the dispersion of both powder and liquid forms—that is, the dissolved form of contamination. For discussion purposes in this article, pneumatic, thermal, and natural means are termed the "nondestructive method" since, during dispersion, there is no infrastructure damage, and there are no explosives involved.

The main advantage of using nondestructive methods is that operations would go undetected. From this advantage emanate a number of benefits to the terrorist operation such as "covert field testing," repeatability of operations, fewer logistical requirements, possible deception about operations, additional spread of contaminants by ignorant victims, and a higher psychological impact due to the "unknown" effects. These advantages hinge on not being detected, which is related to the first merit of using RDDs—the tunnel vision of its victims and the associated element of surprise.

One of the contributing factors in a successful military operation involves the rehearsals that weed out hidden problems. If terrorists had the luxury of not being harassed because of a focus uniquely on cities, they could conduct real-time rehearsals in agricultural areas while concurrently testing the efficacy of the logistics and dispersion. With each rehearsal and testing, whether failed or successful, actual radioactive material could be used, as it would just add to not yet detected or detectable contamination levels. Furthermore, the rehearsal would be a test of the probability of success.

Another advantage, the ability to repeat operations in agricultural areas, would allow them to be conducted again and again until a contamination level considered sufficient to pose a threat of detection is reached. Furthermore, a single dispersion at one release point at a particular site may not be effective; thus, an operations team could move to several points to achieve maximum results, or at least attain levels of contamination that could be considered a success.

This approach would also help terrorists evade one problem. If employed, dispersal devices with explosives would create an added logistical burden. Explosive materials would have to be acquired or made. The inherent one-time use of explosives, unlike other aerosol dispensing machines, would not allow a failed operation to be repeated easily. In addition, an explosion would attract much more attention than the inconspicuous humming of dispensing or spraying machines from the back of a truck driving by or "stalled" at the side of the road.

An added advantage is deception. Terrorists may try to heighten the psychological impact by deceptive means. Projecting a larger-than-actual attack would cause confusion and sow discord and frustration between the population and its government, especially the responding emergency agencies. A number of small simultaneous attacks at different sites could be conducted, and then a deceitful declaration that a large attack was executed could result in the assumption that a large area was under attack and contaminated.

The terrorists could inform the media that a large single attack with a single point of release was executed and give the areas that are affected (the actual numerous smaller sites of attack). Thus, when the verification operations are conducted at these sites, radiation would be detected, resulting in the confirmation of the terrorists' claim. Further investigations and verification of the extent of contamination encompassing areas not in reality under attack would be inconclusive, causing confusion, apprehension, and doubts about detection capability and operations. Using explosives would compromise this plan.

A further advantage of using the nondestructive method is additional spread of contaminants by ignorant victims, as demonstrated in the Goiânia incident. The spread of the Cs-137 came mainly from physical contact by unsuspecting victims. This incident involved a carelessly discarded radiotherapy machine in which 28 g of Cs-137 was found by an unsuspecting victim and distributed to others. It resulted in 244 contaminated persons, 54 seriously sick enough to be hospitalized. This incident was not initiated with a dispersal device but with mere human contact. The damage would have

been greater if contaminants were dispersed intentionally by an aerosol dispensing machine.

A terrifying scenario would be one where a radioactive source similar to that in the Goiânia incident was dispersed in liquid form in an urban setting but through a nondestructive method, rather than the commonly expected powdered form dispersed by explosives. Using an inconspicuous street flusher with a minimum tank capacity of 3,000 gallons, one lane of a 4.25-mile stretch of road could easily be contaminated with radiation that exceeds the Environmental Protection Agency (EPA) and NRC public safety standards.[33] If conducted in Washington, DC, the contamination could be spread from the beginning of Constitution Avenue at Twenty-second Street with a loop around important government buildings, including the White House (another target rich with symbolic significance) and onto I–66 at E Street. The contamination would be further exacerbated by being spread over other streets by vehicles as well as pedestrians traveling along Constitution Avenue to their destination. The lateral spread would consist of office buildings, sidewalks, roads, humans, and possibly the interiors of public transport vehicles. Efforts to verify the contamination and its extent would cause major disruption and panic if publicly announced.

One of the contributing factors to human fear is "not knowing," and this is heightened in an RDD attack using nondestructive methods. In the sarin attack on the Tokyo subway, "a predominant psychological response in Tokyo was a phenomenon known as the 'worried well'—uncontaminated and unexposed individuals who fear, despite evidence to the contrary, that they have been contaminated."[34] In such situations, anxiety would be heightened if the attack was not discovered by authorities but announced by the terrorists themselves. Nondestructive methods would give terrorists the benefit of providing limited information regarding the time of attack and the specific point of release. This would raise many questions in individuals' minds, increasing fear and anxiety among the population about possible direct or indirect contact with the contamination.

TARGET ACQUISITION

Similar to military strategists, terrorists would have to decide the time of execution and target. An attack could be against either farms or food processing and storage facilities. With the current agriculture process, there are numerous opportunities along the food chain for a terrorist to introduce a contamination.[35] (See figure 1 for a depiction of the vulnerabilities of the food process.)

Most farmlands, especially crop farmlands, are not enclosed like a storage or processing facility. Therefore, even though farmers have realized that their land is a lucrative target to terrorists and have tightened security around their farms, attacks could be conducted outside their perimeters and beyond their control.[36] Until the day that crop growing becomes totally enclosed, relying on artificial conditions such as fluorescent light and hydroponics, total security will be impossible.

Other considerations for terrorists would be the time of the execution and the targets. Attacking farms during harvest or prior to distribution has the advantage of spreading contamination during transportation to facilities for sale, processing, and distribution. However, attacking farms immediately after seed planting has more impact, as it would allow contamination to settle directly on the fertile soil without any foliage or canopy hindrance. This would damage the cornerstone of agriculture, the soil, rather than the transient crops. As already noted, if the dissolved form of radioactive material were used, its effects would be more devastating due to liquid's adherent nature. Hypothetically, if just one source that was similar to the Cs-137 used in the Goiânia incident were acquired and dissolved in the appropriate amount of solvent, an estimated area of 8 km^2 could be contaminated with a total effective radiation dose of approximately 100 mSv,[37] exceeding the public safety standards of both the EPA and the NRC.

On the other hand, targeting a storage and processing facility would mean a higher chance of contaminated food being distributed nationwide and internationally, since the immediate destination after the growing process includes exporters and wholesalers. This could prove difficult, however, since these facilities are enclosed infrastructures with tighter security than on farms.

The Federation of American Scientists (FAS) conducted a study using computer simulations to find out the effects of an attack using relatively small radioactive sources: the amounts of (1) cobalt generally found in a single rod in a food irradiation facility, (2) americium usually found in oil-well logging systems, and (3) cesium recently found abandoned in North Carolina (a pea-size amount found in medical gauges). The study reported that dispersing the

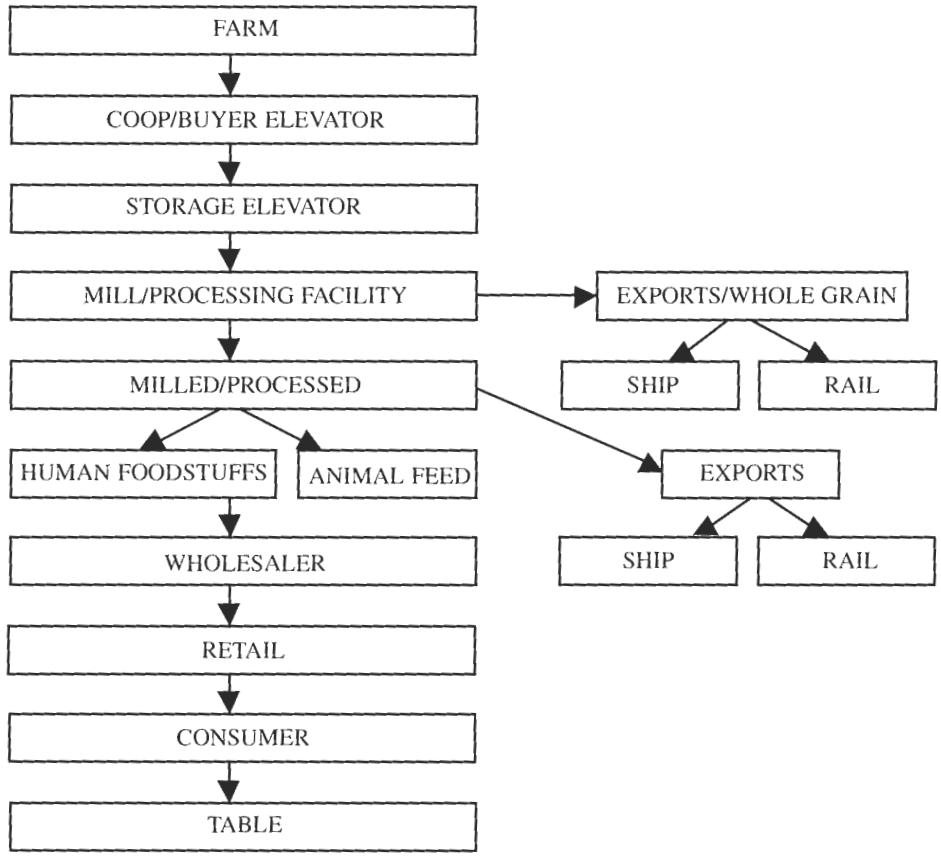

FIGURE 1. Food supply chain for crops.
Source. O. S. Cupp, D. E. Walker II, and J. Hillison 2004. "Agroterrorism in the U.S.: Key Security Challenge for the 21st Century," *Biosecurity and Bioterrorism: Biodefense Strategy, Practice, and Science* 2 (2): 97–105.

Cs-137 with ten pounds of TNT on a calm day with wind speeds of one mile per hour would result in contamination that would not require immediate evacuation. "However, residents of an area of about five city blocks . . . would have a 1-in-1,000 chance of getting cancer. . . . A swath about one mile long covering an area of 40 city blocks would exceed EPA contamination limits."[38] This translates to a swath approximately 2 km in length. In the Co-60 and Am-241 dispersion studies, the contaminated area that would exceed EPA contamination limits was approximated to cover 1,000 km^2 and 6 km^2 respectively. In the case of Cs-137 and Am-241, it would be sufficient to blanket a small farm.

However, imagine a scenario using the statistics of gauges stolen from January 1996 through October 2000 that have not been recovered. Hypothetically, if just half of the 60 percent of the reported stolen gauges that were not recovered were those that contained Cs-137 and were to have found their way to terrorists' hands, i would mean 94 possible separate sites of attack This would total a contamination area o approximately 3,790 city blocks' worth of land

Furthermore, the FAS study highlighted th long-term effects of cancer caused by internaliz ing the radioactive particles. If such an attac were conducted against agriculture, the mer thought of inhaling radioactive particles durir handling or consuming the contaminated food- let alone actually consuming or inhaling the co taminants—could have great adverse impact.

From a military standpoint, targeting farr in general may not produce the desired dama to the U.S. economy or the nation's psychol ical state. A target such as a specific crop, li stock, or poultry would concentrate individ and geographically distributed attacks with greater collective impact. Using an attack corn, for example, the terrorists could sign

cantly harm the economic contribution of the agricultural sector as a whole or the economy of individual states. In 2002, Iowa and Nebraska were among the top five state contributors to the U.S. agricultural sector, with corn constituting 55 percent and 57 percent of their total cash crop receipt respectively, representing $3,120 million and $3,402 million.[39] A synergized attack on corn in these two states could cut these states' income, associated jobs, and any future potential economic income approximately in half.[40] Furthermore, zeroing in on such states would demonstrate that targets are not limited to high-profile cities, such as Washington, DC, or New York, and that leadership symbols are not confined to the political realm, thus increasing the sense of vulnerability and anxiety among citizens.

IMPACTS OF USING RDDs AGAINST AGRICULTURE

The impacts from an RDD attack hinge largely on the psychological effects that it will precipitate. Domestically, the effects could mainly take the form of financial loss from which a cascade of events could follow. In addition, the populace would feel a heightened sense of vulnerability that in turn could have the potential to create new breeding grounds for terrorist recruitment.

Domestic financial loss would result from the decrease in or total abstinence from purchasing the feared contaminated food. With the fear that radiation inspires concerning long-term ill effects, consumers would mostly likely take the "better-safe-than-sorry" approach and totally abstain from the attacked products from all states rather than just the states reported to be attacked. This public fear of consuming contaminated food products represents an advantage to the terrorists who might use the nondestructive dispersion method.

Additional financial losses would come in the form of decontamination costs and loss of productive land. In the Goiânia incident, decontamination costs amounted to approximately $20 million with 3,000 m^3 of contaminated topsoil removed.[41] Moreover, this was not dispersed intentionally with a device but merely by ignorant victims and weather conditions.

In addition to financial losses, the United States could be forced by consumers' fears to import previously self-produced foodstuffs to meet demand, thus leading to the loss of its food security and self-reliance, giving rise to a sense of vulnerability and weakened independence. As a result of the decreased, if not totally halted, sales of a specific product, employment related to the agricultural sector would be affected. The Chilean grape incident in 1988 demonstrated such loss of employment resulting from an attack on agriculture.

On September 11, 2001, terrorists demonstrated that they were able to successfully strike the United States despite its technological and military superiority. This demonstration aided in recruiting terrorists who believed that the success came from supreme intervention and guidance, thus removing inhibitions present in some with aspirations to become terrorists. However, potential terrorists could also be created by popular hatred of "bystanders" being wrongly targeted in hate crimes. If another successful attack were to take place, especially one that was dismissed as unlikely, the feeling of vulnerability and hatred toward the terrorists would be heightened. This feeling, exacerbated by the loss of employment, could lead to doubts about the government's credibility, causing individuals or groups to take the law into their own hands by targeting races or religions believed to be related to the terrorists involved in the attack.[42] Eventually, a vicious cycle could form with both sides feeling victimized, resulting in a new sustained recruitment ground for terrorists, one that derives from hatred and a need to lash back.

American foreign aid programs could also be affected. The United States exports approximately 4.6 million metric tons of crop commodities under the food aid programs[43] to increase global food security and in turn increase global stability. If the safety of U.S. crops were questionable, donations could be halted. The United States could not only fail in its strategic objective of sustaining global security but also lose its currently strong global influence that is linked in part to its humanitarian aid. The terrorists could use the defeat of a strategic U.S. objective as propaganda, demonstrating their ability to thwart the plans of an adversary despite its greater strength in technology and military power.

Besides internal conflict, trade with other countries could be damaged and made more difficult. Trade with other countries is complex, plagued with numerous tariff, non-tariff, and technical barriers. An illustration of this is the European industrial policy, which consists of two different levels: the national industrial policies and the common European Union (EU) industrial policy, with frequent contradictions

between the two levels. The EU industrial policy's objective is to implement the single market program, which aims to dismantle a very large range of non-tariff barriers. However, nations have the power, for example, to manipulate local prices, control local monopolies, set norms for industrial activities, and establish environmental controls, among other powers" that are frequently used.[44] National policies, therefore, give rise to suspicion, at times, that these barriers are for protecting local producers rather than consumers.[45]

Despite this suspicion, consumer opinions are sometimes the real reason for formulating these regulations. A survey conducted in 1997 on genetically modified organisms (GMOs) showed that only 22 percent of Austrian consumers were willing to purchase genetically modified products as opposed to 74 percent in the United States.[46] In addition, a poll showed that only 14 percent of consumers in Britain were agreeable to the introduction of genetically modified foodstuffs with 96 percent wanting food made of genetically modified seeds to be labeled. Thus, the strict regulations such as labeling and traceability of all food and animal feed containing 0.5 percent GM ingredients respond to the opinion of consumers.[47] This would increase significantly if there were a radiological attack.

This power of countries' individual intervention in national industrial policies, coupled with evidence of strong influence by consumers, would be difficult to surmount if trade barriers were created to keep U.S. imports out after an attack on agriculture. Even science may prove to be ineffective in removing these barriers because of the mistrust that it sometimes generates. Consumers in some countries remain opposed to irradiating foodstuff even though the IAEA and the World Health Organization (WHO) have concluded that irradiated food has no health risks in terms of toxicity.[48] Thus, even if scientific research was used to dispel any apprehension about the effects of residual, if any, low-level radiation in imported foodstuffs, consumers may still adopt the "better-safe-than-sorry" attitude.

Therefore, for countries that already erect non-tariff barriers to protect local producers, the possibility of radiologically contaminated imports would give them a reason to add more barriers to the existing ones pertaining to plant and animal diseases and pests and to block U.S. imports. For countries not opposed to U.S. products, U.S. imports could decrease due to genuine fears of contaminated food. In both instances, United States trade would be adversely affected.

The sanitary and phytosanitary regulations could very well be the main justification for barriers erected against possible radiological contaminated foodstuffs.[49] Despite the existence of international standards for food, including the Codex Alimentarius[50] and similar safety standards of the EU and the Nuclear Regulatory Commission, individual countries within the EU could still implement their own acceptable risk limits to prevent imports from the U.S.[51] Their argument could rest on the lack of scientific evidence for the stochastic effects of consuming low-level radiation sources and on legitimate consumer fears. The extrapolation of better verified high-level radiation effects to explain the effects of less well-verified levels is currently a controversial issue among scientists. This issue has already been demonstrated in the political realm between the EPA and the NRC, with the EPA arguing that the NRC standards are not sufficiently stringent.[52] If internal standards cannot be agreed on, overcoming international trade barriers will prove to be even more difficult.

ATTACKING U.S. ALLIES TO HURT U.S. STRATEGIC PLANS

Besides striking U.S. agriculture directly, terrorists could decide to persuade its allies into isolating the United States, thus undermining its strong global influence. This strategy was discussed with regard to the war on Iraq in a forty-two page Arabic document retrieved by a Norwegian think tank, Forsvarets Forskningsinstitutt, from an Islamist Web site.[53] Presently, the U.S.-Egyptian relationship can be seen as sensitive. In exchange for U.S. financial aid, Egypt cooperates in observing the terms of the 1979 Camp David Accords, the Middle East peace process, and the war on terrorism by weakening terrorist financial networks and sharing intelligence. U.S. policymakers and members of Congress, however, have expressed concerns over the frequent anti-American, anti-Israel, and anti-Semitic writing in Egypt's government-controlled press.[54] A conventional terrorist bombing in Egypt would not bring about a dramatic change the way that it did in Spain, as it would not be seen as an extraordinary incident. However, a terrorist attack, especially with radiological material,[55] on its most symbolic and precious agricultural lands, might prove to be more persuasive.

Egypt's arable and permanent cropland represents only 3.3 percent of its total land and is geographically concentrated in the Nile Valley and Nile Delta. Its agriculture accounts for 20 percent of national GDP and 34 percent of workforce labor, with 60 percent of its industry depending on it. An attack utilizing RDDs on its agricultural land would be an easy task compared with targeting the widely distributed agricultural lands of the United States. Compared with the United States, a radiological attack with its potential to affect important agricultural areas could damage Egypt's agricultural industry far more severely.

Egypt does not enjoy the food security the United States does. Its net cereal imports and food aid amount to 66 percent of its share of total consumption.[56] Thus the psychological impact on the populace of an attack on arable land would be severe, with repercussions on the government's credibility. This could result in internal political strife with arguments that relations with the United States caused the suffering, thus resulting in a possible change of government to one that is less friendly to the United States. Another possible outcome is that the current Egyptian regime remains but imposes increased demands on the United States in exchange for continued cooperation. The demands may be in terms of increased financial aid, larger quantities of food aid, strategic demands, and so forth. This would cause more friction and strain on the United States–Egypt relationship, not to mention strain on the U.S. purse strings.

CONCLUSION

At first glance, the use of RDDs on agriculture could be easily dismissed as impractical, involving too much of an effort with too low returns for terrorists. Analysis of the technical aspects of radiation, however, indicates there is some merit in terrorists considering its use in agroterrorism. First, its general impact on living organisms allows it to be dispersed without having to target particular species. This nonspecificity complicates safety and decontamination operations. The ability of radiation to pose a threat to living organisms over a long period due to its radioactive half-life and the continuing problem of neutralizing radiological materials translates into difficulties in decontamination and storage of contaminants. This would result in loss of farm acreage by abandonment of land, removing fertile topsoil, or allocating land for storage of consolidated contaminants that could otherwise be used for productive purposes.

The majority of the effects would result from the cascade of events initiated by fear and anxiety. The uncertainty of the long-term effects of radiation on the initial victims and their offspring and the difficulty in detecting dispersion due to absence of special detection equipment on farms could have at least as great a psychological impact as a biological attack on agriculture. The possible evasion of detection is exacerbated by an overblown focus on biological agents as the only possible threat to agriculture. If an RDD attack on agriculture were dismissed as impractical and improbable but executed successfully, a government's credibility could be terribly damaged, resulting in a greater sense of vulnerability from a failure to prevent an attack that was deemed possible. A government could be severely criticized for not exploring all possibilities and formulating an all-encompassing security network. Furthermore, the feeling of vulnerability, anxiety over health risks, and anger toward the attackers could result in violence against innocent "bystanders" of a community to which the attackers belong. This, in turn, could lead to a breeding ground for developing additional terrorists.

An RDD attack, similar to a biological attack, could lead to both domestic and international trade damage in the form of reduced trade and trade relations, job losses, decontamination operations, and possibly reduced human productivity. International trade could be hindered by trade barriers created either by countries with real consumer concerns or by countries that originally had intentions of preventing U.S. imports into their country, who would, then, use consumer safety as an excuse. Finally, arguments against these barriers could prove to be futile because of disagreements regarding radiation safety levels as well as the mistrust of the exactness of the science involved.

Furthermore, terrorists may not restrict attacks to the United States itself. U.S. strategic plans and policies may be hurt or strained by terrorists' targeting the agriculture of its more vulnerable and important allies. Attacks on agriculture in countries in which agricultural land is scarce could prove to be quite potent. This could lead allies to fear that the benefits of their relationship with the United States do not outweigh the damages that they may incur, thus weakening relations.

Although biological agents are indisputably the best choice for an attack on agriculture in the WMD realm, heightened security and surveillance may be a deterrent to terrorists with intentions of using it. This, however, may not push terrorists to abandon the idea of targeting the agricultural sector but merely force them to find an alternative means to attack it. This alternative means may indeed take the form of radiological dispersal devices.

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37. To obtain a 100 mSv/yr accumulation, an external exposure of approximately 10 R/hr would need to be created. This would require approximately a source with 4.0576 x 10^{-3} curies and this translates to an estimated 5.627 x 10^{-5} g of Cs-137. If a source of Cs-137 similar to the Goiânia incident was obtained, the source could be dissolved in 337,640 liters of water to attain a concentration of 5.627 x 10^{-5} g /L. Assuming 1 liter could cover an area of 25 square miles, a commercially available 1,250-gallon agricultural cannon sprayer could cover 142,062.5 square miles with the desired external exposure. Since the Goiânia incident had 19 g of 1,370 ci and is the basis of this hypothetical scenario, 19 g could be dissolved in 337,640 liters (74,280 gallons) and which would involve approximately 59 sprayers with full tanks; thus, a total area of approximately 8 km^2 could be contaminated.

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50. The Codex Alimentarius is a set of statutes and regulations that was created by the Food and Agriculture Organization and the World Health Organization. It promotes consumer protection and facilitates world trade in foods through the development of food standards through codes of practice and other guidelines. There are currently 160 member countries. See the Codex Alimentarius Commission brochure, http://www.fsis.usda.gov/oa/codex/codex.pdf (accessed August 21, 2004).

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53. The document discussed striking individual coalition forces in the American-led war, thus isolating the United States to bear casualties and expenses on its own, eventually wearing them down. Three countries that were the European backbone of the coalition—Britain, Poland, and Spain—were discussed. Among them, Spain was considered the best choice due to its government's plunging into Iraq without its population's consensus. Poland was the most resolute, with its populace largely supporting the war. The British, although there was a large strike before the war in February, would not withdraw unless there was a very sharp increase in casualties. The bombings in Madrid before the elections proved successful as the government changed to a Socialist Party that was not in favor of the war and thus promised to withdraw troops from Iraq. See Lawrence Wright, "The Terror Web," *New Yorker,* August 2, 2004, http://www.newyorker.com/fact/content/?040802fa_fact (accessed August 27, 2004).

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