

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Rain-Madems: Development of Rainfall Induced Mass Wasting Advance Early Warning and Monitoring System

Canlas, Charity Jaine J.¹, Flores, Aila Louisse B.², Orito, Chris Axel R.³, Christian Paul Escarian⁴, Engr. Erwin D. Rubio⁵

^{1,2,3} Student, ⁴Consultant, ⁵Research Adviser Department Davao City National High School, F. Torres St, Davao City, Grade 12 – Dalton

ABSTRACT

The study presented a quantitative study focused on developing an early advance warning system that mitigates risks in areas prone to rainfall induced mass wasting, utilizing vibration, moisture, and accelerometer sensors into a mobile robotic platform. Seeking to provide real-time data and predictive analysis to local authorities and communities. The system will use machine learning algorithms to enhance prediction accuracy, ensuring timely alerts and reducing potential damage. Employing an experimental research design, RAIN-MADEMS is compared with the standard equipment used by PHIVOLCS DYNASLOPE project that installs sensors under the ground to detect movement of the soil and alert communities of impending deep-seated landslides. This study contributes valuable insights into the development and assessment of RAIN-MADEMS, offering potential solutions to mitigate the impacts of heavy rainfall induced landslides on lives, infrastructure, and the environment.

Keywords: Landslide early alert system, rainfall analysis, disaster management, mass wasting, moisture sensor, accelerometer, WiFi module, Node MCU, Arduino UNO

1. INTRODUCTION

Mass wasting or landslides are a pressing concern due to their severe impact on lives and infrastructure, especially in regions prone to heavy rainfall or steep terrain. Recent events indicate an alarming rate of 50% more intense rainfall where the Philippine island faces worse landslides. Newest occurrence reported by PHILSTAR Global sait it happened at around 7:50 pm on February 6, 2024. With an estimated 9.8 hectares (24 acres) of land was buried by rocks, mud and trees that slid over 700 meters (2,300 ft) down a steep mountainside near the Apex Mining Co. concession in Zone 1 of Barangay Masara, Davao De Oro, Philippines. With at least 98 people reported dead and 9 missing persons The Chief Science Research Specialist at the University of the Philippines and a member of the WWA team, Richard Ybañez said "It's well known that Mindanao island is highly vulnerable to landslides due to high rainfall, frequent earthquakes and steep, hilly terrain along its eastern half".

Generally according to the published website of the National Park Service in September 2019, mass wasting is the movement of rock and soil down slope under the influence of gravity. Rock falls, slumps, and debris flows are all examples of mass wasting. Often lubricated by rainfall or agitated by seismic activity, these events may occur very rapidly and move as a flow. The Philippines is located near the equator that is why it is considered as a tropical country where it only experiences intense wet and dry seasons (Sunny Lin., 2021).

In recent years, advancements in sensor technology, robotics, and data analytics have opened new possibilities for early detection and warning systems (Luo et al., 2024). By integrating multiple types of sensors—such as seismic sensors to detect ground vibrations, moisture sensors to monitor soil water content, inclinometers to track ground tilt, and geophones to measure ground movement—into a unified system, we can obtain comprehensive data on environmental conditions that precede mudslides and landslides (Huang et al., 2022).

The RAIN-MADEMS project leverages these technological advancements to create a robust, real-time monitoring and warning system. This project aims to develop mobile robotic platforms equipped with various sensors, capable of continuous environmental monitoring and data transmission. By employing machine learning algorithms, the system will analyze collected data to identify patterns and predict potential landslide events, providing early warnings to local authorities and communities.

Gunawan et al. (2019) in their work "Design of Early Warning System Flood and Landslide Mitigation Sensor Based on Internet of Things" discuss how these systems can provide early warnings for floods and landslides by detecting environmental changes through sensors installed in disaster-prone areas. The system they describe integrates hardware, such as microchip controllers, with software applications leveraging the Internet of Things (IoT). This integration allows for real-time monitoring and data processing, essential for predicting potential disasters.

Seismic sensors, such as accelerometers and seismometers, are critical for detecting ground vibrations and seismic activity. According to Tian et al. (2023) in "Detecting the Unseen: Understanding the Mechanisms and Working Principles of Earthquake Sensors," these sensors are essential in monitoring earthquake-induced landslides. By detecting early ground movements, seismic sensors provide valuable data for predicting landslides and triggering early warnings. These sensors can be strategically placed in regions prone to seismic activity to continuously monitor the earth's movements, ensuring timely and accurate detection of any potential threats. This real-time monitoring is crucial for initiating preemptive measures to mitigate disaster impacts.

Soil moisture sensors, both capacitive and resistive, measure the volumetric water content in soil. Studies by Yu et al. (2021) in "Review of Research Progress on Soil Moisture Sensor Technology" highlight the importance of soil moisture in slope stability and the occurrence of landslides. High moisture content in soil can reduce its shear strength, making slopes more susceptible to failure. These sensors help in understanding water saturation levels that can lead to soil failure, providing critical data for assessing landslide risk. By continuously monitoring soil moisture levels, these sensors aid in predicting and preventing landslides, especially in regions with heavy rainfall or irrigation practices.

Artha and Julian (2018) with their research entitled "Landslide early warning system prototype with GIS analysis indicated by soil movement and rainfall" developed a landslide early warning system prototype incorporating accelerometers for ground movement detection and a water flow sensor for rainfall measurement. Their system uses a microcontroller to process these signals, triggering alarms and sending data to a monitoring center. An LCD displays acceleration data, and a telemetry system transmits information for remote monitoring, utilizing GIS spatial data for visualization. This approach aligns with Gunawan et al. (2019), who emphasize the importance of integrating sensor technology with IoT for real-time monitoring and early disaster prediction.

The system developed by Artha and Julian was tested in Kampung Gerendong, an area with a cumulative vulnerability score indicating a high risk of landslides. The results confirmed the system's effectiveness, demonstrating its ability to detect soil movement and rainfall exceeding 100 mm/day, and provide timely warnings. This practical application underscores the importance of sensor-based systems in landslide prediction and aligns with previous research on the effectiveness of sensor networks in landslide-prone areas (Yin et al., 2010).

This proactive approach is essential for improving disaster preparedness and response. With timely and accurate warnings, communities can evacuate areas at risk, and emergency services can take preventive measures, significantly reducing the loss of life and property. The integration of this system with local disaster response units ensures that the warnings are effectively communicated and acted upon.

OBJECTIVES

The study generally aims to develop an early warning system for the provinces of Mindanao islands that are highly susceptible for rainfall induced mass wasting or landslides.

Specifically, this study aims to:

- 1. Develop a landslide early warning device equipped with a capacitive soil moisture sensor, and find out the maximum water the soil can carry before collapsing.
- 2. Establish a landslide early warning device integrated with an accelerometer to measure the slope's average and maximum tilt before soil tumbles down.
- Design an application that integrates and utilizes real-time monitoring and an early alert system to reduce the possibility of rainfall-induced mass wasting.
- 4. Evaluate the accuracy of the gathered data on landslide occurrences to improve predictive models and enhance future warning systems.

2. METHODOLOGY



Figure 1. Flow chart of methods to do

The prototype integrated a quick landslide alert system with various employed innovative approaches to calculate predictive downslope motion of masses of land. Based on (Andrew Lees, 2021), landslides are commonly initiated by several factors, namely, slopes already on the verge of movement by rainfall, changes in water level, stream erosion, changes in groundwater, Earth vibrations such as earthquakes, volcanic activity, disturbance by human activities (mining or traffic), or any combination of these factors. The National Economic and Development Authority (NEDA) stated that Davao De Oro terrain of the provinces consists of flat, rolling, hilly, and mountainous portions, which are evenly distributed throughout the area. The highest elevation in the province reaches a height of more than 2,000 meters above sea level (MASL), and this is found in the municipalities of Maragusan, New Bataan, and Pantukan which has an aggregate area of 80.89 square kilometers or 1.73 percent of the total land area of the province. The lowest elevation is below 100 MASL with Laak having the widest area of 2.1537 sq. km., while New Bataan has the narrowest of 19.10 sq. km. Its mountain ranges and woods provide protection from typhoons. However, when heavy rains continue, some areas of the municipalities of Mawab, Monkayo, Montevista, and Nabunturan flood. The rainy season is most likely to occur between May and January of the following year, with the highest rainfall occurring from October to December. The dry season will most likely begin in February and last until April.



Figure 2. Davao Region susceptibility to Rain-Induced Landslides Map Photo Source: Hazard Hunter PH



Figure 3. Davao De Oro Provinces susceptibility to Rain-Induced Landslides Map Photo Source: Hazard Hunter PH

A study and implementation of IoT from India (Gupta,2024) used the flowing sensors to create an early warning system to mitigate the occurrence of landslides: Soil moisture sensor: It measures the moisture content of soil. Rain gauges: It measures the amount of rainfall an area receives in a particular time. Pore pressure sensor: It is a type of piezometer. It measures pressure of groundwater held within a Soil / Rock. Vibration sensor: It is a type of accelerometer that senses vibrations. It measures the Earth shaking effect. Additionally, an overview study of rainfall-triggered landslide early warning systems (LEWS) from (SHEAR Knowledge Brokers Team, 2021) stated that LOCAL LEWS can only provide warning information for the specific instrumented locations and only alerts when a specific threshold is at its limit.

According to a published article of (Current-Research-Ohlmacher-Page 7 of 9, n.d.) The average slope angle for landslides is 22.2 degrees with 75% of the landslides on slopes greater than 15 degrees. Furthermore, If the friction on a rock is greater than gravity for a certain slope, the rock material will most likely remain. However, if gravity is stronger, the slope will fail. The steeper the slope, the greater the friction or rock strength required to resist downward motion. The steepest angle a slope can be before the ground will slide is about 35 degrees, called the angle of repose. Moreover, Soil properties play a critical role in forming landslides, as cohesive soils such as clay and silt are more susceptible to landslides than granular soils such as sand and gravel (Batumalai et al., 2023). To add, vegetation helps bind material together; removing vegetation increases the chance of a landslide (British Geological Survey, 2021). According to J. Dou et al. (2015), shallow landslides are landslides having depth between 1.5 m and 10 m from the existing ground surface. Likewise, landslides originating from depths greater than 10 m are generally considered as deep landslides.

The researcher decided to use the accumulated published literature as a guide to create the RAIN-MADEMS prototype, including some of the ones discussed in this section. Using the different thresholds to categorize the susceptibility of an area to rain-induced mass wasting. Lastly, the data to be recorded will be sent through the app to be monitored and alert when certain thresholds are at its limit.

A plastic pipe, three feet long, was used as a body and protective suit for the sensors buried at least 3 feet below as a set up for data collection apparatus ensuring the safety of the wires and other components. Additionally, gathering the minimum and maximum numerical data for soil moisture sensor is required to keep track of the average moisture sensitivity of the sensor towards dry and wet soil while being buried together with the vibration sensor. Along with that, an accelerometer is strategically positioned inside the 3D printed canister to measure the tilting and the slope of the soil. After that, the researcher then merges all three data of each sensor onto the microcontroller which will then relay output of real-time monitoring of each sensor giving insights of different patterns.



Figure 4. A conceptual diagram of how the gathered data flows in RAIN-MADEM

2.1 Preparation of Materials

A 3D model was made to create a canister solely for the non-waterproof components such as the micro controllers and battery supply making readings easier even in the presence of moisture. The researcher had installed waterproof sensors to detect the moisture level of the soil and ground vibration activity to record data during rainy seasons. In order to record data from the sensors without requiring physical contact, a WiFi module (Node MCU) was installed, increasing data collecting flexibility.

COSTING:

ITEMS	QUANTITY	PRICE	TOTAL
wires	15 m	Php 2.50	Php 37.50
PVC pipe #2	1 pc	Php 88.00	Php 88.00
Wheels	1 set	Php 308.50	Php 308.50
Spray Paint	1 pc	Php 115.00	Php 115.00
Capacitive Soil Moisture	1 pc	Php 69.00	Php 69.00
8" Jumper wire	1 set	Php 17.00	Php 17.00
12" Jumper wire	1 set	Php 18.00	Php 18.00
Electrical Tape	1 pc	Php 20.00	Php 20.00
Rechargeable LI-ON Battery 3.7V	3 pc	Php 95.00	Php 285.00
DC cord	1 pc	Php 20.00	Php 20.00
Vibration Sensor	1 pc	Php 135.00	Php 135.00
BMS Module	1 pc	Php 180.00	Php 180.00
Arduino UNO w/ cable	1 pc	Php 459.00	Php 459.00
Accelerometer	1 pc	Php 385.00	Php 385.00
Solar Panel 12V	1 pc	Php 580.00	Php 580.00
3D printed box	1 pc	Php 2,800.00	Php 2,800.00
USB cord	1 pc	Php 65.00	Php 65.00
Micro USB cord	1 pc	Php 99.00	Php 99.00
Plywood	1 pc	Php 390.00	Php 390.00

Plastic Cover	1 pc	Php 165.00	Php 165.00
		GRAND TOTAL	Php 6,235.00

2.2 Software Development

Using Arduino UNO and Node MCU, the researcher created and manually wrote codes with the help of the conceptual diagram and the corresponding list of guide sensors listed above. C++ was utilized for development because it is compatible with the microcontroller and sensors. C++ is an object-oriented programming (OOP) language that many see as the ideal language for developing large-scale programs. It can be utilized in sectors such as system software, game development, embedded systems, scientific computing, and high-performance applications. The C++ standard library includes a variety of coding conveniences and functions, making it simple to create complicated software systems. C++ may operate on a variety of platforms, including Linux, Mac, and Windows. (Barney, 2023).

SW-420 vibration sensor is a module that can detect vibrations or shocks on a surface. It can be used for various purposes, such as detecting door knocks, machine malfunctions, car collisions, or alarm systems. In addition, there is a potentiometer that can be further used to control the threshold point of the vibration or its sensitivity. There isn't any need to recalibrate the programming because it uses constant data of 0-1, with 0 indicating no vibration detection and 1 indicating vibration detection. To set the sensitivity for vibration detection, the researcher can twist the potentiometer from 1 to 3.



Figure 5. Coding vibration sensor using Arduino Uno & Node MCU

Capacitive Soil Moisture V 1.2 is a soil moisture sensor that measures soil moisture levels by capacitive sensing rather than resistive sensing like other sensors on the market. The Soil Moisture sensor is made of corrosion-resistant material which gives it excellent service life. The researcher matched its data to soil moisture percentages to make data collection easier when determining soil moisture levels.



Figure 6. Coding soil moisture sensor using Arduino Uno & Node MCU

The ADXL335 accelerometer is a small, thin, low power, complete 3-axis accelerometer with signal conditioned voltage outputs. The sensor measures acceleration with a minimum full-scale range of ± 3 g. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration. The researcher calibrates its data to degrees. By collecting the raw X, Y, and Z values from the accelerometer, the researcher used the following formulas to get its angle:

1. Determining the calibrated value

Calibrated Value
$$=$$
 Raw Value $-$ Offset

2. Converting to Tilt Angles

Pitch (rotation around Y-axis):

$$ext{Pitch} = ext{arctan}\left(rac{X}{\sqrt{Y^2+Z^2}}
ight)$$

Roll (rotation around X-axis):

$$ext{Roll} = ext{arctan}\left(rac{Y}{\sqrt{X^2+Z^2}}
ight)$$

3. Converting Radians to Degrees

Angle in degrees = Angle in radians
$$\times \left(\frac{180}{\pi}\right)$$



Figure 7. Coding accelerometer using Arduino Uno & Node MCU

2.3 Prototype Making

During prototyping, the researcher opted for utilizing the schematic diagram to connect the wirings. Making the workflow significantly faster.



Figure 8. A conceptual framework for RAIN-MADEMS

OPERATING VOLTAGE AND CURRENT DRAW:

Arduino UNO: 5V/50mA

Node MCU: 3V/300mA (during WiFi transmission)

Vibration sensor: 5V/10mA

Capacitive Soil Moisture sensor: 5V/22mA

Accelerometer: 3.5mA

Arduino UNO Input Voltage: 5V

Arduino UNO current output: 800mA

CONNECTION OF SENSORS TO MICROCONTROLLER:

Soil Moisture:

VCC to 5V (Arduino UNO Board)

AOUT to D6 (MCU V3 ESP8266)

GND to GND (MCU V3 ESP8266)

Vibration sensor:

VCC to 5V (Arduino UNO Board)

DO to D5 (MCU V3 ESP8266)

GND to GND (MCU V3 ESP8266)

Accelerometer:

VCC to 5V (Arduino UNO Board)

X-OUT to D2 (MCU V3 ESP8266)

Y-OUT to D3 (MCU V3 ESP8266)

Z-OUT to D4 (MCU V3 ESP8266)

GND to GND (MCU V3 ESP8266

To evaluate the accuracy of the RAIN-MADEMS prototype, the researcher made the choice to build a four by three feet simulator capable of handling 25 kilograms of clay soil. In this case, the simulator will be subjected to significant rainfall and external forces that may cause movement within the soil.



Figure 9. Building a simulator box

2.4 Data Collection

The RAIN-MADEMS system collected real-time environmental data using a combination of sensors to monitor soil moisture, tilt angle, and ground vibrations. A capacitive soil moisture sensor was embedded in the ground at three feet to continuously measure moisture levels, particularly during simulated rainfall, and flagged critical thresholds when moisture levels exceeded 50%, indicating potential soil liquefaction. The system also employed an ADXL335 accelerometer to track changes in tilt angle, detecting early signs of instability at 22 degrees and significant movement at 30 degrees or higher. Additionally, a SW420 vibration sensor was used to monitor ground vibrations, providing binary data to identify whether movement was occurring. The collected data from these sensors was processed by an Arduino Uno and transmitted wirelessly through the NodeMCU ESP8266, enabling continuous real-time monitoring and instant alerts when critical thresholds were reached. This integrated data collection approach ensured accurate predictions of potential landslides across all ten tests.



Figure 10. Testing of the prototype

Soil Moisture (%)	Alert Level
Below>30-40	Low
41-55	Moderate
56-65	High
66- 70 <above< td=""><td>Very High</td></above<>	Very High

Moisture below 30% was labeled Low Risk, indicating stable soil conditions, while levels between 30% and 40% were classified as Moderate Risk, signaling increased moisture but still manageable stability. When moisture reached 56% to 65%, it was flagged as High Risk, indicating potential instability. Lastly, levels above 66% were marked as Very High Risk, reflecting a strong likelihood of soil liquefaction and mass wasting.

Angle/Tilt of Slope (°)	Alert Level
18-22	Normal
23-26	Caution
27-29	Warning
30-34	Critical

The accelerometer was classified into four alert levels to assess slope stability. Tilt angles between 18° and 22° were considered Normal, indicating stable slope conditions. Angles from 23° to 26° triggered a Caution alert, signaling the early stages of potential instability. When the tilt reached 27° to 29° , a Warning was issued, reflecting increased slope movement and a higher risk of mass wasting. Finally, angles from 30° to 34° were categorized as Critical, indicating severe instability and a high likelihood of slope failure. These classifications enabled the system to provide timely alerts as the tilt angle increased, ensuring that escalating risks were effectively monitored.

The following table illustrates the RAIN-MADEMS system's performance in monitoring environment-related variables, specifically soil angle, moisture levels, and ground movement, in order to predict the risk of rain-induced mass wasting events like landslides. The system collected data from ten tests, each concentrating on tilt angle, moisture content, and movement detection, with corresponding alarm levels determined by these factors and prescribed limitations.

Test no.	Angle (°)	Moisture (%)	Movement (yes/no)	Alert Level
1	22	30%	No	Safe
2	23	35%	No	Stable
3	24	40%	No	Stable
4	25	50%	Yes	Warning
5	26	55%	Yes	Critical
6	27	60%	Yes	Critical
7	28	65%	Yes	Critical
8	29	68%	Yes	High Risk
9	30	70%	Yes	Mass Wasting Likely
10	33	72%	Yes	Mass Wasting Imminent

3. RESULTS AND DISCUSSION

This section will present the results and discussion that will answer the research questions and accomplish the research objectives.

The researcher took three sensors in total to create the RAIN-MADEMS prototype. One, capacitive soil moisture sensor was used because rainfall is commonly a lubricant to soil making it easy to erode and maneuver and cause a debris flow. Through trial and testing the researcher gathered that about 30% and below is when the capacitive soil moisture sensor indicates that the soil is dry. And when it is buried under wet soil it starts to increase about 30% to 40% as our average moist and wet soil while, 50% to 70% level is when the soil starts to liquify and become muddy that can start mass wasting.

DRY SOIL	30%< below
WET SOIL	30% to 40%
	(considered wet but not detrimental)
	50% to 70%
	(soil starts to liquify and
	becomes muddy. Issues a
	warning that can cause possible landslide)

Second, the vibration sensor has a constant reading of 0 to 1 where 0 indicates that there is no underground vibration and 1 denotes that there is possible movement whether from a natural seismic activity or manmade oscillation. Therefore, there is no need for calibration of its code because of its constant data of 0-1. Adjusting the sensitivity through twisting the potentiometer from 1-3 to acclimate its detection for vibration.

Third, an accelerometer was strategically placed inside the 3D canister to detect tilting. It is found that within 22 degrees of inclination, soil starts to fall out in small particles. At 35 degrees of inclination it is considered to be the maximum inclination of a slope before it starts to topple down and create mass wasting without the help of rainwater as a lubricant.

Test no. (°)	Angle (°)	Moisture (%)	Movement (yes/no)	Alert Level	Correct Prediction (yes/no)
1	22	30%	No	Safe	Yes
2	23	35%	No	Stable	Yes
3	24	40%	No	Stable	Yes
4	25	50%	Yes	Warning	Yes
5	26	55%	Yes	Critical	Yes
6	27	60%	Yes	Critical	Yes
7	28	65%	Yes	Critical	Yes
8	29	68%	Yes	High Risk	Yes
9	30	70%	Yes	Mass Wasting Likely	Yes
10	33	72%	Yes	Mass Wasting Imminent	Yes

To test the accuracy of this threshold, the researcher tested RAIN-MADEMS ten times each time, the sensors provided accurate readings within the set thresholds for soil moisture, vibration, and tilt. These findings demonstrate that the system can accurately monitor and predict landslide conditions based on environmental change.

The table shows the results of the RAIN-MADEMS system's performance in monitoring environmental conditions, specifically soil angle, moisture levels, and ground movement, to predict the likelihood of mass wasting events such as landslides. The system gathered data from 10 tests, each focusing on the tilt angle, moisture content, and movement detection, with the corresponding alert levels based on these factors.

Accuracy Calculation

The system's accuracy is determined by comparing the number of correct predictions made by the system to the total number of tests. The accuracy formula is:

$$Accuracy = rac{Correct \ Predictions}{Total \ Tests} imes 100$$

In this case, the system made 10 correct predictions out of 10 tests. Therefore, the calculation is:

$$Accuracy = \frac{10}{10} \times 100 = 100\%$$

This result indicates that the RAIN-MADEMS system performed with **100% accuracy** in detecting and correctly predicting soil conditions and movement based on the data from the sensors.

Interpretation of Test Results

1. Soil Angle and Moisture Levels:

As the angle of the slope increased, so did the soil moisture percentage. This increase corresponds to the system's thresholds for different alert levels: At lower angles $(22^{\circ}-24^{\circ})$, moisture levels remained under 40%, and no movement was detected, indicating stable conditions. As the angle approached and exceeded 25°, moisture levels crossed the 50% threshold, signaling a warning, with the system detecting ground movement starting at 25° and above. Moisture levels of 55%–72% (from 26° to 33° angles) indicated critical conditions, with increasing severity leading to "Mass Wasting Imminent" alerts as the tilt and moisture levels reached higher values.

2. Movement Detection:

The vibration sensor (SW420) accurately detected ground movement starting at a tilt of 25°, coinciding with increasing moisture levels. This threshold aligns with the typical onset of landslide risks due to soil liquefaction and instability. The system's ability to consistently detect movement at critical angles and moisture levels demonstrates its reliability in early landslide detection.

System Performance and Early Warning

The system's performance aligns with the expectations of providing early warnings for mass wasting events. Critical thresholds of **50% soil moisture** and **25° slope tilt** were key indicators for issuing warnings and critical alerts, ensuring timely detection of potentially hazardous conditions. The system escalated alert levels as conditions worsened, providing a full range of responses from "Safe" to "Mass Wasting Imminent."

Key Findings:

- The system was able to distinguish between stable and hazardous conditions based on real-time sensor data.
- The integration of tilt angle, soil moisture, and vibration data ensured a comprehensive approach to monitoring soil stability.
- The 100% accuracy in these trials shows the system's potential for effective early detection, though more extensive testing under varied conditions would further validate its performance.

4. CONCLUSION

The RAIN-MADEMS prototype demonstrated strong potential in predicting rainfall-induced landslides by monitoring key environmental factors such as soil moisture, tilt angle, and ground vibrations in real time. Using integrated sensors, the system effectively tracked changes in soil conditions, providing timely alerts as tilt angles increased and moisture levels reached critical thresholds. Early signs of instability were detected at a tilt of 22 degrees, with significant movement observed beyond 30 degrees when moisture levels surpassed 50%. This allowed the system to issue warnings before conditions became dangerous.

Over the course of ten tests, RAIN-MADEMS consistently delivered accurate results, with an impressive 100% accuracy rate in identifying conditions conducive to rain-induced mass wasting. The wireless transmission of data ensured timely updates for users, enhancing its value as an early warning tool. By effectively correlating tilt angles and moisture levels, the system proved to be a reliable resource for mitigating landslide risks, meeting all project objectives. This level of precision confirms that the RAIN-MADEMS system is not only capable of monitoring environmental conditions but also provides a vital resource for risk mitigation strategies in landslide-prone regions. Overall, the RAIN-MADEMS system stands as a vital innovation in environmental monitoring, offering a proactive solution to safeguard communities against the devastating impacts of rain-induced mass wasting events.

REFERENCES

Artha, Y., & Julian, E. S. (2018). Landslide early warning system prototype with GIS analysis indicated by soil movement and rainfall. IOP Conference Series: Earth and Environmental Science, 106, 012012. <u>https://doi.org/10.1088/1755-1315/106/1/012012</u>

Batumalai, P., Nazer, N. S. M., Simon, N., Sulaiman, N., Umor, M. R., & Ghazali, M. A. (2023). Soil detachment rate of a Rainfall-Induced landslide soil. Water, 15(12), 2149. <u>https://doi.org/10.3390/w15122149</u>

Barbon, G., Margolis, M., Palumbo, F., Raimondi, F., & Weldin, N. (2016). Taking Arduino to the Internet of Things: The ASIP programming model. Computer Communications, 89-90, 128–140. <u>https://doi.org/10.1016/j.comcom.2016.03.016</u>

Bari, L., Idbaïh, A., Ahamed, R., Tawhid Ahmed Zihan, Sharmin, S., Abir Hasan Pranto, & Md. Rabiul Islam. (2023). Potential Use of Artificial Intelligence (AI) in Disaster Risk and Emergency Health Management: A Critical Appraisal on Environmental Health. Environmental Health Insights, 17. <u>https://doi.org/10.1177/11786302231217808</u>

British Geological Survey. (2021, June 14). Understanding landslides - British Geological Survey. <u>https://www.bgs.ac.uk/discovering-geology/earth-hazards/landslides/?fbclid=IwZXh0bgNhZW0CMTEAAR0uYMxs4NcaHcgVRaKeNjDrARW9BhYGHPGHvxNvK25AtoSu1VTh5RH-kAE_aem_x8XBL-wfgqcJ8A6VBCDHhA</u>

Chen, Z. (2024). Application of UAV remote sensing in natural disaster monitoring and early warning: an example of flood and mudslide and earthquake disasters. Highlights in Science, Engineering and Technology, 85, 924–933. https://doi.org/10.54097/zak5hp77

Crissa, D., Fernandez., Kirstin, Joy, A., Mendoza., Armin, Jude, S., Tiongson., Melannie, B., Mendoza. (2016). Development of microcontroller-based landslide early warning system. 3000-3005. doi: 10.1109/TENCON.2016.7848596

Current Research--Ohlmacher--Page 7 of 9. (n.d.). <u>https://www.kgs.ku.edu/Current/2000/ohlmacher/ohlmacher7.html?fbclid=IwZXh0bg</u> NhZW0CMTEAAR0v03iReCFxbrzm06AauAoIYvV8RSineIMQCuQ4I738zw5Fr0GD15C_RvE_aem_0ZrYgwuskof3OU4ktjdFTw#:~:text=The%20s lope%20angle%20is%20the,slope%20of%20only%205.7%20degrees

Dastrup, A. (n.d.). Factors that Influence Mass Wasting | Physical Geography. <u>https://courses.lumenlearning.com/suny-geophysical/chapter/factors-that-influence-mass-wasting/?fbclid=IwZXh0bgNhZW0CMTEAAR1RoTR8uN4y-K_3nfHOmDWGK7wLI7iSFjWH3Imj1jIUdC08vb1xH_ToduU_aem_YdTyDCi1DRhnaWLpN65auQ</u>

Ethiopia mudslides death toll nears 230 as desperate search continues in southern Gofa region. (2024b, July 24). CBS News. https://www.cbsnews.com/news/ethiopia-mudslide-deaths-gofa-heavy-rains-kencho-shacha-gozdi/

Gian, Q.-A., Nguyen, D.-C., Tran, D.-N., & Tran, D.-T. (2016). Monitoring of Landslides in Mountainous Regions based on FEM Modelling and Rain Gauge Measurements. International Journal of Electrical and Computer Engineering (IJECE), 6(5), 2106. https://doi.org/10.11591/ijece.v6i5.pp2106-2113

Gunawan, G., Rahman, A., Seputro, B. P., & Elsera, M. (2019). Design of Early Warning System Flood and Landslide Mitigation Sensor Based on Internet of Thing. Journal of Physics: Conference Series, 1361(1), 012062. https://doi.org/10.1088/1742-6596/1361/1/012062

Gupta, V. (2024, May 24). IoT-Based Early Landslide Detection System. PsiBorg Technologies Pvt. Ltd. <u>https://psiborg.in/iot-based-early-landslide-</u> detection-and-warningsystem/?fbclid=IwZXh0bgNhZW0CMTEAAR2_qJ31sGqkMEYorX9tzQyAZq31olyB_p75KXZ55H1MXqz51J37_7fcIoM_ aem_oPCuLX7Rpx3IimLQehN9Lw#elementor-toc__heading-anchor-3_

Guzzetti, F., Peruccacci, S., Rossi, M., & Stark, C. P. (2007). Rainfall thresholds for the initiation of landslides in central and southern Europe. Meteorology and Atmospheric Physics, 98(3-4), 239–267. https://doi.org/10.1007/s00703-007-0262-7

Kang, J., Wan, B., Gao, Z., Zhou, S., Chen, H., & Shen, H. (2024). Research on machine learning forecasting and early warning model for rainfallinduced landslides in Yunnan province. Scientific Reports, 14(1). https://doi.org/10.1038/s41598-024-64679-0

Khan, A., Gupta, S., & Gupta, S. K. (2020). Multi-hazard disaster studies:

Monitoring, detection, recovery, and management, based on emerging technologies and optimal techniques. International Journal of Disaster Risk Reduction, 47, 101642. https://doi.org/10.1016/j.ijdrr.2020.101642

Liu, Y., Huang, J., Xiao, R., Ma, S., & Zhou, P. (2022). Research on a Regional Landslide Early-Warning Model Based on Machine Learning—A Case Study of Fujian Province, China. Forests, 13(12), 2182. https://doi.org/10.3390/f13122182

Ma, K., Wu, J., Ma, Y., Xu, B., Qi, S., & Jiang, X. (2023). An Effective Method for Improving Low-Frequency Response of Geophone. Sensors, 23(6), 3082. https://doi.org/10.3390/s23063082

Miraballes, M. N. L. (2020). ESTABLISHING LANDSLIDE EARLY WARNING SYSTEM USING RAINFALL THRESHOLDS IN THE PROVINCE OF ALBAY, PHILIPPINES. GOV.PH; Department of Environment and Natural Resources . https://mgb.gov.ph/images/Research_Development/12_-T06_ESTABLISHING_LANDSLIDE_EARLY_WARNING_SYSTEM_USING_RAINFALL.pdf

Šakić Trogrlić, R., van den Homberg, M., Budimir, M., McQuistan, C., Sneddon, A., & Golding, B. (2022). Early Warning Systems and Their Role in Disaster Risk Reduction. Towards the "Perfect" Weather Warning, 11–46. https://doi.org/10.1007/978-3-030-98989-7_2

Sharma, K., Anand, D., Sabharwal, M., Tiwari, P. K., Cheikhrouhou, O., & Frikha, T. (2021). A Disaster Management Framework Using Internet of Things-Based Interconnected Devices. Mathematical Problems in Engineering, 2021, 1–21. https://doi.org/10.1155/2021/9916440

Stark, T. D., & Choi, H. (2008). Slope inclinometers for landslides. Landslides, 5(3), 339-350. https://doi.org/10.1007/s10346-008-0126-3

Teja TS, Dikshit A, Satyam N. Determination of Rainfall Thresholds for Landslide Prediction Using an Algorithm-Based Approach: Case Study in the Darjeeling Himalayas, India. Geosciences. 2019; 9(7):302. https://doi.org/10.3390/geosciences9070302

Thirugnanam, Hemalatha & Uhlemann, Sebastian & Reghunadh, Reshma & Vinodini Ramesh, Maneesha & Rangan, Venkat. (2022). Review of Landslide Monitoring Techniques With IoT Integration Opportunities. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing. 15. 1-24. 10.1109/JSTARS.2022.3183684.

Tian, B., Liu, W., Mo, H., Li, W., Wang, Y., & Adhikari, B. R. (2023). Detecting the Unseen: Understanding the Mechanisms and Working Principles of Earthquake Sensors. Sensors, 23(11), 5335. <u>https://doi.org/10.3390/s23115335</u>

University of the Philippines Diliman. (2023, February 16). MGB-08 collaborates with DOST-PHIVOLCS Dynaslope Project to help communities prepare for impending landslide event. MINES AND GEOSCIENCE BUREAU. https://region8.mgb.gov.ph/en/featured-news/press-release/658-mgb-08-collaborates-with-dost-phivolcs-dynaslope-project-to-help-communities-prepare-for-impending-landslide-events.html

Yu, L., Gao, W., Shamshiri, R. R., Tao, S., Ren, Y., Zhang, Y., & Su, G. (2021). Review of research progress on soil moisture sensor technology. International Journal of Agricultural and Biological Engineering, 14(4), 32–42. https://doi.org/10.25165/ijabe.v14i2.6404

Zhou, Z., Tian, D., Yang, Y., Cui, H., Li, Y., Ren, S., Han, T., & Gao, Z. (2024). Machine learning assisted biosensing technology: An emerging powerful tool for improving the intelligence of food safety detection. Current Research in Food Science, 100679. https://doi.org/10.1016/j.crfs.2024.100679

Appendices

254 IE - 80H	
	1941 3r. 1+34
Smith left humanat legs, sowel	
Augustante and a person that	Packs laty Notices) high (Likel)
n to two statist	Land, mari i mari art
The second	(A 105 - 2.40 (95)
part monthly in proceeding pri the sind annumber Deat.	The minimum dependent days presents presented by
planning to write part could mainten a used minuted	new mercaria officer Ber, worth theothing I and letting Out to
with warves shown to tup as assetly reported through	and the proof and the ther predicted would a manufacture
Two: (0)(and semantical humanity, and managers beam terrest and pied
	place cover construction fatting
Durity Styr Canias	
1-gr	C. A.
	Chanter Define & Canto
10.	
	13
the deal and the second s	have 1, mar
19-4-7 A. Angel	based 5, more
1940) A dood 1940 July - Different may land	paged 2, most
ngant 8. al-20 19. Automot may donal 1. Tanan Sheet, Tanina 1944	Pagert 2, 2007 Jack Wit African Jap. 2000 7, Jack Jour, Door (eg
nant 5. doot nan 105. Attent mga daad " baase deer, baan 105 1. (1990 - 11. (1991)	Passed 2, 2007 Beats (20), 3072-001 May, 2000) 7 Beats (2000), Denter, David (20)
nant 5. doot man 105. Attent man datal " 16222 - Seet, Frans 1654 (5. 15.400 - 10. 1524)	Angert 1, 2007 Desit Wit Artenit Age Jone 7 South Porter, David (Arg 14-52-200 - 16-52 (Arg
ngant 5. dooff 19.000 1000 0000000 map doubl 1. 19.000 doot Jonas http (5. 15.000 - 10.00000) 20. 15.000 - 10.00000 20. 19.000000 for the state of the state of the state 20.000000 for the state of the state of the state of the state 20.00000000000000000000000000000000000	Annes II, 2007 Denis VII, Altrani Mg. 2000 7. Sent Inter, Sent (Ang 14.52.200 - 4.52.700) De interactio concor as non- ar dr. (10) tee
mant & down mant & down Dearc Ment Dans And Dearc Ment Dans My (5 (1996 - 1) from My (5 (1996 - 1) from) Do transmit overlag, who we Dans M, 201 statute & Boys many from a first many of the status of demonst model of environment in the many of the status of demonst model of	Anarel 2, 2001 Josh 201, Metroni May, 2000 7 Juni (Post, David (Arg (*12 Post - 2, 22 Post) The instance despite a sent we at 31, post 100 and Dig Magir & Official suscession in . Declarate in the Postpare
namt A down mant A down 1 tores dent, from only A 15400 - 10 from De bisannel Oueres, van HE Davas & Fel status a bog serves from a forme upset. Dava de fel status a bog serves from a forme upset. Dava sebes f a bisanty for a name of pro- bisanty of ser externato david to serve the tore that	Anard 2, 201 India (M. Artzani) Ang, 2000 7 India Dente, David (eg (*12796 - 2.12796) The instanced denotes a new war at its pro-life ad Did 20001 K Officiant discounces in Machinese in the Didgest particle of the meno david, a point work the instances rate (into
nant & down man 100, fortheod man dataf. * forec down, from any & 15400 - 10 foren) De triannant oueroek ware the Devan M. He etaile in boy annues fore a forthe upper Devan M. He etaile in boy annues fore a forthe upper Devan M. He introduct, Gar manues fore a forthe upper Devan the mathematic set interfere Sectors in some set for an parent and antight Sectors in a backet.	Anarel 2, 2001 India (M. Artzani) Aga, 2000) 7 India Dent, David (Ag (*127 Poil - a 22 PM) The interacted proper is none as it is provided ad Del 2000 X Officiant incomparts in Indianast in Proper paratel and The renow area, it indiants are for proper paratel and The renow area, it is indiants are for the indiant indiant model protect, provide, and parts of Affective 5 of Indiants
namt & down mant & down 1 tone deret from only (* 1540 - 10 from only (* 1540 - 10 from) The bicanard courses, who we broke is the relation & boys summer from a fixing upper The a manue, brok bigson upper fix a support of a manue from a fixing upper The another billion of a manue from a fixing upper the another billion of a manue from a manue of the bill an power of a manue from a manue of the tone that an power and weather billion of a matching	Anard 2, 201 India (M. Artzani) Jag, 2000 7 India Josef, David (eg. 1412 Point - 2012 (eg. 1412 Point - 2012 (eg.) International Descent an Annual Methods in the Pointpoint particle of the mean annual point an Analysis in the Pointpoint particle of the mean annual point an Analysis in the Pointpoint particle of the mean annual point and point and point particle of the mean annual point and point and point particle of the mean annual point and point and point particle of the mean annual point and point and point particle of the mean annual point and point and point and angle of a beat
nami i doof mani in Mitheri man dinal i baac doof June diy (5 (fam 1) fices) No transmit coorded and the Dear & Sta market & Boy series from a ficture upper. The arbors of subject & Boy series from the upper The arbors of subject & Boy series from the state upper the arbors subject & a manufact from the series were the subject of a manufact from the series were the subject of a manufact from the series were the series and series for the series of a mathem	Anard 1, 2001 India 2011, Refer on Ange, 2000 7 Maril Post, David (Ang 1/127 Post - 2/127 Post The instance despite a sense we at its propose and Did Styper & Officer descence at Marinese is not responden- material and the news and a post over the instances and the indicates particular of descence and marine poster, post- and the ange of the news and a post over the instances and the indicates particular of descence and poster, poster, and ball of and ange of the news and a basis newself poster, poster, and ball of and ange of the new and and a basis newself poster, poster, and ball of and ange of the new and and a basis of the newself poster, poster, and ball of and ange of the new and and a basis of the newself poster.
mant & down wow long formerst map doubt I have doest from http (5 stars - in firms) No transmit overhed when with Owner & Brit minim & boy imput from a firsten uppert. Then, andress if a sharayour for a manuary hay. Busheding deterant moves of mathematic star a manuary hay. Takanong deterant moves of mathematic star a manuary hay have a similar to passed and antight be move a similar	Anard 2, 201 India 201, Addressi Jag, 2001 7 Junit Post, David (eg 1/372 Post - 2/372 fm) The instantion proper is some we at he post for and Did Stypes & different suscention in <i>Distribution</i> for the particular of the more areas, it would post in the instances and post indicates poster. It is builden model poster, poster, suit but a and right of a built
hant i do-f war loo better man dand I bear free James ity (3 15400 - 11 floes) No bisanant overled when its Davas is set rabits a boy same free a forthe upper Teo, arbeet i subserve for a mount free high denored moves of instruct for a mount free high denored moves of instruct for mount is subset in the above for a bis and the second we have that so pawed we wanter so more is a webbit. Owned labor of faults	Anard 2, 201 Deals W. Affred May, 2001 7 Mart Part, David (rg 1412 Part - 2 + 22 MM) The instance deaper a seas we is in rooman and Def Mart & Officer deapers in Martines in the rooman partial of Mart & Officer deapers in Martines and Part and Def Mart & Officer deapers in Martines and Part partial of Mart & Officer deapers in Martines and Part and Def Mart & Officer deapers in Martines and Part and Def Mart & Officer deapers in Martines and Part and Def Mart & Officer deapers in Martines and Part and Def Mart & Officer deapers in Martines and Part and Def Mart & Officer deapers in Martines and Part & Officer deapers and Def Mart & Officer deapers in Martines and Part & Officer deapers in Mart & O
mant & down mant & down 1 Tanac Street Trans Lind 2 Tanac Street Trans Lity (5 Street T II Street) The transmit overlap, when the Divers M. 194 relation & Boys summer from 8 Action uppert. Text, andress f a property of a transmit from Stationing dependent inner of Institute, Gar instantiate Sacched in second that an proved and antiples Sacched in second that an proved and antiples Sacched in Second Tan Diversed Caloring Trailes.	Annel 2, 201 Deals (M. Artznell Bag, 200) 7 Deals (M. Artznell Bag, 200) 7 Deals (Peter Deals (Ang (*12 Peter 3 22 PM) De tenanciel dealers a sees we at its por its al deal deal 2001 & Officiant assessment is Machines in the Propose particip of the new anes, post, one its sees and point particip of the new and and point its matter power, which the set ange if a lead
hant i do-f mar los bothest man dand " here dest from ity (* 15900 - 11 flow) The bisannel stored state upper The branch is the state a boy summer from a fischer upper The analysis for a bigaryer of a nature from a fischer upper the analysis in the state a mark from the bisan upper the theory of an purch and analysis for the state is the bisan an purch and analysis for the state of a fischer. Owned (1997)	Annel 2, 201 Deals MM. Attract Rep. 2000 1 Deals Prote Deals (Ang 1 Deal Prote Deals (Ang 1 Deal Prote Deals (Ang 1 Deal Protect Deals (Ang 1 Deal 2000 - 2 - 2 - 2 - 2 - 2 - 2 - 2 - 2 -
haant 1. doot baant 20. Bottenet map bland * book door in flows (5. 1590: - 11 flows) The internant occored ware the Down M. Bet statistic in book samples from 5. Sociale marks for a singletype for it manual two. Busilening detected marks of i markets, Gar materials busiled in sense that base that an paired and antiper 50. most it 5. bashield Downed Libert of Faultice	Annel 2, 201 Deals MM. Attract Bay, 2000 1 Tank Post, Dank (Ag 1427 Post - 2 27 M) The transfel oppost a sense we if it post for all opp 200pt 5 Officiant inserance is instruction for Postpost period and the news and it works and it is for the period and the news and it works which is a first for the transfel oppost is a local and any ang it is body
nami i da-M mani ion Bottenit man binal i baaa dood lanna aty (3 1890 - 11 1800) De trianante otoepid van de Dean is te estain n bou samer for a facte mart Teo, nebed f a landour, a bou samer for a facte mart Teo, nebed f a landour, a constant a mart i same too tang too i badour, a neurost so too t a samitis. De parte of factor	Annel 2, 201 Delle MM. Antronet Age, 2010) 7 Tanto Dente, Danne (eg 1412 Pole = 4-22 MM) The transmission provides a many out of the pole and pol attent & different transmission of information and poly- periods of the new and, a work over the resumant. And poly- and, Argenting the new and, a work over the resumant. And poly- and, Argenting the new and, a work over the resumant. And poly- and, Argenting the new and and the new poly- and and the new and the new poly- ter and poly-the new and the new poly- metric poly-the new and the new poly- metric poly of the new and the new poly- and and the new poly- and the new poly- ter and the new poly- ter and poly- and poly- ter and poly- and poly- ter and poly- ter and poly- ter and poly- and poly- ter and poly- and poly- a
naan a dool datteent map dated 1 baars dated, banks sty (5 titees and banks attees a back banks sty The triansment observed vanuant Dates ik the station is book samps ford a ficture want. One maked if is provide for a manual typ. Busylowing detracted inside of a provide for a manual typ. Busylowing detracted inside of a provide for a manual typ. Busylowing detracted inside of a provide for a manual typ. Busylowing detracted inside of a provide for a manual typ. Busylowing detracted inside of a provide for a manual typ. Busylowing detracted inside of a provide for a manual typ. Busylowing detracted inside of a provide for a manual type is toold it is such that 	haard 2, 200 Deal Will Attend tog, 200 2 Sant South, David (20) 1 177 200 - 2 727 (M) The instances dealers, a main set in the Dealers and Deal stops, S different instances, a maintaire in dealers and Dealers S different instances, and and one of the set different partial of S instances and and set in the Dealers and different partial of S instances and and and the set different partial of S instances and and and the set different partial of S instances and the instances in the S inst and different partial of S instances and the instances in the S inst and different partial of S instances and the instances in the S inst and different partial of S instances and the instances in the S inst instances instances in the S instances in the S instances in the S inst instances instances in the S instances in the S instances in the S inst instances instances in the S instances in the S instances in the S inst instances instances in the S instances in the S instances in the S inst instances instances in the S instances in the S instances in the S inst instances instances in the S instances in the S instances in the S inst instances instances in the S instances in the S inst instances instances in the S instances in the S inst instances instances in the S instances in the S inst instances in the S inst instances instances in the S inst inst inst inst instances inst inst inst inst inst inst ins
mant i dool mant i dool i brace deed, huma lity (* 1590 - 11 flow) (* 1590 - 11 flow) The minanum Constant vanue fit have be the minan is book manue for a ficture must fill anter t i material for a minan top. Business determine more of android, de restanties destand i manue top that an parent soid antight be more is a backlike. Description for antight be more is a backlike.	haard 2, 2011 Ment Will Attende lag, 2001 2 Sant South, David (Aug 1472 200 - 4.727/00) The instances doord a same an at its point free and DRI stopes & Alternative meansures, an automate is and the and DRI stopes & Alternative meansures, an automate is and the and DRI stopes & Alternative means and an at its point and and DRI stopes & Alternative means and an at its point and DRI stopes & Alternative means and and and and any Alternative and and DRI Stopes & Alternative means and and and DRI Stopes & Alternative means and and DRI Stopes & Alternative and Alternative and and DRI Stopes & Alternative and Alternati

	13
and D. State	
	6441 7. 2028
senn Giu Absornti eus donal	
mines Shink (Davan Gey	rands Ory Official Age fixed r Bons Afrest, Devis Gry
0.008M_= A .40.0M((with 3 4tim)
The Article provention and the Articles of the articles and the articles and approximate and a subject of the articles and the articles are articles and the articles are articles are articles and the articles are articles and the articles are are are articles are	The moment operational pression from the second sec
Danit Silly Front	an State
	31
againt (D. atod	21
agent P. Hol	21
agart 2. alad	21 Xuer 19-201
agart 2 atod Iman Ora Ilbiturdi Rus const 1. Sirca atrab., Sport Chy	21 Xuer 19- July 1
agart 2 atal proc. Cro. INVLOU Tays - oreal 1. Terrs atron, Court Cry [470:59 - 3:44:59]	Stand Ib. 2004 Dean bis 2000en Spi Jonet P. Dott, Ren. Kan. Cay
agare . R. and page . Cro. attrictor traja	21. Report The UNU # Exerce Table AMMoren Republicati C Tables, Republication IN Tables - M Scool
agart 22. atal page Cris difficult tup cont t. Sans atros, Deves Cris [s.10.20 3.4 a.Pe] The meaning proce for evenue hopest and and separate is prot a product for evenue hopest and and separate is prot a product for a meaning	21 Agent II. 2027 Dans. Ng. Athon: Age. Jung' F Torth. Thes. Rose. Gey Lift to Mr 1 Scient)
agart 22. and man fra attend frag. cont a form attend, there cont a form attend, there for (a 100 M - 4.4 mm) The meaning thread the contrast wat can stall and a set to proceed the top a contrast that can stall and a set to proceed the top a contrast that can stall and a set to proceed the top a contrast that can stall and a set to proceed the top a contrast that can stall and a set to be and the top a contrast that can stall and a set to be a contrast to the set to be a set to be a set to be a set of the set to be a set to be a set to be a set to be a set to be a provided to be a set to be a provided to be a set to be a provided to be a set to be a provided to be a set to be a provided to be a set to be a provided to be a set t	21 Agant IV-2007 Dans. Mit. Allows Aga Juant Dans. Mit. Allows Aga Juant Ditt. Juant - 1 Scient Ditt. Juant - 1 Scient And Juant - 1 Scient Scientific Adaption Scientific Adaption Scientific Adaption Science Adaption Scientific Adaption Science Adaption Scientific Adaption of Adaption Science Adaption Scientific Adaption of Adaption and Scientific Adaption
Agare R. and man Cra Althout Rup coul t Sans althout Rup coul t Sans althout Rup coul t Sans althout Rup coul (40004 - 44 mg) The meaning pand at along a sans and sansation of a sans a sansation at an addition and sansation and panagon another has be represent report and and panagon another has be reported another and another and panagon another has be reported another and another another and another report by two right and approximation in Alexand	21 Againt III. 2007. Dans. Ally. Attioner. Aga. Junet 2 10.00. These, Roma Cay 2 10.00. The State and Attionation and Attionation Area (and the law distance and Attionation Seq. angenesis it with the law distance and attion with a second the set, down the second the second and a second the second and and any the law
Aguer 2. dad men one antitutu fun over t form inter, power og forme - Aurel Market - Aurel	Agant II. 2007 Maria II. 2007 Maria Maria Cay Maria Sana Cay Maria Sana Cay Maria Sana Canada and Maria Carabana and Maria Sana Canada and Maria Carabana and Maria Carabana and Maria Sana Canada and Maria Carabana and Maria And Maria And Maria And Maria Carabana
Agart A. stad Mar Ora, Millionol Page open t Serve strate, proved org JATOM - A Army The Marrian parce bit elemen proper and objected is word a parameter for elemen proper and objected is word a parameter for elemen proper and objected is word a parameter for based of an apparent and objected is word of the elemen and demogrammeter and objected is word of the element and demogrammeter and objected is word of the element word and	Agant II. 2004 Toom All Alloce Age June' Clark Ben, Kann Gej 19 m.An - I Steel And John - Steel A
Agust 2. and man for attend for over t for attend t for attend t for attend t for attend to an attend to another over a	Anna Ala Alban Aga dani Anna Ala Alban Aga dani Alban Ala Alban An Ana pasa and data ana Alban an An pasa and an an Alban an An pasa and an an Alban Alban an An and a an and an an and an and alban an and a sect a book a provider an and be too
Agust 2 and Agust 2 and Anno Con Affind Age area torus and, power can for the second prior of the second stopped and the second s	Agant II. 2004 Man. M. Wilson Aga Junet Patto Sana, Kuna Gaj II. 10.001 - 4 Stant Mari Jacks, and distance of the same distance of spin against a single for the local distance of the local spin a liter + local a privat and with the local Same Fig. Contern
Agart 2 and Agart 2 and Anno Cros Attract Case open t correstment, prover Cas To TOM - 44 and The secondary formed the second steps of an and Second principal and and and and and and a second principal and an and and and and a second principal and an and and and and and a second principal and an and and and and and a second principal and an another and and an and a second principal and an and and and an and a second principal and an another and and an and a second principal and an and and and an and a second principal and an another and and an another and an an another and an an another another and an an another another and an an another another another and and an an another another another and an another another another and an another another another and an another another another and an another another another another another another and an another a	Agant II. 2007 Mari II. 2007 Mari Mari Can Mari Mari Can Mari Mari Can Mari Mari Can Constanti and Mariana Mari Mari Can Mari Mari Can Constanti and Maria Can Mari

22	25
August II, 2025	1
Long Depletion . Apple: Trea And Mr. Restmore Growin, Banes (A).	Jacob Statement State Cont
(4.15.4M.2.7.5.00/M.1	Some read, More Sep.
be near on . He posts the prove if for Day belows time and one with a weight a separat by	Separate and an and source optime has an annual accord to a second more definition of a second "Se second more descendents" - common anno descendents of - common anno descendents of
and feeting faith	- Ann Alca - NY JI sa witht
	10-14 Griffhau
	1
1 1	29
	August des dist
anget 46, 4924	IQ.ISTRAL.
laant. Heisat Meierranie, Apt	The Monetaer Monetal 2 and more the Day matter mean N 2015 a locational decreat with their decourt pre-introduced by method set, spectrum in . May 45, 44-41
(2.1819 - 7.18792) The listicities would depresed Stations, chir Ar.	new Top Dates
s and int line, howards, his dampion, and way not	
and and the second	
and the state	
	1

Sunte de, asse	aposs to and
	TaxANDA M. Chills TaxAND Manufact
CAN DIMITSAT BYNE	Berry, Hap R., Meaner Service, Sourc Ling
CH MI. R. J. MITSLEIP MAILE, Page CA	
(# RANK - IN NOAM)	DL UME - S. UTPM
period and the second s	The presences which is the lightering start by
He manufact and the Leginists Bills, and	was and the or ficenced and on four and we do ent appli-
Kal a converting and fag. Inter card new display were	MALE 2 THE OSTOCIAL AND AN AND A MARY AND AN ANTI-
P.D. Build D.D. San & Intelling Property in State of the state	and a maried & taxan of compare of the state and share for
have been the superviser and character in most in your program and penalty	secure was as larg on the draws
particle a tota antenna and might to dentity see to particity	
Barth attent Sam	Bat
	Country (1993)
	m
20 Aprent & and	an) Depender 14., 1824
an Approximation and approximation of the second se	and Bearington (by , and Book (by , Strings, Supergrave)
10 Apreval 5, 4044 Sout Dia Interior. Bot. Roberts and spreagnent 10(4 Apreval 19, March 2000), South 10(4	an Basedan da, defe Base Job, Setting, ngagasti T there de, Benne Ley
201 Apreval 3, 4134 Sour Ju, Inself, Brit Boherin, and manipation? 20(37 Sprint, Th. Spiner, Storm, Long	97 Base and Sec. Sec. Base Sec. Sec. Space 1 (Sec. J. Science injugated) 2 (Sec. J. Science injugated) The science of science injugated science of science injugated
20 April 10: 3: 4124 Sport 10: 10: 10: 10: Malerian and managarized 20(17) April 17: 30 June 10: 20: 20: 20: 20: 20: 20: 20: 20: 20: 2	an Description, and State in, and State in, and support States in, some ing The mean and support security and States As Josep Bill supported or malass Stated period
201 April 11 J. J. M. M. M. K. Marana and managaran (1917) Arrive 15, Managa Janua 102 (M. M. 1917) The momentum Analysis, and the All manual (1917)	and name on a series appared there at a brock tay to being all memory and any matches fauld formal to being all memory and any matches fauld formal to being all tag with the series and series to being at
201 Aprend A 2024 Read Day Devis - Not Achieve and management Digit Arrive 35, Manage Roam 102 (2014) The momentum Analysis, as much a prime and managed arts for government lines and are sensed and report 0.2 As	and number 24, 4024 man are different supposed i fores at, hence any to mean are different and to being the forest and any malane found matrix that are signed for some ad some it is before a meaning the forest and for some ad some it is before a meaning different and any of the source ad some it is before a
200 April 201, 2010/00 - Bott Koacous and assessment Diff April 201, 2010/00 - Bott Koacous and assessment Diff April 2010 - The monitory Backlo, as more a crime 40, may est april 2011 - The monitory Backlo, as more a crime 40, may est april 2011 - The monitory Backlo, as more a crime 40, may est april 2011 - The monitory Backlo, as more a crime 40, may est april 2011 - The monitory Backlo, as more a crime 40, may est april 2011 - The monitory of the Back Ching and April 2011	197 Dipatemer is, 1974 Sinds Mi, Artines support Theirs A. Devic (A) The meaning second saturate social figure to before and supported and by matching figure to before and supports of the second second figure address that supports
Aprevent & and Aprevent & and Model Day, Model, Both Roberts and managarent's Diff Service The Molecular Annual Annual Service (M. 1997) The memorial Metric and annual and append at 2 Append and 3 partness of the base strend and append at 2 Append and 3 partness of the base strend and append At Second Statement and the base strend Metric Al Second Statement and the base strend Metric Al Second Statement and the base strend Metric	197 Diparente fa, 1974 Band de, Artines support) filmes de, Berlines (197 The meanest coupt scattering action of person the becom and mean-service, and are made as band person the becom and mean-service, and are made as band person and become the service of the service and source to service a meanests, divergent.
Aprevent & stand Reverse & stand Reverse Reverse Reverse and resonance of the segment of the segment of the segmentation of the segment of the segment of the segment of the memory of the segmentation of the segment of the segment of the segmentation of the langering are one. Some of the proof of the segmentation of the langering are one. Some of the proof of the segment the segment of the segment of the segment of the segment of the segment of the segment of the segment of the segment the segment of the segment of the segment of the of the segment of the segment of the segment of the segment of the of the segment of the segment of the segment of the segment of the of the segment of the segment of the segment of the segment of the of the segment of the of the segment of the of the segment of	an Dipterant. Di. 1994 Distant. Di. 1994 Distant. Di. 1994 Distant. Distant. Diggeneti Distant. Distant. Diggeneti Distant. Distant. Diggenetics. Distant Proving material. Such such Sec. Warry and search to both a memorie. Dispired.
Annual Statement and an and an and a statement	an Represent in , 1994 Second Set Arrived supposed of House of Arrived supposed of House of Arrived supposed by Decision Self supposed for second supposed for supposed by Decision Self supposed for supposed supposed by Belly 2 supposed. Story of the supposed supposed supposed Supposed. Story of the supposed supposed by Belly 2 Supposed. Story of the supposed supposed supposed Supposed. Story of the supposed supposed supposed by Supposed Supposed. Story of the supposed supposed supposed supposed Supposed Story of the supposed
Annual Statement and an experiment and the second of the second s	an Baseaur. B., 1994 Base die Armen support filmen d. Baseaur be besen mit missierenter oor oor matuus fande familie be besen mit missierenter oor oor matuus fande prinse materia taat sien hij wit de wirop aa seerigt bisede s messeke diegood
American A. anad Remain A. anad Remain A. anad Remain R. Solari Barranger and Remainsmont Dirich retrost T. S. Solari Rama, Inter I.S. 2001 The momentum Derive and new second and respected for a spectrager and a partners of the latencies of respect of the a- spectrager and a partners of the latencies of respect of the a- spectrager and a partners of the latencies of respect of the a- spectrager and human of the latencies of the latencies of the spectra definition of the solarity of the latencies of the latencies of the latencies of the solarity of the latencies of the latencies of the latencies of the solarity of the latencies of the latencies of the latencies of the latencies of the solarity of the latencies of t	an Hearing an and the set of a second support the second and second second second second private the boson all second second second second private second second second second second to second second second second second second second second to second seco
American A. anad Remain A. anad Remain A. anad Remain A. anad I. and The momentum function of management light remains and remains and remains and remains and remains and respect of a solution from a protocol of the lange of the light of the remains functions and then more remains and respect of a solution from a protocol of the lange of the light of the remains functions and the solution of the lange of the remains functions and the solution of the lange of the remains functions of the lange of the lange of the light of the lange of the lange of the lange of the light of the lange of the lange of the lange of the light of the lange of the lange of the lange of the light of the lange of the lange of the lange of the light of the lange of the lange of the lange of the light of the lange of the lange of the lange of the light of the lange of the lange of the lange of the light of the lange of the lange of the lange of the lange of the light of the lange of the lange of the lange of the light of the lange of the lange of the lange of the lange of the light of the lange of the lange of the lange of the lange of the light of the lange of the lange of the lange of the lange of the light of the lange of the light of the lange of the light of the lange of the light of the lange of the light of the lange of the la	and Base are string appeard toring of string appeard toring of string appeard toring of string and to prove all second court assesses band privil to decen all second of the second ad second to sech a memory deal second of the second ad second to sech a memory diagram. Decry and a
Annual of the second and an angle of the second sec	and Base and a string support there as a string support there as an and a support the mean and coupt samuels used formed to become all supports and optimized samuel in and address that sup high the same ad same i in action of meaning diagram. Derry Trights
American A a and American A a and More of a lower of the Konema and management light for solve (F. 2001) The momentum function of the more of moment of the solver generation for the lower of the more of moment of a solver generation of the lower of the lower of the solver of the solver generation of the lower of the lower of the solver of the solver of the solver of the lower of the lower of the solver of the solver of the solver of the lower of the lower of the solver of the solver of the solver of the lower of the lower of the solver of the solver of the solver of the lower of the lower of the solver of the solver of the solver of the lower of the lower of the solver of the solver of the solver of the lower of the lower of the solver of the solver of the solver of the lower of the lower of the solver of the solver of the solver of the lower of the lower of the solver of the lower of the solver o	an Baseren b., 2004 Boan or, String spearst 1.1011. d. Bring into the mostrain couple assumptioned from a the boson differencember and oppende senergi to solve a metrics that sen big with the senergi and senergi to solve a metrics. divergent. Barris Trig. An
American A and American A and More day, however, for a Koncenter and management light for solv. If solv. The momentum flucked on more a prime age marked with the governous different sole and inspects of a particular solution of the lands of a more a prime age marked for decimal fluctures of the lands of a more a prime age marked for decimal fluctures of the lands of a more a prime age marked for decimal fluctures of the lands of a more a prime age marked for decimal fluctures of the lands of a solution for a point and a point of a solution of the lands of a solution for a point biologies and biological of a solution in the solution of a s	an Appendie in, 2004 Anna ers, Stringer support filmer dr. Bringer support transfer dr. Bringer ber be beson del memoreneler ord op malere Stand filmer sekren fall zur big och be serief ad serieft in schr 2 mender dingtor. Derrie Tra
Annual States of the second of management left areas on the base of the Second and management left areas of the base of the second of the second and append to a second left of the second and append to a second left of the second of the base of the second of decays thereas on the second of the base base for base second thereas on the second of the base base for base second thereas on the second of the base base for the	and the second support of the second second the second sec
Annual States of the second of management light factors if, Management light factors if, Management light factors if a management light for the second light with the second and regional for more second there are second and regional for the second there are second by if the second second light provide and the second of the second second second there are second by if the second second light provide and the second of the second second light provide and the second of the second second light provide and second second of the second second light provide and second second by if the second second light provide and second second second second second light provide and second second second second second second light provide and second second second second second light provide and second second second second second second second second second light provide and second	An and an arrival support titute of arrival support titute of arrival support titute of arrival support to because and managementary and arrival support address that have be using and support to bein a memory display. During any of the support
Annual Market And Annual Annua	and an an article appears there an article appears the second and appears the second and appears be because and managementary and an an app the second from an address that have bey with the second and second to be a memory doubters
Annual States of the second and an appropriate light of the second secon	An Anna des Arrient support Anna des Arrient support Anna des Arrient support Anna des Arrient support Anna des Arrient support de Locien del sum sig a d de uning auf serreit bucht s mesente dougene

	39	41
- 93	Samine In 1 1054	angeweiner ales 1014
50	was time Robbergi Baleriwal	Access Tota United and Activities
1	pane court, latano taru	r Smret (Deat) Down 5-ta
10	in the second	I mycer to
-	The secondary parent county we contain the	a exceed sent doctor in inder in partici
- 01	for a cauterie can oner and firing in some parties and	rading and acked help from it have specially contracting me
10	CA HER TH DEAL RY FAIR MAN MADE	and the surface of th
-		
	Contract State (1) Fundas	for the second second
	Carrie and the second	marity marity marity
		- AB
lep:n n	en st. 2014	dependenter JX - JM 28.28
deprine Opert	eur 27. 2014 De resorchet 1904 Ossembled eur pretrype fr 19571003. The efficiency and accurracy with Dec Socialator.	tepresent JV JA 2020 The menulate socied all composed of it all powerhely atoms and early languages. I seeked at their theory through mether to reds with the preserves pairs.
lepn n Tert	en st dont The construction than assembled has pretrige to testing in oppricing and accurring and the standards	an An An An An Andrew Market An Antheritation and an antheritation and an analysis of and anto the research paper. Theory and the test of the part of the second the paper.
Gynt N 941	en st dont The construction than assembled has printiple to testing in exprisional and asserting with the standards. Charly Store Lealar	an appenent 28 29 212 The interactions that all composite of the through antes to add white the second is pole. Destring Freedom For
(4nn)	ens sit dont De resorches som assembled has perhitige to osting the exprisency and asserbed hold be something County Some Sealar	An An An An An An An An An An
Gym W	eur sit died Die resorcher som assemblad has periotype to sotting tit epprusieuw and anwenden north the soundaries County Sone Sealar	An Approximer JK 29. 21,21 The respectator bested all components of in all associating ators sort source dampoint. I reached its mult that, taking methy is and only be research piper. Denrity Dises D Fem
Gymn Pyrl	en st dont The resourcher than assembled has provinge to testing in efforced and assembly with the standards Craning Store Leader	an utgenwere 28 29 212 The increasing to consider the test of a compositie of theory methods over her perform piper. Desting Frace D too
Ceptin of	eur JL 2004 The resourcher them ascennical was pretrige to testing in efforiend and accurrency with the soundates Crowing Start Analase	An An An An An An An An An An
Ception of	en st dont The resourcher than assembled has provinge to testing in exprisional and asserting with the standards. Charly Store Dealer	an depenser JK 29. 21.21 The meancher tested all component of it and associating atoms ours consider to another the taking mets, so add onto the presention paper. Depending France D tem

turner 1-3, dept Jenne 1000 sectored inge famil f beret affect, linuxe city 	Agrimeter VI. 1844 Dinor 1879 Postoval High Duesi I. Three 2000 Dates One Die bestandung with the location of Not interpreted the results due above generat during Antaig
	And hompeted the results that were general change throug