Risk Mapping for the Protection of Carbonate (Karst) Aquifers (Ramallah-Al Bireh District)

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Hazard Mapping

■ In the *origin-pathway-target model,* the risk of contamination of groundwater depends on three elements:

• The hazard posed by a potentially polluting activity (equivalent to *origin).*

• The intrinsic vulnerability of groundwater to contamination (equivalent to *pathway).*

• The potential consequences of a contamination event (the *target is the groundwater).*

Hazard Mapping

- In a karst groundwater protection context, **risk assessment requires:**

- Identification of potential hazards. For existing hazards, this can be achieved by hazard mapping.

- Analysis of the potential impact of hazards on groundwater. This requires details on the contaminant concentration and quantity. A system for rating and weighting hazards can assist this process.

- Information on the hydrogeological characteristics of geological materials beneath hazards, which influence contaminant movement and attenuation. This is shown by the vulnerability of the groundwater, either by means of vulnerability maps or vulnerability
  Assessments.

Rating and Weighting of Hazards

- According to COST Action 620 hazards should be classified according to the type of land use into three main categories (Infrastructure, Industrial and Agricultural activities). These main categories are proposed as Level I Categories of Hazards in the Hazard Inventory.

- For additional classification, Level II Categories was proposed to distinguish between hazards according to the main source (solid or liquid contaminants) of possible groundwater contamination, or else to refer to types of industrial or agricultural activities with their corresponding spectrum of possible pollutants. A further subdivision Level III Categories was also proposed for a more detailed classification of the Hazards.

Rating and Weighting of Hazards

- Moreover, COST Action 620 has developed a criterion for weighting different hazards as well as their properties regarding solubility and mobility. They determine the weighting coefficient or the **"harmfulness of a hazard to groundwater (H)"**. H value ranges from 10 (lowest hazard) to 100 (highest hazard).

Rating and Weighting of Hazards

No.	Hazards	Weighting Value	Marker	Line	Shade
1	**Infrastructural development**				
1.1	Waste Water				
1.1.1	urbanisation (leaking sewer pipes and sewer systems)	35			1
1.1.2	urbanisation without sewer systems	70			1
1.1.3	detached houses without sewer systems	45	1		
1.1.4	septic tank, cesspool, latrine	45	2		
1.1.5	sewer farm and waste water irrigation system	55	3		9
1.1.6	discharge from an inferior treatment plant	35	4		
1.1.7	surface impoundment for urban waste water	60	5		9
1.1.8	runoff from paved surfaces	25	6	1	
1.1.9	waste water discharge into surface water courses	45	7		
1.1.10	waste water injection well	85	8		
1.2	Municipal Waste				
1.2.1	garbage dump, rubbish bin, litter bin	40	9		8
1.2.2	waste loading station and scrap yard	40	10		8
1.2.3	sanitary landfill	50	11		8
1.2.4	spoils and building rubble depository	35	12		8
1.2.5	sludge from treatment plants	35	13		
1.3	Fuels				
1.3.1	storage tank, above ground	50	14		
1.3.2	storage tank, underground	55	15		
1.3.3	drum stock pile	50	16		
1.3.4	tank yard	50	17		11
1.3.5	fuel loading station	60	18		
1.3.6	gasoline station	60	19		
1.3.7	fuel storage cavern	65	20		
1.4	Transport and traffic				
1.4.1	road, unsecured	40		2	
1.4.2	road tunnel, unsecured	40	21		
1.4.3	road haulier depot	35	22		11
1.4.4	car parking area	35	23		11
1.4.5	railway line	30		3	
1.4.6	railway tunnel, unsecured	30	24		
1.4.7	railway station	35	25		
1.4.8	marshalling yard	40	26		
1.4.9	runway	35	27	2	
1.4.10	pipline of hazardous liquids	60		4	
1.5	Recreational facilities				
1.5.1	tourist urbanisation	30	28		2
1.5.2	camp ground	30	29		2
1.5.3	open sport stadion	25	30		3
1.5.4	golf course	35	31		3
1.5.5	skiing course	25	32		3
1.6	Diverse hazards				
1.6.1	graveyard	25	33		10
1.6.2	animal burial	35	34		10
1.6.3	dry cleaning premises	35	35		
1.6.4	transformer station	30	36		
1.6.5	military installations and dereliction	35	37		13
2	**Industrial activities**				
2.1	Mining (in operation and abandoned)				
2.1.1	mine, salt	60	38		7
2.1.2	mine, other non-metallic	70	39		7
2.1.3	mine, ore	70	40		7
2.1.4	mine, coal	70	41		7
2.1.5	mine, uranium	80	42		7
2.1.6	outdoor stock piles of hazardous raw material	85	43		6
2.1.7	ore milling and enrichment facilities	70	44		
2.1.8	mine waste heap and dirt refuse	70	45		6
2.1.9	ore tailings	70	46		6
2.1.10	mine drainage	65	47	5	
2.1.11	tailing pond	65	48		6
2.2	Excavation sites				
2.2.1	Excavation and embankment for development	10	49		
2.2.2	gravel and sand pit	30	50		12
2.2.3	quarry	25	51		12

Rating and Weighting of Hazards in Ramallah-Al Bireh District

Number	Level I Categories of Hazards	Level II Categories of Hazards	Level III Categories of Hazards
1	Infrastructural Development	Wastewater	Urbanization (leaking sewer pipes and sewer systems) Septic tank, cesspool, latrine Discharge from an inferior treatment plant. Surface impoundment for urban wastewater Runoff from paved surfaces
		Municipal Waste	Garbage dump Sanitary landfill
		Fuels	Gasoline Station
		Transport and Traffics	Road unsecured
		Diverse Hazards	Graveyard Military installation and dereliction
2	Industrial Activities	Excavation Sites	Quarry
		Industrial Plants	Metal processing and finishing industry Chemical industry Food industry
		Diverting and Treatment of Wastewater	Surface impoundment for industrial wastewater
3	Livestock and Agriculture	Livestock	Factory farm (sloughing house)
		Agriculture	Intensive agriculture area (with high demand of fertilizers and pesticides)

Rating and Weighting of Hazards

- However, the hazardous substances involved within each individual category are more or less the same or can be considered to be from the same group. Therefore, the difference in harmfulness within each hazard category will be mainly due to variable quantity (**hazardous ranking Q_n**) of harmful substances, which can be released and further seep into the underground. Hence, a ranking value between 0.8 and 1.2 is recommended in order to maintain a fair balance with the average weighting values. Depending on the amount of the hazard 0.8 is for low, 1.0 for medium and 1.2 for high hazards.

Rating and Weighting of Hazards

- The **reduction factor (R_f)** considers the probability for a contamination event to occur. The reduction factor ranges from 1 to 0. In a situation where the value is set to zero, it follows that there is no risk of groundwater contamination, while a factor of 1 indicates there are no reasons known to reduce the likelihood of an impact to the groundwater according to the European approach. For most of the hazards in Ramallah-Al Bireh District no information was available concerning their technical status and level of maintenance and therefore R_f was defined as 1 (no reduction).

Hazard Index (HI)

- Finally, **Hazard Index (HI**) is calculated based on the considered factors. It describes the degree of the harmfulness of the substances. The possibility of the hazard index HI is scored from 0 to 120. HI is calculated as follows:

$$HI = H \cdot Q_n \cdot R_f$$

# Hazard Index (HI) in Ramallah-Al Bireh District

| Code	Hazard	Examples from the study area	HI
Infrastructure Development			
1.1.1	Urbanization (leaking sewer pipes and sewer systems)	Ramallah, Al-Bireh, Bitunia cities	35
1.1.4	Septic tank, cesspool latrine	Most community in the study area	19-54
1.1.6	Discharge from an inferior treatment plant	Al Bireh wastewater treatment plant	35
1.1.7	Surface impoundment for urban wastewater	Ramallah wastewater treatment plant	60
1.1.8	Runoff from paved surfaces	All communities in the district	25
1.2.1	Garbage dump	In each community in the district	20-60
1.2.3	Sanitary landfill	In most community in the district	25-50
1.3.6	Gasoline Station	There are 26 gasoline station	24
1.4.1	Road unsecured		40
1.6.1	Graveyard	Each community has its own graveyard	25-30
1.6.5	Military installed and dereliction	All Israeli settlements	35
Industrial Activity			
2.2.3	Quarry	There are 6 main quarries in the district	25
2.4.3	Metal processing and finishing industry	Plastic pipes and tiles factories	40
2.4.6	Chemical industry	Detergents factory	65
2.4.10	Food industry	Sinnuqrot factory, Coca cola, dairy products	45
2.7.2	Surface impoundment for industrial wastewater	Ramallah wastewater treatment plant	65
Livestock and Agriculture			
3.1.3	Factory farm (sloughing house)	Ramallah and Al	30
3.2.4	Intensive agriculture area with high demand of fertilizers and pesticides)	-	30

Hazard Mapping

- The hazard map shows the distribution and location of different kinds of hazards with a common defined attribute. The hazards are represented on the map by means of symbols or signatures of different color to indicate their potential degree of harmfulness as derived from the calculation of a Hazard Index.

Hazard Index	Hazard Index Class	Hazard Level	Color
0 - 24	1	no or very low	Blue
> 24 – 48	2	low	Green
> 48 – 72	3	moderate	Yellow
> 72 – 96	4	high	Orange
> 96 - 120	5	very high	Red

Unclassified Hazard Index Map
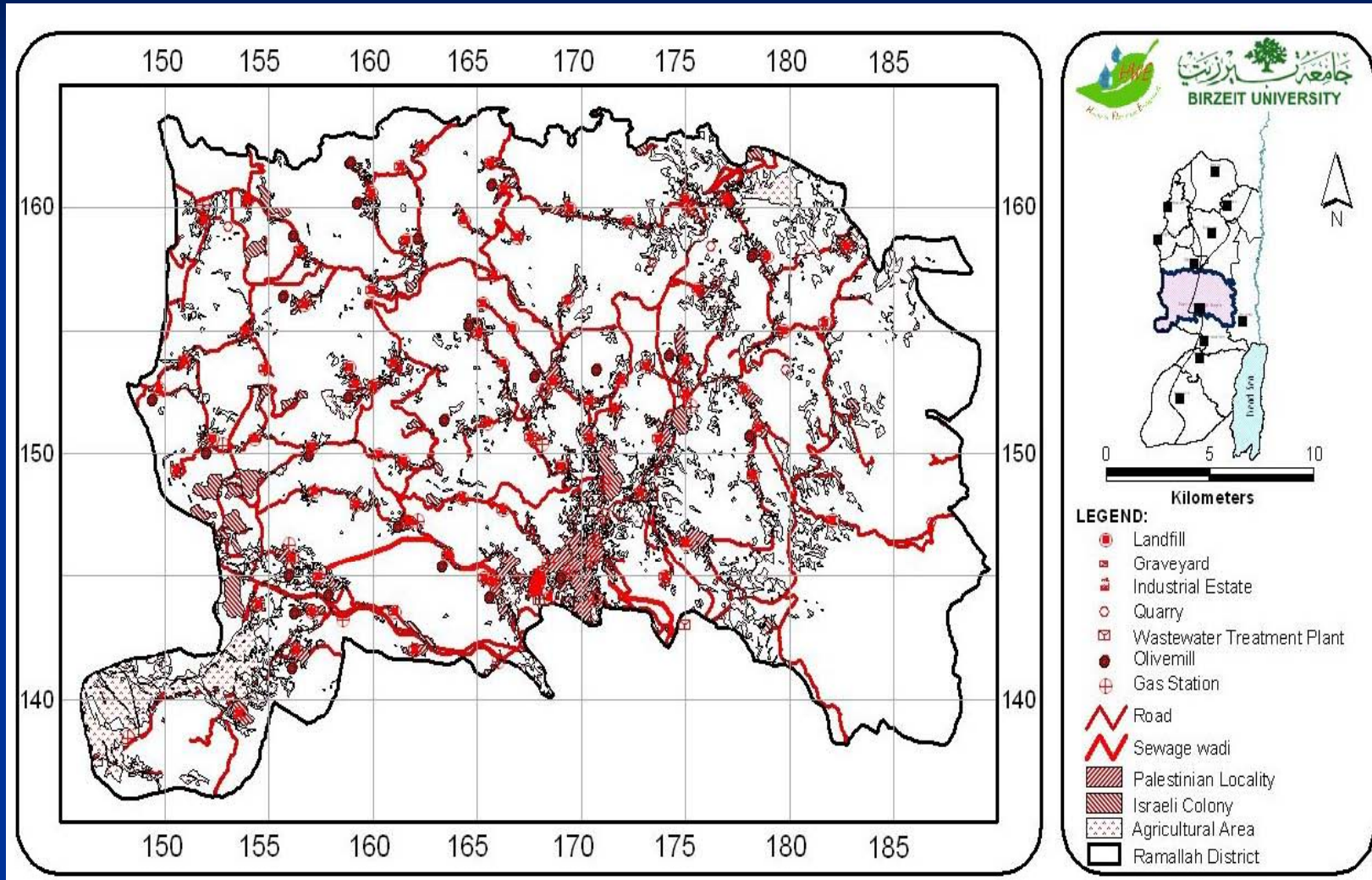
Classified Hazard Index Map
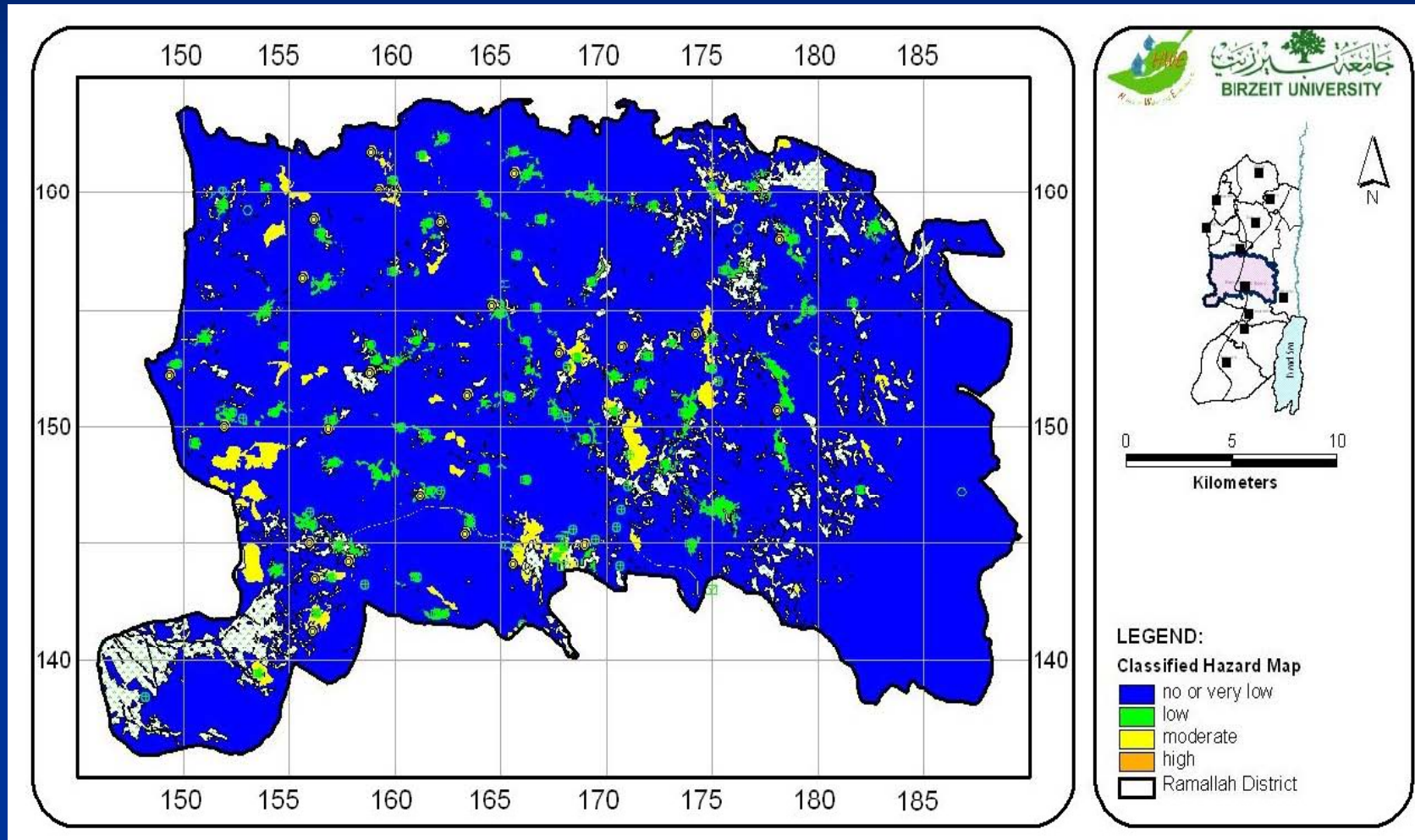
Risk Map

- After preparing the hazard map and the vulnerability map one can predict the pollution risk by preparing a risk assessment map.

- The risk assessment is based on the intrinsic vulnerability map constructed using the PI method and the hazard map and focuses on risk assessment for the groundwater resource. By overlaying the vulnerability and hazard maps and multiplying the specific assessment value of the vulnerability by the assessed value of the hazard a new value is calculated. This new value describes the risk of groundwater contamination dependent upon the hazard characteristics and the nature of the pathway to the groundwater that is given by the vulnerability map.
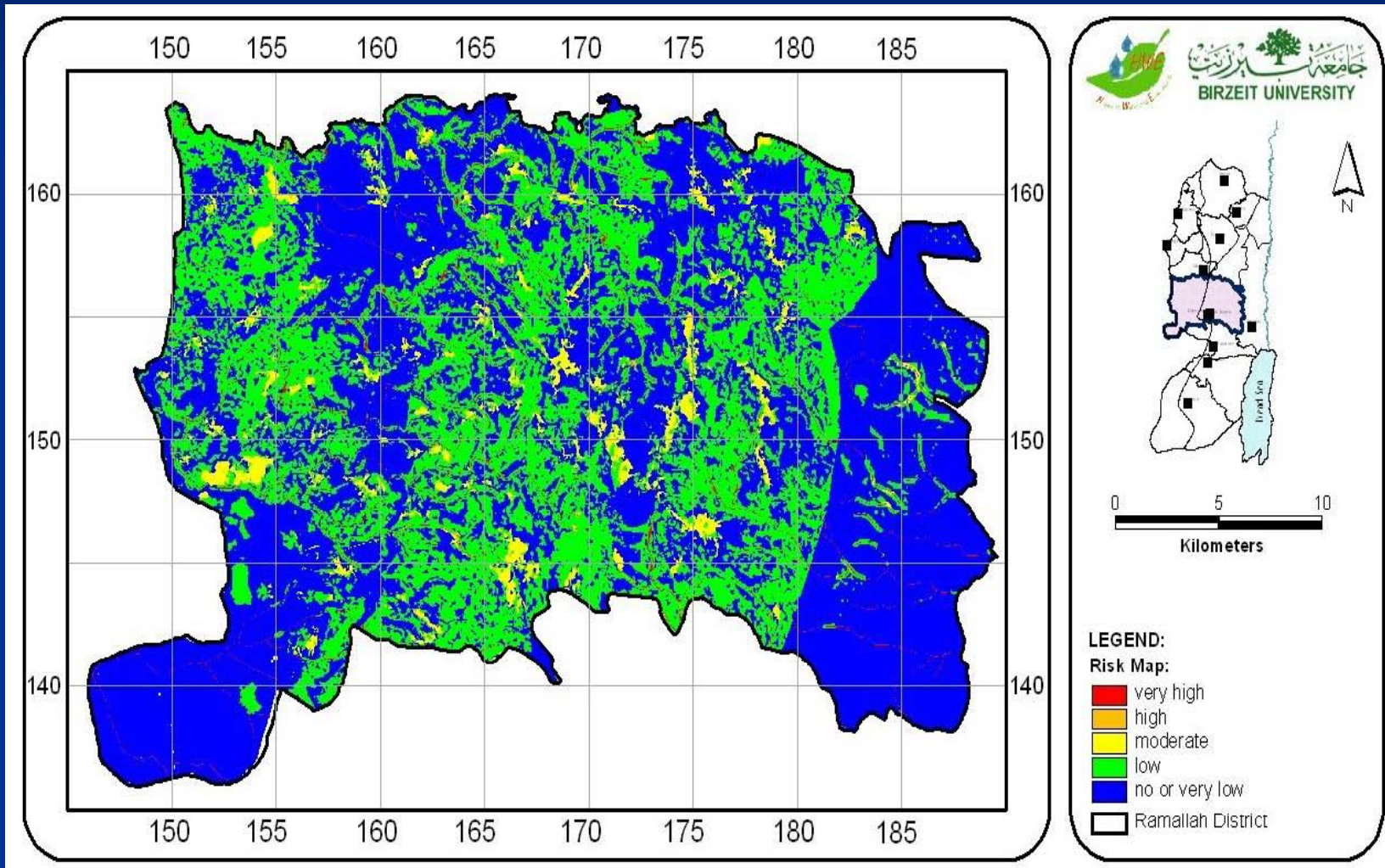
Risk Map

Using the following equation:

$$R = \left(\frac{1}{HI} \right) \cdot \pi$$

Where,

R	risk value
HI	Hazard Index
π	PI- Factor (vulnerability)

π- factor	HI	1/HI	$\pi \cdot$ (1/HI)	Risk Class	Risk Level	Color
4-5	0-24	> 0.042	> 0.167	1	no or very low	Blue
3-4	24-48	0.042-0.021	0.167-0.063	2	low	Green
2-3	48-72	0.021-0.014	0.063-0.028	3	moderate	Yellow
1-2	72-96	0.014-0.010	0.028-0.010	4	high	Orange
0-1	96-120	< 0.010	< 0.010	5	very high	Red

Risk Map

THANK YOU