

**"AN INTERPRETATION FOR THE FUTURE"**

**EXPERIMENTAL PROPOSALS FOR BUILDING THE  
SAHARA DESERT BY HIDDEN RESOURCES**

AUTHOR: MOHAMED NABIL ELSAYED ELSHEIKHA 796939  
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SUPERVISOR: PROF. ELISA CATTANEO

*To the poor, oppressed, and peace seekers..*

ABSTRACT:

THE THESIS WORK IS A TRIAL FOR A SOLUTION TO MANY THREATS FACING THE MEDITERRANEAN REGION. THE MEDITERRANEAN IS A VERY COMPLICATED REGION, CONNECTING THREE DIFFERENT CONTINENTS, A SOURCE OF LIFE FOR MILLIONS OF PEOPLE WHO SHARE THE SAME SEA, BUT NOT THE SAME CULTURE, LANGUAGE, GOVERNMENT, AND NATURE.

ILLEGAL MIGRATION BY CROSSING THE MEDITERRANEAN SEA TO ENTER EUROPE IS ONE OF THE MOST THREATENING PROBLEMS FACING THE REGION. THE HIGH DENSE CITIES, AND BUILDING ON AGRICULTURAL LANDS ARE TWO MAJOR PROBLEMS FACING NORTH AFRICAN COUNTRIES, WHICH LEADS TO THE ILLEGAL MIGRATION TO EUROPE WHERE THERE IS A PERCENTAGE OF UNEMPLOYMENT FOR EUROPEAN YOUTH, WHICH DOES NOT SOLVE THE PROBLEM, BUT MAKES IT MORE COMPLICATED. ALSO THE FLOODING POSSIBILITY IS A THREAT FOR BOTH SIDES OF THE MEDITERRANEAN SHORES. THE THESIS IS PROPOSING A GENERAL IDEA AS A SOLUTION FOR THE MENTIONED THREATS.

MIGRATION TO THE NORTH BY CROSSING THE MEDITERRANEAN SEA IS A DANGEROUS SOLUTION. THE THESIS IS ALSO PROPOSING MIGRATION, BUT A BIT TO THE SOUTH INSTEAD; MOVING TO THE SAHARA DESERT IN NORTHERN AFRICA! IS IT POSSIBLE? THE ANSWER TO THIS QUESTION IS SHOWN IN THE DIFFERENT CHAPTERS OF THE THESIS, TAKING IN CONSIDERATION THE THREE KEYWORDS OF THE PROPOSAL (MOVING TO THE SAHARA DESERT). THE THESIS DESCRIBES AND ANALYSES THE "SAHARA" IN DETAIL, HIGHLIGHTING SOME IMPORTANT NATURAL RESOURCES WITH HIGH POTENTIAL THAT COULD BE USED IN THE EXPERIMENTAL PROPOSALS, ALSO STUDYING VERNACULAR ARCHITECTURE AND THE TECHNOLOGY OF EARTH BUILDING. INFRA-FREE SYSTEMS, BUILDING IN EXTREME ENVIRONMENTS, AND HOT WEATHER IS MENTIONED AS A PROOF OF THE POSSIBILITY OF BUILDING IN A "DESERT". SHOWING MIGRATION CONCEPTS, AND SOME FORCED MIGRATION CASE STUDIES IS ESSENTIAL FOR THE THIRD KEYWORD OF THE PROPOSAL, WHICH IS "MOVING". FINALLY, THE THESIS PROPOSES LAND USE, URBAN, ENVIRONMENTAL AND ARCHITECTURAL EXPERIMENTAL PROPOSALS USING THE SAHARA'S RESOURCES FOR THE POSSIBILITY OF LIVING IN IT AND CREATING NEW PEASANT COMMUNITIES FOR THE FUTURE OF THE REGION'S AGRICULTURE AND FOOD INDEPENDENCY.

IT IS POSSIBLE TO LIVE IN THE SAHARA; THE THESIS'S PROPOSAL PROVES THIS POSSIBILITY AND SHOWS THAT IT COULD BE INHABITABLE WITH THE LEAST COSTS, ONLY BY USING ITS LOCAL RESOURCES, ALSO SHOWS IN TIMELINE HOW FAST IS THIS POSSIBILITY WITH SELF-SUFFICIENCY. AS FOR INFRASTRUCTURE, THERE MUST BE A GOVERNMENTAL WILL FOR CONNECTING THE SAHARA WITH THE EXISTING NORTH AFRICAN DENSE CITIES.

FINALLY, THE THESIS INTERPRETS THE FUTURE OF THE SOUTHERN MEDITERRANEAN REGION IN GENERAL, AND IT'S MOST SIGNIFICANT PROBLEM WHICH IS MIGRATION.

## CONTENTS

1 THE MEDITERRANEAN REGION	9	4 EXTREME ARCHITECTURE	83
1.1 THREATS		4.1 INFRA-FREE SYSTEMS	84
1.1.1 HIGH DENSITY	10	4.2 BUILDING IN HOT WEATHER	86
1.1.2 BUILDING ON AGRICULTURAL LANDS	12	4.3 BUILDING IN HOT WEATHER CASE STUDIES	90
1.1.3 SOCIAL AND ECONOMIC PROBLEMS	14	A) SCHOOL BUILDINGS, GRADO AND DANO, BURKINA FASO	
A) MIGRATION		B) CENTRAL MARKET, KOUDOUGOU, BURKINA FASO	
B) UNEMPLOYMENT			
1.1.4 FLOODING POSSIBILITY	18		
1.2 A POSSIBLE SOLUTION (GENERAL IDEA)	20	5 MIGRATION	99
		5.1 NOMADIC ARCHITECTURE	100
		5.2 MOVABLE ARCHITECTURE	102
		5.3 FORCED MIGRATION CASE STUDIES	104
2 THE SAHARA DESERT	23	A) NEW GOURNA VILLAGE, LUXOR, EGYPT	
2.1 WHY THE SAHARA?	24	B) DUNE, SAHEL REGION, AFRICA	
2.2 WHAT IS THE SAHARA?			
2.2.1 DESCRIPTION AND INFRASTRUCTURE	26		
2.2.2 IMPORTANT RESOURCES	28		
2.2.3 PHYSICAL CHARACTERISTICS	30	6 THE POSSIBLE SOLUTION	111
2.2.4 CLIMATE	32	6.1 A PROPOSED PROJECT	112
2.2.5 LIVING CREATURES	34	6.2 THESIS PROPOSAL	114
2.3 HOW TO LIVE IN THE SAHARA?			
2.3.1 SOCIAL LIFE AND TRADITIONAL BUILDING	36		
A) SIWA OASIS, EGYPT		7 EXPERIMENTAL PROPOSALS	117
B) GHARDAIA, ALGERIA		7.1 RESOURCES USAGE CONCEPT	118
C) TOZEUR OASIS, TUNISIA		7.2 ECOLOGY SYSTEM	120
2.3.2 BUILDING TECHNIQUES	42	7.3 FOOD PRODUCTION	122
A) BUILDING WITH SALT		7.4 TIMELINE//STOREYBOARD	124
B) BUILDING WITH SAND		7.5 LAND USE STRATEGIES AND GUIDELNES	126
C) BUILDING WITH MUD		7.6 URBAN//ENVIRONMENTAL STRATEGIES AND GUIDELNES	128
		7.7 LANDSCAPE INFRASTRUCTURE	130
		7.8 ARCHITECTURAL PROPOSALS	132
		7.9 MASTERPLAN CONCEPT	134
		7.10 IMAGINARY MASTERPLAN	136
3 VERNACULAR ARCHITECTURE	49		
3.1 VERNACULAR ARCHITECTURE	50		
3.2 BUILDING WITH EARTH			
3.2.1 THE TECHNOLOGY OF EARTH BUILDING	56		
A) INTRODUCTION			
B) THE PROPERTIES OF EARTH AS A BUILDNG MATERIAL			
C) RAMMED EARTHWORKS			
D) WORKING WITH EARTHEN BLOCKS			
E) LARGE BLOCKS AND PREFABRICATED PANELS			
F) DIRECT FORMING WITH WET LOAM			
G) WET LOAM INFILL IN SKELETON STRUCTURES			
3.2.2 BUILT EXAMPLES	78		
		8 REFERENCES	140



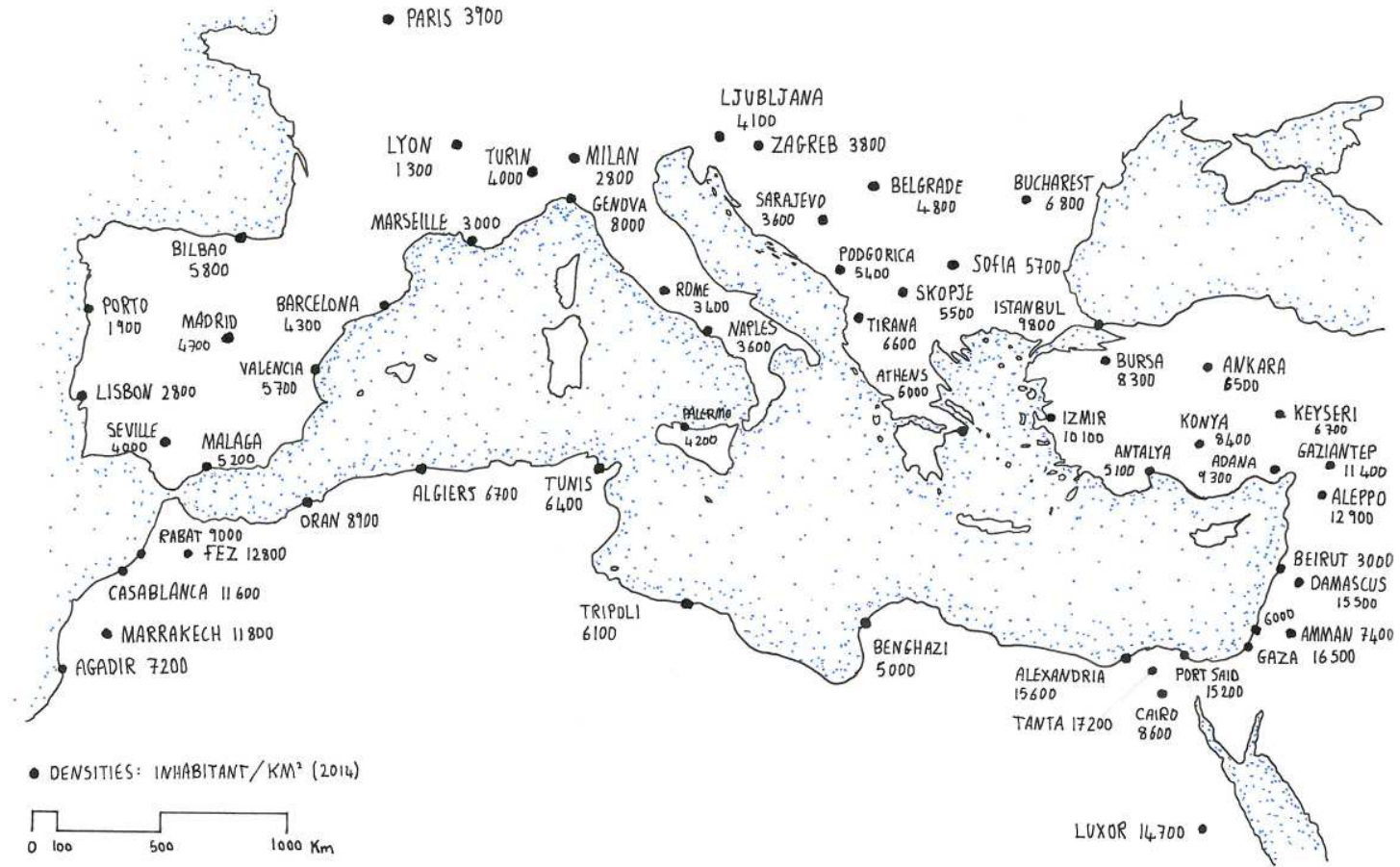
## CHAPTER 1

### THE MEDITERRANEAN REGION

**THE MEDITERRANEAN REGION  
THREATS**

**HIGH DENSITY**

THE TOTAL POPULATION OF THE MEDITERRANEAN COUNTRIES GREW FROM 276 MILLION IN 1970 TO 412 MILLION IN 2000 (A 1,35% INCREASE PER YEAR) AND TO 466 MILLION IN 2010. THE POPULATION IS PREDICTED TO REACH 529 MILLION BY 2025. FOUR COUNTRIES ACCOUNT FOR ABOUT 60% OF THE TOTAL POPULATION: TURKEY, EGYPT, FRANCE, AND ITALY. OVERALL, MORE THAN HALF THE POPULATION LIVES IN COUNTRIES ON THE SOUTHERN SHORES OF THE MEDITERRANEAN, AND THIS PROPORTION IS EXPECTED TO GROW TO THREE QUARTERS BY 2025. THE MEDITERRANEAN REGION'S POPULATION IS CONCENTRATED NEAR THE COASTS. MORE THAN A THIRD LIVE IN COASTAL ADMINISTRATIVE ENTITIES TOTTALLING LESS THAN 12% OF THE SURFACE AREA OF THE MEDITERRANEAN COUNTRIES. THE POPULATION OF THE COASTAL REGIONS GREW FROM 95 MILLION IN 1979 TO 143 MILLION IN 2000. IT COULD REACH 174 MILLION BY 2025. THE CONCENTRATION OF POPULATION IN COASTAL ZONES IS HEAVIEST IN THE WESTERN MEDITERRANEAN, THE WESTERN SHORE OF THE ADRIATIC SEA, THE EASTERN SHORE OF THE AEGEAN-LEVANTINE REGION, AND THE NILE DELTA. OVERALL, THE CONCENTRATION OF POPULATION IN THE COASTAL ZONE IS HIGHER IN THE SOUTHERN MEDITERRANEAN COUNTRIES.



CAIRO  
10



CASABLANCA



ALEXANDRIA



**THE MEDITERRANEAN REGION  
THREATS**

**BUILDING ON AGRICULTURAL LANDS**

IN THE LAST DECADES, NORTH AFRICAN COUNTRIES MOVED BETWEEN THE NEED TO EXPLOIT THEIR COMPARATIVE ADVANTAGES IN PRODUCTION AND EXPORTS OF FRUITS AND VEGETABLES, AND THE NEED TO FOSTER THEIR TRADITIONAL FARMING TO REDUCE FOOD DEPENDENCY. ONE OF THE REASONS OF THE DECREASE OF AGRICULTURAL DEVELOPMENT IS BUILDING ON AGRICULTURAL LAND AS AN EXTENSION OF EXISTING CITIES AND URBAN AREAS.

**AGRICULTURE IN NORTH AFRICA:**

AGRICULTURE IS AN IMPORTANT SECTOR ON BOTH SHORES OF THE MEDITERRANEAN BASIN. MORE THAN AN ECONOMIC ACTIVITY, IT IS PART OF THE CULTURE AND LANDSCAPE OF THE COUNTRIES OF THE REGION. IN NORTH AFRICAN COUNTRIES, THE RURAL WORLD REMAINS A SIGNIFICANT RESERVE OF LABOR FORCE FOR THE REST OF THE ECONOMY. THESE COUNTRIES STILL EXPERIENCE CONSIDERABLE POPULATION GROWTH AND ARE HIGHLY DEPENDENT ON IMPORTS OF BASIC PRODUCTS (CEREALS, MEAT, AND MILK AND DAIRY PRODUCTS), WHICH COMPETE WITH TRADITIONAL PRODUCTION SYSTEMS THAT FACE STRUCTURAL AND NATURAL CONSTRAINTS.

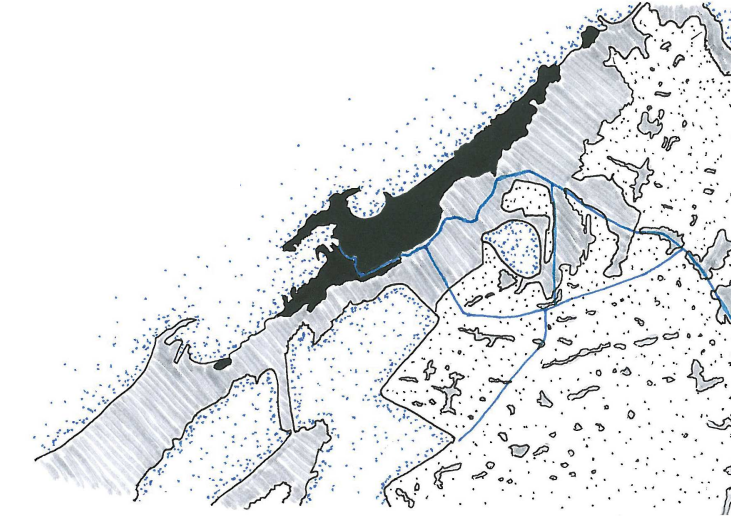
**AGRICULTURAL CONSTRAINTS:**

ALTHOUGH NORTH AFRICAN COUNTRIES HAVE MADE CONSIDERABLE EFFORTS TO IMPROVE THEIR AGRICULTURAL CONDITIONS, THEY CONTINUE TO STRUGGLE WITH A POOR ENDOWMENT OF CULTIVABLE LAND AND WATER. IN NORTH AFRICA, THE DRY CLIMATIC AND SOIL CONDITIONS SEVERELY LIMIT INCREASES IN ACREAGE. IN ALMOST ALL COUNTRIES OF THE REGION, THE IRRIGATED AREA HAS GROWN SIGNIFICANTLY DUE TO THE BUILDING OF VARIOUS KINDS OF DAMS, PARTICULARLY IN EGYPT. BUT GRAIN YIELDS REMAIN VERY LOW IN MOROCCO, TUNISIA, AND ALGERIA, LOWER THAN YIELDS IN OTHER COUNTRIES OF THE EURO-MEDITERRANEAN REGION (TURKEY, LEBANON AND ISRAEL). YIELDS ARE HIGHER UNDER IRRIGATION, AS IS THE CASE WITH RICE IN EGYPT.

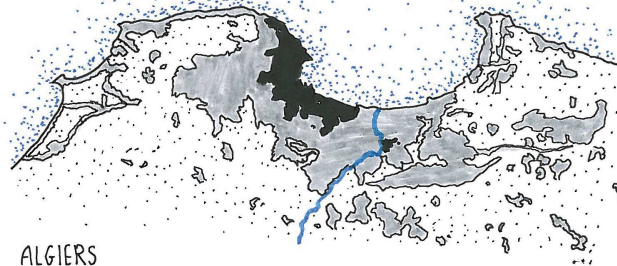
AGRICULTURE IS STILL THE MAIN LIVELIHOOD OF A SUBSTANTIAL PART OF THE POPULATION IN A REGION LIVING BELOW THE POVERTY THRESHOLD. THOUGH THE SHARE OF AGRICULTURAL WORKERS IN TOTAL EMPLOYMENT HAS GENERALLY DECLINED, AGRICULTURAL EMPLOYMENT STILL ACCOUNTS FOR OVER 30% OF THE TOTAL WORKFORCE IN EGYPT AND NEARLY 30% IN MOROCCO. 70% OF THE POOR ON THE SOUTHERN SHORE OF THE MEDITERRANEAN BASIN ARE CONCENTRATED IN RURAL AREAS.

**FOOD SECURITY PROSPECTS:**

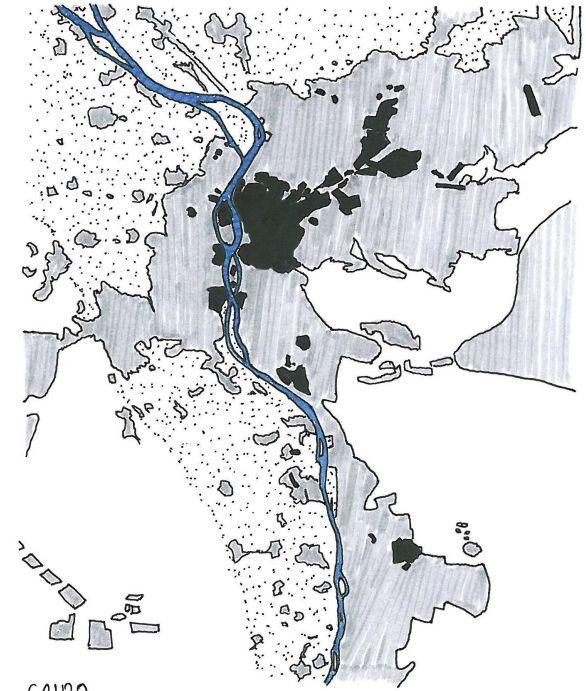
THE EFFORTS TO EXPAND THE AGRICULTURAL AREA (AND EVEN THE IRRIGATED AREA) AND MODERNIZE THE AGRICULTURAL SECTOR HAVE RESULTED IN A



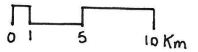
ALEXANDRIA



ALGIERS



CAIRO



- BUILT-UP AREA 1950s
- AGRICULTURAL LAND
- BUILT-UP AREA 2010s
- DESERT

SIGNIFICANT INCREASE IN AGRICULTURAL PRODUCTION IN RECENT YEARS. HOWEVER, THERE ARE CONSIDERABLE ANNUAL FLUCTUATIONS IN PRODUCTION DEPENDING ON WEATHER CONDITIONS, AND DOMESTIC FOOD DEMAND HAS CONTINUED TO GROW IN STEP WITH DEMOGRAPHIC CHANGE AND URBANIZATION. WITH REGARD TO DOMESTIC MARKETS, NORTH AFRICA IS ONE OF THE WORLD REGIONS WITH THE LARGEST PERCENTAGE OF RURAL POPULATION WITH POOR MARKET ACCESS. AN OUTSTANDING FEATURE IN NORTH AFRICAN COUNTRIES IS THE NET NEGATIVE AGRICULTURAL TRADE BALANCE.



SATELLITE IMAGE OF CAIRO



**THE MEDITERRANEAN REGION**  
**THREATS**  
**SOCIAL AND ECONOMIC PROBLEMS**

**MIGRATION**

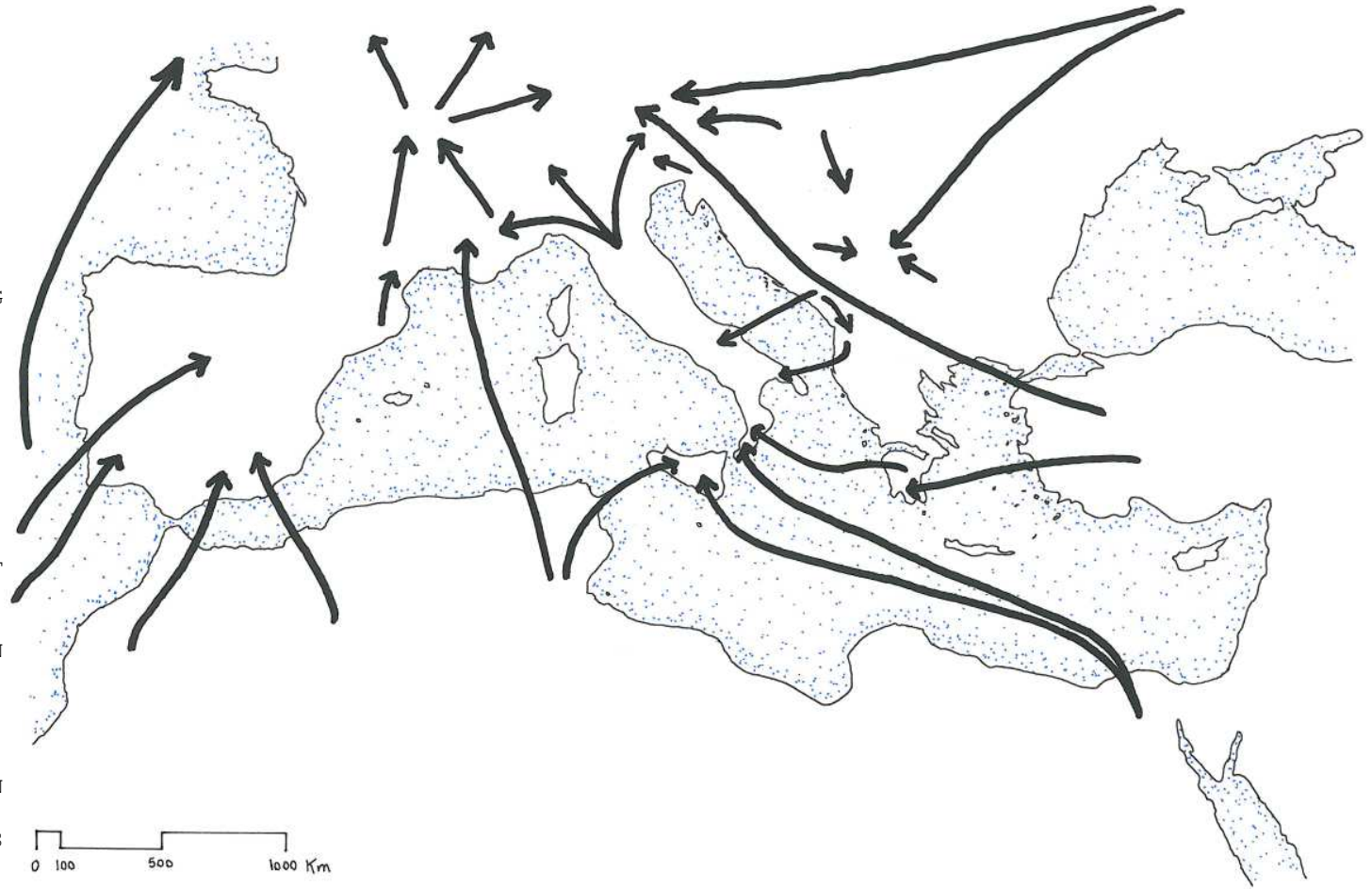
*THE MEDITERRANEAN: A SEA OF MIGRANTS IN DANGER*  
THOUSANDS OF MIGRANTS RISK THEIR LIVES TO GET TO EUROPE BY CROSSING THE MEDITERRANEAN. THEY DO SO TO ESCAPE WAR, PERSECUTION OR POVERTY. MANY DO NOT SURVIVE THE JOURNEY.

THE MAJORITY OF MIGRANT BORDER-RELATED DEATHS HAVE OCCURRED IN THE MEDITERRANEAN SEA. ACCORDING TO ESTIMATES BY THE INTERNATIONAL ORGANIZATION FOR MIGRATION (IOM), 3072 PEOPLE HAVE DIED ONLY IN 2014 TRYING TO REACH EUROPEAN TERRITORY BY CROSSING THE MEDITERRANEAN. THIS FIGURE REPRESENTS 75% OF THE TOTAL MIGRATION-RELATED DEATHS IN THE WORLD THIS YEAR.

ACCORDING TO THE IOM'S REPORT FATAL JOURNEYS: TRACKING LIVES LOST DURING MIGRATION, 22,394 PEOPLE DIED IN MIGRATORY ROUTES TO EUROPE FROM 1996 TO 2014. HOWEVER, IOM BELIEVES THE NUMBER OF CASUALTIES MAY BE EVEN HIGHER THAN STATED IN THE REPORT.

IN OCTOBER 2013, LAMPEDUSA HIT THE HEADLINES WHEN 360 PEOPLE DIED WHILE TRYING TO REACH EUROPEAN TERRITORY AFTER A BOAT WITH MORE THAN 500 MIGRANTS ON BOARD SANK NEAR THE ITALIAN ISLAND. THIS WAS NEITHER THE FIRST NOR THE LAST INCIDENT INVOLVING MIGRANTS TO HAPPEN IN THE MEDITERRANEAN SEA. SINCE 2011, AN INCREASING NUMBER OF PEOPLE HAVE BEEN RISKING THEIR LIVES IN DECAYING VESSELS TO ENTER EUROPE.

THE ITALIAN ISLAND OF LAMPEDUSA HAS BEEN ONE OF THE MAIN EUROPEAN ARRIVAL POINTS. THE LOCAL RECEPTION CENTRE FOR MIGRANTS IS OVERCROWDED.



ITALIAN SHORES



ITALIAN SHORES

**THE MEDITERRANEAN REGION**  
**TREATS**  
**SOCIAL AND ECONOMIC PROBLEMS**

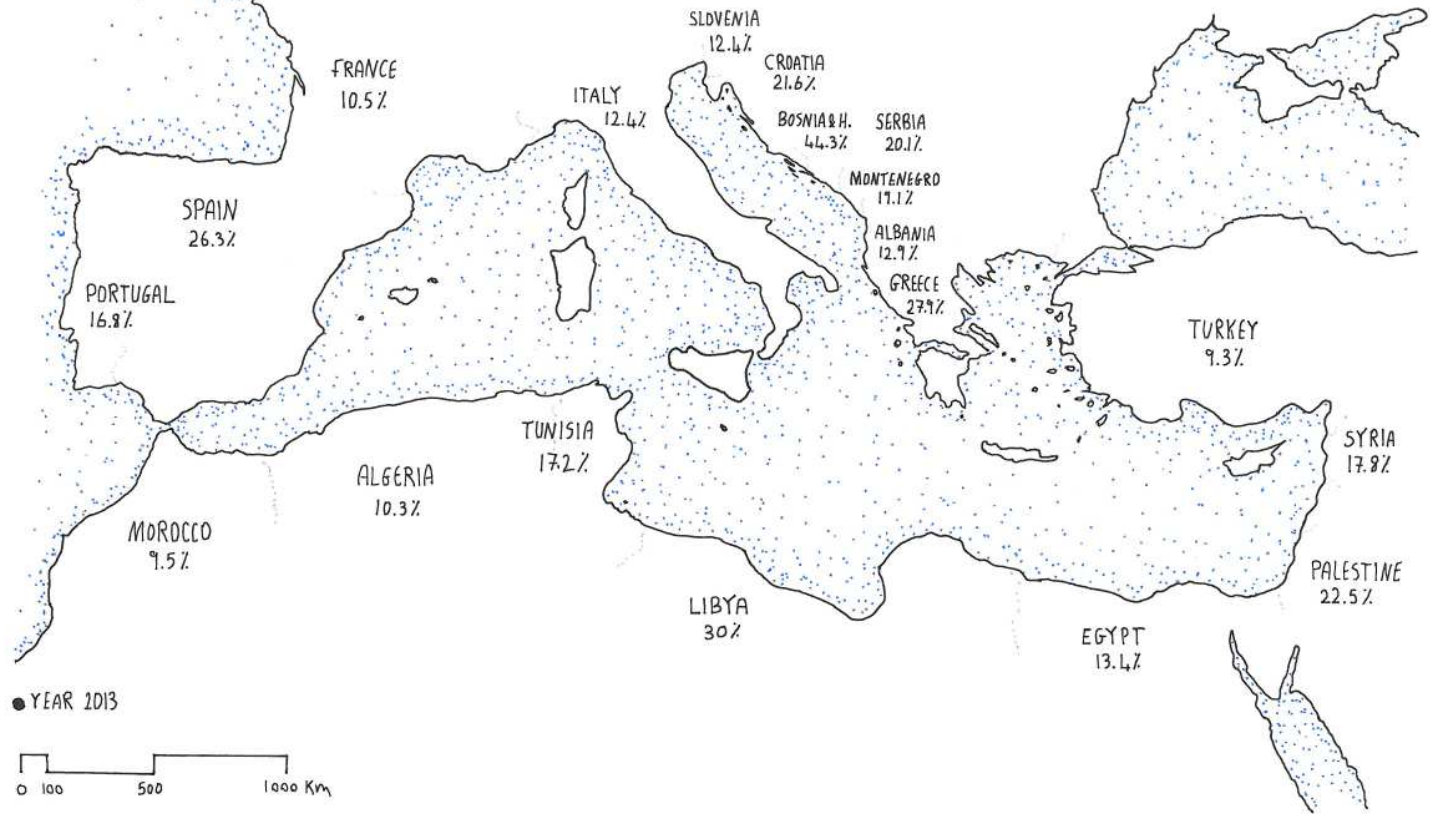
**UNEMPLOYMENT**

THE PAIN OF SOUTHERN EUROPE'S UNEMPLOYED GREECE, WHERE THE UNEMPLOYMENT RATE IS 27.9%, SPAIN, WITH A RATE OF 26.3%, AND PORTUGAL, WITH A RATE OF 16.8%.

PERHAPS THE MOST DISTURBING FIGURE IS FOR YOUTH UNEMPLOYMENT. THE AVERAGE RATE FOR THE UNDER 25S IN THE EU IS 23.5%. NEARLY A QUARTER OF EUROPE'S YOUTH ARE NOT WORKING. IN SPAIN THE FIGURE IS 55.7%.

FOR THE MOMENT THE STRATEGY FOR KEEPING THE EUROZONE TOGETHER IS SHARPENING EUROPE'S DIVIDE. THE GERMANS BELIEVE THAT A COMBINATION OF AUSTERITY AND STRUCTURAL REFORMS WILL EVENTUALLY SPARK GROWTH IN SOUTHERN EUROPE AND NARROW THE GAP IN COMPETITIVENESS.

THERE ARE A SIGNIFICANT NUMBER OF OFFICIALS AND ECONOMISTS, HOWEVER, WHO DOUBT THE POLICY IS WORKING. INDEED THEY BELIEVE THAT SEVERAL COUNTRIES ARE NOW TRAPPED IN A CYCLE OF DECLINE. THE FRENCH PRESIDENT FRANCOIS HOLLANDE SAID THAT "STICKING WITH AUSTERITY WOULD CONDEMN EUROPE NOT JUST TO RECESSION BUT AN EXPLOSION".



GREECE



SPAIN



SPAIN



## THE MEDITERRANEAN REGION THREATS

### FLOODING POSSIBILITY

CORE SAMPLES, TIDE GAUGE READINGS, AND, MOST RECENTLY, SATELLITE MEASUREMENTS TELL US THAT OVER THE PAST CENTURY, THE GLOBAL MEAN SEA LEVEL (GMSL) HAS RISEN BY 10 TO 20 CM. HOWEVER, THE ANNUAL RATE OF RISE OVER THE PAST 20 YEARS HAS BEEN 3.2 MM A YEAR, ROUGHLY TWICE THE AVERAGE SPEED OF THE PRECEDING 80 YEARS.

OVER THE PAST CENTURY, THE BURNING OF FOSSIL FUELS AND OTHER HUMAN AND NATURAL ACTIVITIES HAS RELEASED ENORMOUS AMOUNTS OF HEAT-TRAPPING GASES INTO THE ATMOSPHERE. THESE EMISSIONS HAVE CAUSED THE EARTH'S SURFACE TEMPERATURE TO RISE, AND THE OCEANS ABSORB ABOUT 80% OF THIS ADDITIONAL HEAT.

THE RISE IN SEA LEVELS IS LINKED TO THREE PRIMARY FACTORS, ALL INDUCED BY THIS ONGOING GLOBAL CLIMATE CHANGE:

1. THERMAL EXPANSION: WHEN WATER HEATS UP, IT EXPANDS. ABOUT HALF OF THE PAST CENTURY'S RISE IN SEA LEVEL IS ATTRIBUTABLE TO WARMER OCEANS SIMPLY OCCUPYING MORE SPACE.

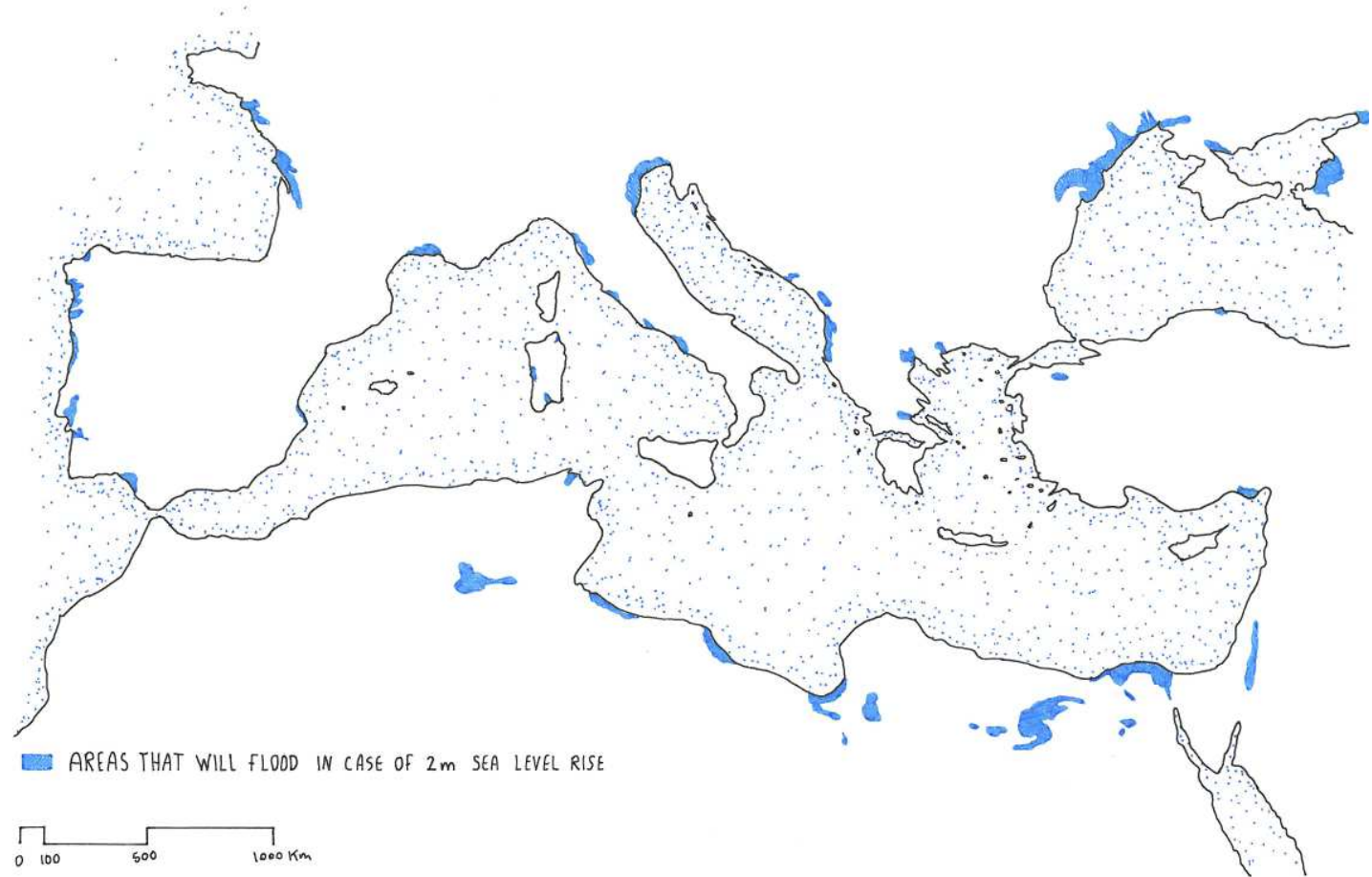
2. MELTING OF GLACIERS AND POLAR ICE CAPS: LARGE ICE FORMATIONS, LIKE GLACIERS AND THE POLAR ICE CAPS, NATURALLY MELT BACK A BIT EACH SUMMER. BUT IN THE WINTER, SNOWS, MADE PRIMARILY FROM EVAPORATED SEAWATER, ARE GENERALLY SUFFICIENT TO BALANCE OUT THE MELTING. RECENTLY, THOUGH, PERSISTENTLY HIGHER TEMPERATURES CAUSED BY GLOBAL WARMING HAVE LED TO GREATER-THAN-AVERAGE SUMMER MELTING AS WELL AS DIMINISHED SNOWFALL DUE TO

LATER WINTERS AND EARLIER SPRINGS. THIS IMBALANCE RESULTS IN A SIGNIFICANT NET GAIN IN RUNOFF VERSUS EVAPORATION FOR THE OCEAN, CAUSING SEA LEVELS TO RISE.

3. ICE LOSS FROM GREENLAND AND WEST ANTARCTICA: AS WITH GLACIERS AND THE ICE CAPS, INCREASED HEAT IS CAUSING THE MASSIVE ICE SHEETS THAT COVER GREENLAND AND ANTARCTICA TO MELT AT AN ACCELERATED PACE. SCIENTISTS ALSO BELIEVE MELTWATER FROM ABOVE AND SEAWATER FROM BELOW IS SEEPING BENEATH GREENLAND'S AND WEST ANTARCTICA'S ICE SHEETS, EFFECTIVELY LUBRICATING ICE STREAMS AND CAUSING THEM TO MOVE MORE QUICKLY INTO THE SEA. MOREOVER, HIGHER SEA TEMPERATURES ARE CAUSING THE MASSIVE ICE SHELVES THAT EXTEND OUT FROM ANTARCTICA TO MELT FROM BELOW, WEAKEN, AND BREAK OFF.

### CONSEQUENCES:

WHEN SEA LEVELS RISE RAPIDLY, AS THEY HAVE BEEN DOING, EVEN A SMALL INCREASE CAN HAVE DEVASTATING EFFECTS ON COASTAL HABITATS. AS SEAWATER REACHES FARTHER INLAND, IT CAN CAUSE DESTRUCTIVE EROSION, FLOODING OF WETLANDS, CONTAMINATION OF AQUIFERS AND AGRICULTURAL SOILS, AND LOST



HABITAT FOR FISH, BIRDS, AND PLANTS.

WHEN LARGE STORMS HIT LAND, HIGHER SEA LEVELS MEAN BIGGER, MORE POWERFUL STORM SURGES THAT CAN STRIP AWAY EVERYTHING IN THEIR PATH.

IN ADDITION, HUNDREDS OF MILLIONS OF PEOPLE LIVE IN AREAS THAT WILL BECOME INCREASINGLY VULNERABLE TO FLOODING. HIGHER SEA LEVELS WOULD FORCE THEM TO ABANDON THEIR HOMES AND RELOCATE. LOW-LYING ISLANDS COULD BE SUBMERGED COMPLETELY.

### HOW HIGH WILL IT GO?

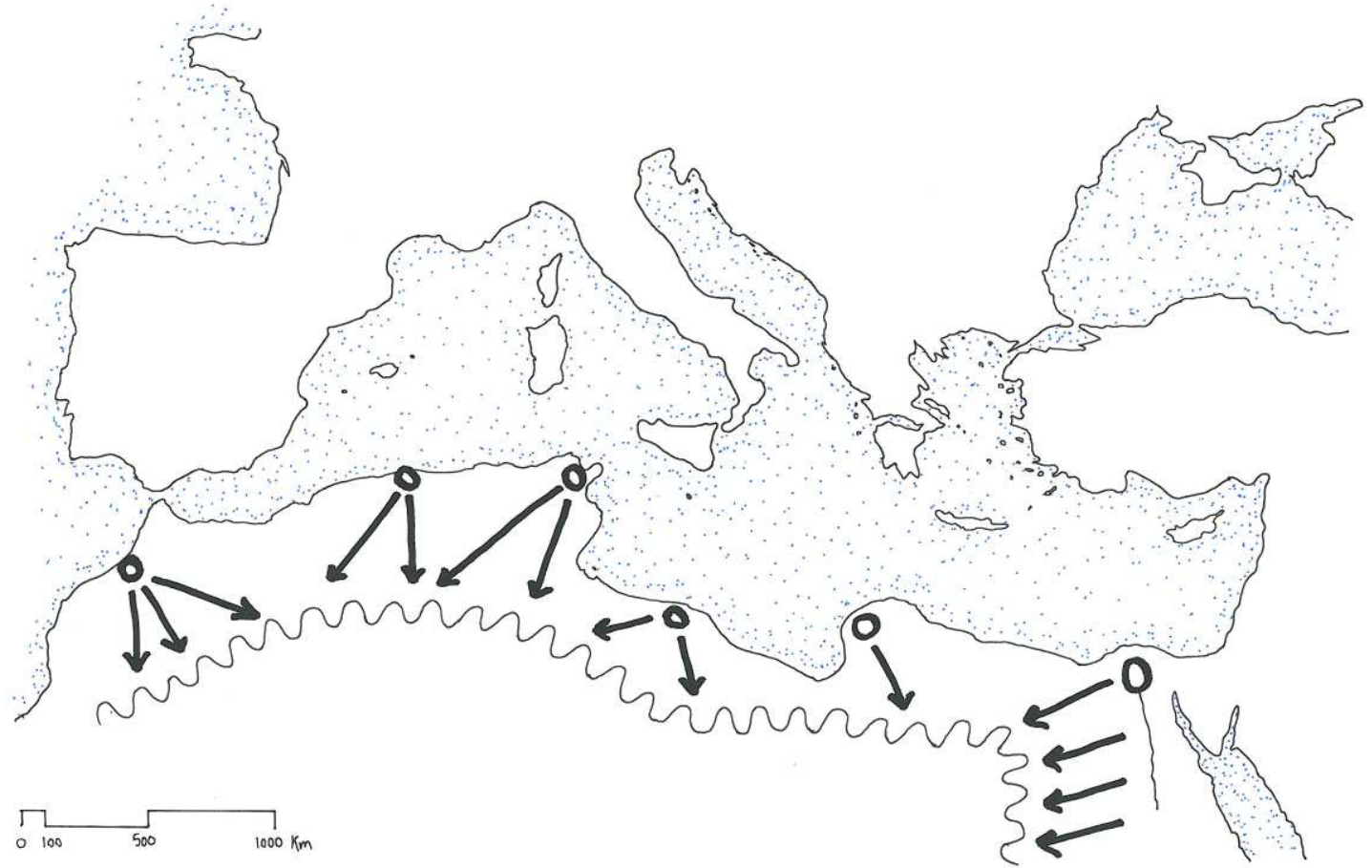
MOST PREDICTIONS SAY THE WARMING OF THE PLANET WILL CONTINUE AND LIKELY WILL ACCELERATE. OCEANS WILL LIKELY CONTINUE TO RISE AS WELL, BUT PREDICTING THE AMOUNT IS AN INEXACT SCIENCE. A RECENT STUDY SAYS WE CAN EXPECT THE OCEANS TO RISE BETWEEN 0.8 AND 2 METRES BY 2100.

**THE MEDITERRANEAN REGION  
A POSSIBLE SOLUTION**

**GENERAL IDEA:**

MOVING TO THE SAHARA DESERT IN THE NORTHERN PART OF AFRICA IS ONE OF THE SOLUTIONS FOR THE ABOVE MENTIONED THREATS, OTHER NATURAL DISASTERS THAT MAY HAPPEN, OR EVEN LOSS OF RESOURCES IN THE NEAR FUTURE.

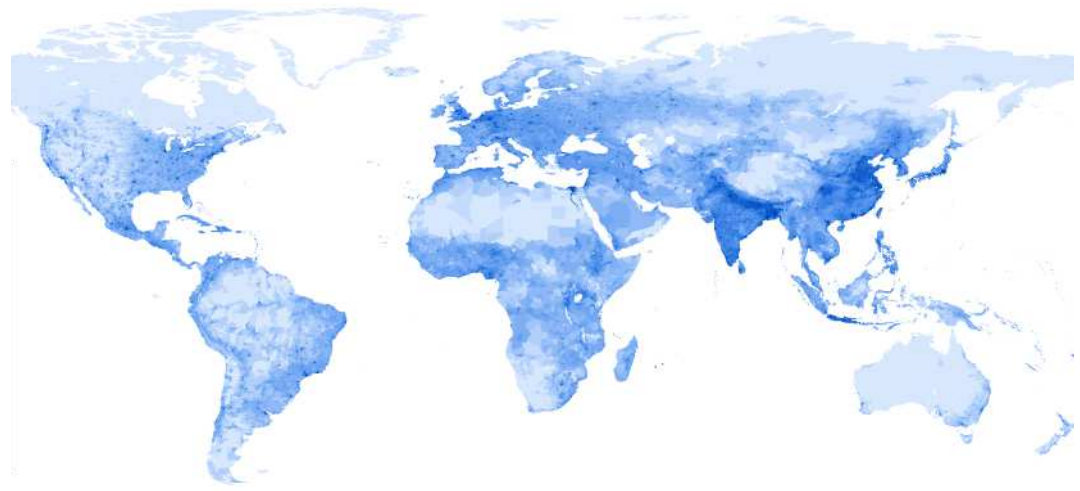
THE SAHARA IS ONE OF THE EMPTIEST PLACES IN THE WORLD, WHERE THE DENSITY IS LESS THAN 0.4 PERSON PER SQUARE KILOMETRE (EXCLUDING THE NILE VALLEY).



THE SAHARA VS THE NILE VALLEY



THE MEDITERRANEAN



WORLD DENSITY

## CHAPTER 2

### THE SAHARA DESERT



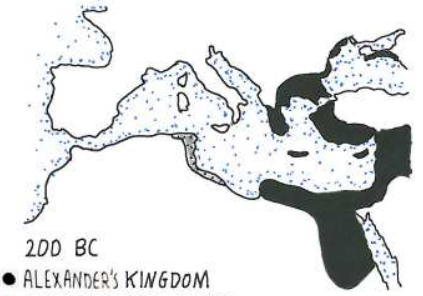
**THE SAHARA DESERT**  
**WHY THE SAHARA?**

HISTORICALLY, SEVERAL ANCIENT CIVILIZATIONS AND STRONG EMPIRES WERE LOCATED AROUND THE MEDITERRANEAN SHORES; THUS IT HAS HAD A MAJOR INFLUENCE ON THOSE CULTURES. IT PROVIDED ROUTES FOR TRADE, COLONIZATION AND WAR, AND PROVIDED FOOD (BY FISHING AND THE GATHERING OF OTHER SEAFOOD) FOR NUMEROUS COMMUNITIES THROUGHOUT THE AGES. THE SHARING OF SIMILAR CLIMATE, GEOLOGY AND ACCESS TO A COMMON SEA LED TO NUMEROUS HISTORICAL AND CULTURAL CONNECTIONS BETWEEN THE ANCIENT AND MODERN SOCIETIES AROUND THE MEDITERRANEAN.

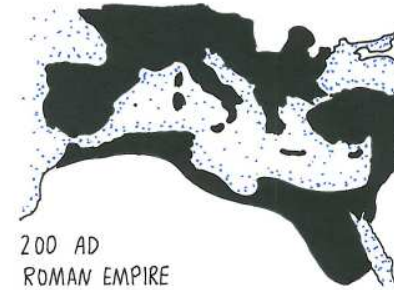
THE SAHARA WAS ALWAYS A PART OF THESE CIVILIZATIONS AND EMPIRES, IN WHICH IT PROVIDED MANY IMPORTANT RECOURSES.



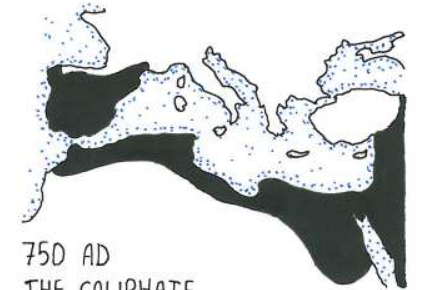
1500 BC  
 ● EGYPTIAN CIVILIZATION  
 ■ AEGEAN CIVILIZATION



200 BC  
 ● ALEXANDER'S KINGDOM  
 ■ CARTHAGINIAN EMPIRE



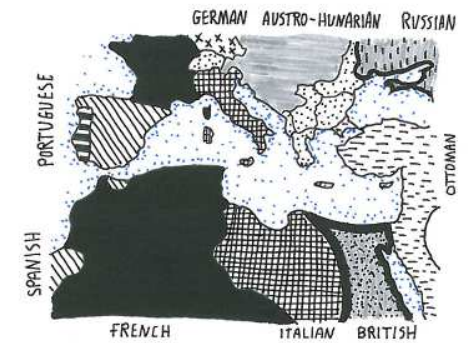
200 AD  
 ROMAN EMPIRE



750 AD  
 THE CALIPHATE



1648 AD  
 OTTOMAN EMPIRE



1914 AD  
 EUROPEAN EMPIRES

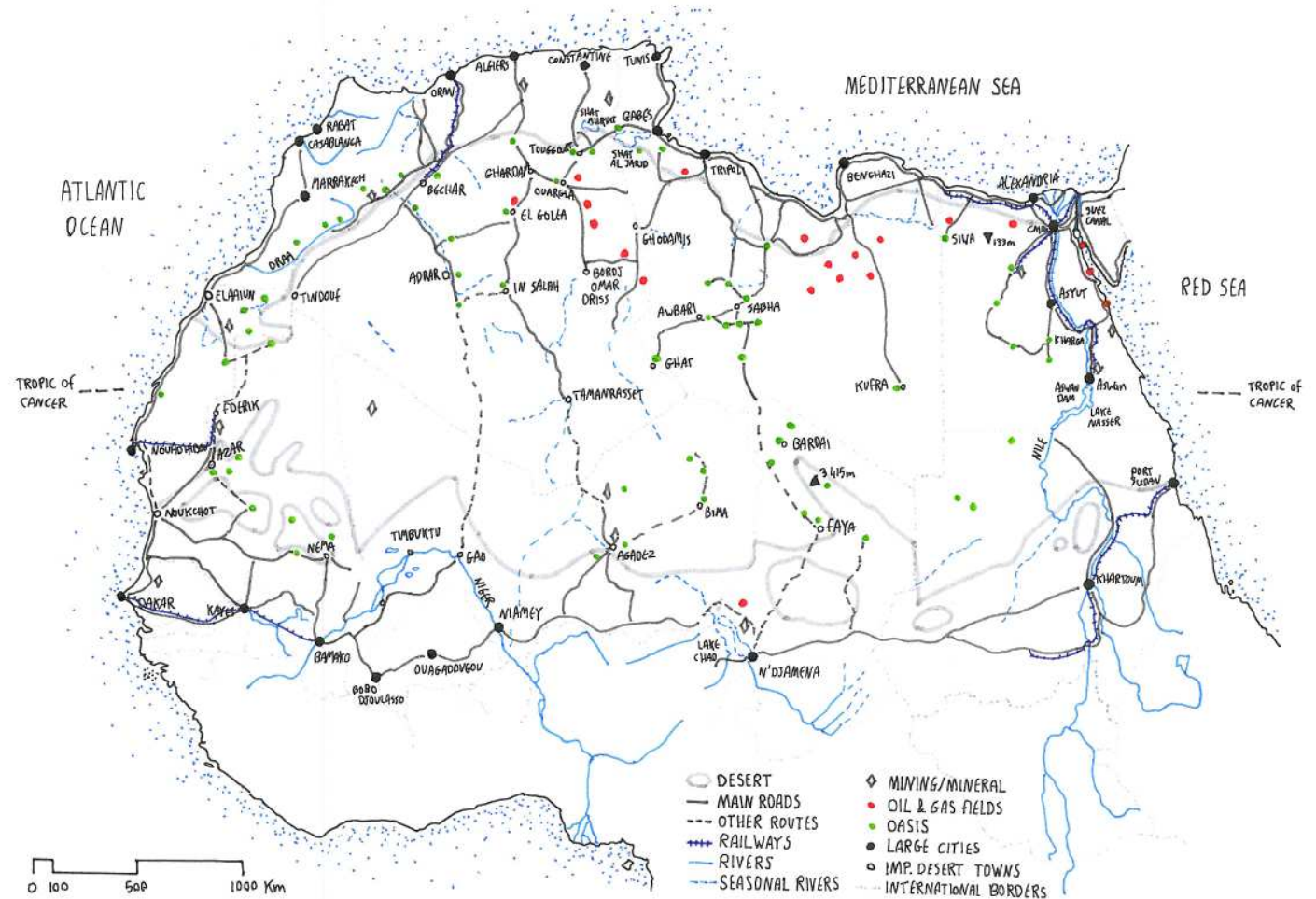
**THE SAHARA DESERT**  
**WHAT IS THE SAHARA?**

**DESCRIPTION AND INFRASTRUCTURE**

THE SAHARA IS THE WORLD'S LARGEST DESERT, A WILDERNESS OF STONY PLAINS, MOUNTAINS, HIGH ROCKY PLATEAUS AND BARREN IMMENSE SAND SEAS, STRETCHING FROM THE RED SEA IN THE EAST TO THE ATLANTIC OCEAN IN THE WEST, AND FROM THE SOUTHERN SHORE OF THE MEDITERRANEAN TO ABOUT 10° LATITUDE. THE SAHARA COVERS 9 MILLION SQUARE KILOMETRES, AND CROSSES THE BOUNDARIES OF 11 STATES. SUCH A HUGE AREA INEVITABLY INCLUDES A RANGE OF CLIMATES. THE GREAT, HYPER-ARID CORE DESERT OF THE CENTER HAS IMMENSELY HOT SUMMERS, WHEN TEMPERATURES CAN REACH WELL OVER 55°C IN THE SHADE. IN PLACES LIKE KUFRA, IN LIBYA, OR TOUDENNI, IN MALI, IT MAY NOT RAIN FOR YEARS ON END. BUT ON THE NORTHERN FRINGES, EVEN OF THIS CORE DESERT, IT IS NOT UNCOMMON TO SEE HOAR FROST ON THE DUNES ON A WINTER MORNING. IN THESE PARTS THERE IS VIRTUALLY NO VEGETATION, EXCEPT ALONG SOME OF THE LARGER VALLEYS, WHERE A FEW ACACIA TREES MAY SURVIVE AGAINST THE ODDS, OR IN THE VERY FEW OASES. MOVING NORTH OR SOUTH, THE RAINFALL INCREASES, AND LOW SCRUB, SPARSE GRASS AND THEN TREES APPEAR. IN THE SOUTH, A NEW HAZARD INTRUDES: THE STRONG HARMATTAN WIND BLOWS IN WINTER, OBSCURING THE SUN WITH DUST. IN CONTRAST, THE SUMMITS OF THE AÏR AND TIBESTI ARE QUITE COOL, ESPECIALLY IN WINTER, AND SUPPORT A FEW BUSHES OF THE MEDITERRANEAN FLORA.

**THE LANDSCAPE:**

ALTHOUGH CREATED ON AN ERODED BLOCK OF VERY ANCIENT ROCK, THE SAHARA CONTAINS AN ASTONISHING VARIETY OF LANDSCAPES. IN THE CENTER ARE THE TWO MASSIVE VOLCANIC BLOCKS OF AÏR AND TIBESTI. THE VOLCANIC CONES ARE STILL PRESERVED IN THE TIBESTI, BUT ALL THAT REMAINS IN THE AÏR ARE THE GREAT PILLARS OF LAVA PLUGS. THE VOLCANIC ROCKS REST ON ANCIENT SANDSTONE PLATEAUS, WHICH CONNECT THE AÏR AND TIBESTI MASSIFS AND SPREAD OUT THROUGH THE CENTRAL SAHARA. ON THE FRINGES OF THESE PLATEAUS THERE ARE BROAD, STONY, NEARLY FEATURELESS PLAINS, KNOWN AS SERIR. THE TWO LARGEST ARE THE CALANSCIO SERIR IN LIBYA AND THE TANEZROUFT IN ALGERIA AND MALI (CROSSED EACH YEAR BY THE PARIS-DAKAR RALLY). THESE ARE AS BIG AS FRANCE, AND CAN TAKE DAYS TO DRIVE ACROSS. SAND SEAS COVER ONE-THIRD OF THE SAHARA. IN THE ISSOUANE N ARRARARENE IN ALGERIA, SOME DUNES REACH 122 METRES IN HEIGHT. THE GREATEST SAND SEAS, OR ERGS, LIE IN THE NORTH, NOTABLY THE GREAT EASTERN AND GREAT WESTERN SAND SEAS IN ALGERIA, THE IDEHAN MOURZOUK IN LIBYA AND THE GREAT SAND SEAS OF EGYPT'S WESTERN DESERT. THE GREAT EASTERN ERG COVERS 192,000 KM<sup>2</sup>.



BETWEEN THE SHIFTING DUNES, LONG CORRIDORS OF ROCKY OR COARSE SANDY SOIL CARRY THE CARAVAN ROUTES, AND PRESERVE THE REMAINS OF LAKES THAT FILLED THE HOLLOW IN WETTER TIMES.

**HUMAN SETTLEMENT:**

IN PREHISTORIC TIMES, THE SAHARA WAS MUCH BETTER WATERED. THE EVIDENCE INCLUDES FISH-HOOKS IN AREAS WHERE RAINFALL IS NOW SELDOM EVEN AN ANNUAL EVENT. DURING THE 4000S BC, THE SAHARA BEGINS TO TURN ARID AGAIN. THE RE-ESTABLISHMENT OF THE DESERT CAUSED THE NORTH AND SOUTH TO DEVELOP SEPARATELY, AND TWO MIGRATIONS OF BERBER AND ARAB PEOPLES INTO THE NORTHERN AREA INCREASED THIS DIVISION.

**THE SAHARA DESERT**  
**WHAT IS THE SAHARA?**

**IMPORTANT RESOURCES**

THE SAHARA IS A HOSTILE ENVIRONMENT. RAINFALL IS TOO SCARCE TO SUPPORT CROPS, AND EVEN LIVESTOCK REARING IS NOT GENERALLY A VIABLE ACTIVITY. THIS BARREN ENVIRONMENT CAN BARELY SUPPORT WILDLIFE, LIVESTOCK AND PEOPLE, AND THE FLORA AND FAUNA THAT DO EXIST HAVE HAD TO ADAPT DRAMATICALLY IN ORDER TO SURVIVE. HUMAN COMMUNITIES OF THE SAHARA THROUGHOUT HISTORY HAVE DEVELOPED A RANGE OF REMARKABLE AND INVENTIVE STRATEGIES IN THEIR STRUGGLE FOR SURVIVAL.

THE SAHARA IS CROSSED BY TWO MAJOR RIVER SYSTEMS - THE NILE AND THE NIGER - AND A NUMBER OF SMALLER ONES, SUCH AS THE LAKE CHAD SYSTEM AND THE OUED SAOURA IN ALGERIA. THESE INVALUABLE WATER RESOURCES SUPPORT THE MAJORITY OF THE HUMAN POPULATION OF THE DESERT. OUT OF THE MILLIONS WHO LIVE IN THE SAHARA REGION, THE RIVER SYSTEMS PROVIDE LIVELIHOODS FOR ABOUT 78% OF THEM.

ALTHOUGH THEY ARE LESS THAN 1% OF THE WORLD'S POPULATION, THE DESERT THEY INHABIT COMPRISES ABOUT 8% OF THE EARTH'S LAND AREA. THE SEGMENT OF THE SAHARAN POPULATION THAT RELIES ON THE RESOURCES OF THE DESERT ITSELF, RATHER THAN THE RIVER SYSTEMS, A MERE 0.2% OF THE WORLD'S POPULATION. THIS MAKES THE SAHARA ONE OF THE EMPTIEST REGIONS ANYWHERE ON EARTH.

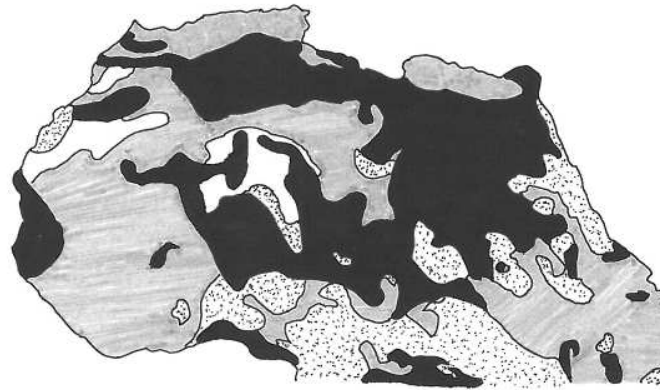
**AN INFINITE RESOURCE?**

WITH SURFACE WATER SO SCARCE AND UNRELIABLE, GROUNDWATER HAS ALWAYS BEEN ENORMOUSLY SIGNIFICANT. THE GROUNDWATER OF THE SAHARA IS OFTEN OF A VERY HIGH QUALITY AND SUITABLE BOTH FOR AGRICULTURAL AND DOMESTIC USES. OVER HALF OF THE EXPLOITABLE WATER IS ANCIENT WATER, WHICH FELL AS RAIN MANY THOUSANDS OF YEARS AGO. THESE WATER RESOURCES ARE FINITE, AND ARE USUALLY REFERRED TO AS "FOSSIL" WATER. MOST OF THE GROUNDWATER OF THE NORTHEASTERN SAHARA, PARTICULARLY IN LIBYA AND SOUTHWEST EGYPT, CONSISTS OF FOSSIL WATER. THE MAJOR AQUIFER THAT UNDERLINES ALGERIA AND SOUTHERN TUNISIA, THE CONTINENTAL INTERCALAIRE, IS RECHARGED FROM THE MEAGRE RAINS THAT FALL ON, AND GRADUALLY FILTER DOWN INTO, THIS VAST RESERVE. THE MOST SPECTACULAR DEVELOPMENT OF SAHARAN GROUNDWATER RETRIEVAL WAS CARRIED OUT IN LIBYA DURING THE 1970S AND THE EARLY 1980S. AT THIS TIME, THE WATER WAS USED MAINLY IN THE KUFRAH AREA AND IN FEZZAN. HOWEVER, THE SCHEMES BASED ON THESE REMOTE WATER RESOURCES WERE NOT ECONOMICALLY OR SOCIALLY SUCCESSFUL. ACCORDINGLY, DEVELOPMENT EMPHASIS SHIFTED IN THE LATE 1980S AND EARLY 1990S WITH THE CONSTRUCTION OF MASSIVE PIPELINES TO CONVEY WATER FROM THE AQUIFERS TO THE MEDITERRANEAN COASTAL REGION.

**MINERAL RESOURCES:**

IN ECONOMIC TERMS, MINERALS HAVE PROVED TO BE THE SAHARA'S MOST IMPORTANT NATURAL RESOURCE. LIBYA AND ALGERIA HAVE BENEFITED GREATLY

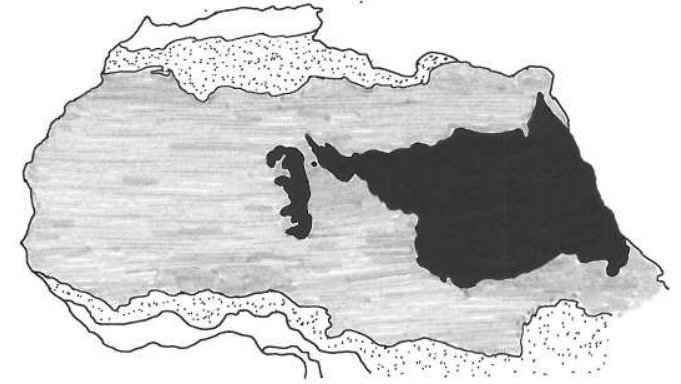
**GROUDWATER**



**AQUIFER PRODUCTIVITY**  
**[LITERS/SEC.]**

- 0
- ▨ ≥ 0.1
- ▨ 0.5-5
- ≥ 5

**SUNLIGHT**



**AVERAGE ANNUAL SUM of DIRECT**  
**NORMAL IRRADIATION [Kwh/m<sup>2</sup>]**

- 1800
- ▨ 2000
- ▨ 2200
- 2400

FROM THEIR OIL AND NATURAL GAS RESOURCES. BOTH COUNTRIES DERIVE OVER 90% OF THEIR EXPORT EARNINGS FROM THESE HYDROCARBONS. TUNISIA AND EGYPT HAVE ALSO BENEFITED FROM OIL, BUT TO A MUCH SMALLER EXTENT.

OTHER MINERAL RESOURCES HAVE BEEN, AND REMAIN, MAJOR CONTRIBUTORS TO THE ECONOMIES OF THE SAHARAN COUNTRIES. PHOSPHATES, FOR EXAMPLE, ARE TUNISIA'S MAJOR EXPORT, AND WHILE MOROCCO, MAURITANIA AND WESTERN SAHARA ARE ALSO MAJOR PHOSPHATE PRODUCERS, THE STABILITY OF THESE EXPORTS HAS BEEN DISRUPTED BY THE INSECURITY AND MILITARY ACTIVITY OF THEIR BORDER ZONE. IRON ORE RESOURCES ARE ALSO SIGNIFICANT, ESPECIALLY IN LIBYA, AND HAVE LED TO PROCESSING AND MANUFACTURE.

ANOTHER OF THE SAHARA'S MAJOR NATURAL RESOURCES, SUNLIGHT, IS AS YET UNDEVELOPED BECAUSE OF THE PRIMITIVE STATE OF THE TECHNOLOGY FOR SOLAR ENERGY CONVERSION. HUGE AMOUNTS OF SUNSHINE FALL ON THE REGION THROUGHOUT THE YEAR, AND THE SAHARA'S VAST LAND AREA GIVES IT THE GREATEST POTENTIAL FOR SOLAR ENERGY DEVELOPMENT OF ALL THE WORLD'S DESERTS. HOWEVER, WITH TECHNOLOGY IN ITS CURRENT STATE, HUGE TRACTS OF THE DESERT WOULD HAVE TO BE COVERED BY SOLAR ENERGY RECEPTORS TO PROVIDE EVEN A MEAGRE SUPPLY OF ELECTRICITY. THIS WOULD, UNFORTUNATELY, INVOLVE UNACCEPTABLE LEVELS OF INVESTMENT. BUT THE SAHARA'S COMPARATIVE ADVANTAGE FOR SOLAR ENERGY GENERATION COULD TRANSFORM THE FUTURE POTENTIAL OF THE REGION FOR ECONOMIC ACTIVITY. CHEAP AND ACCESSIBLE SOLAR ENERGY WOULD ENABLE A WIDE VARIETY OF URBAN ECONOMIC ACTIVITIES TO BE SUSTAINABLE. SOLAR ENERGY COULD EVEN BE SIGNIFICANT IN MITIGATING THE WATER SHORTAGES, SINCE IT COULD PROVIDE THE POWER FOR DESALINATION SCHEMES. IN TURN, DESALINATION WOULD RAISE THE QUALITY OF THE WIDELY AVAILABLE, LOCAL BRACKISH WATER TO THAT NEEDED FOR AGRICULTURE AND OTHER ECONOMIC USES.



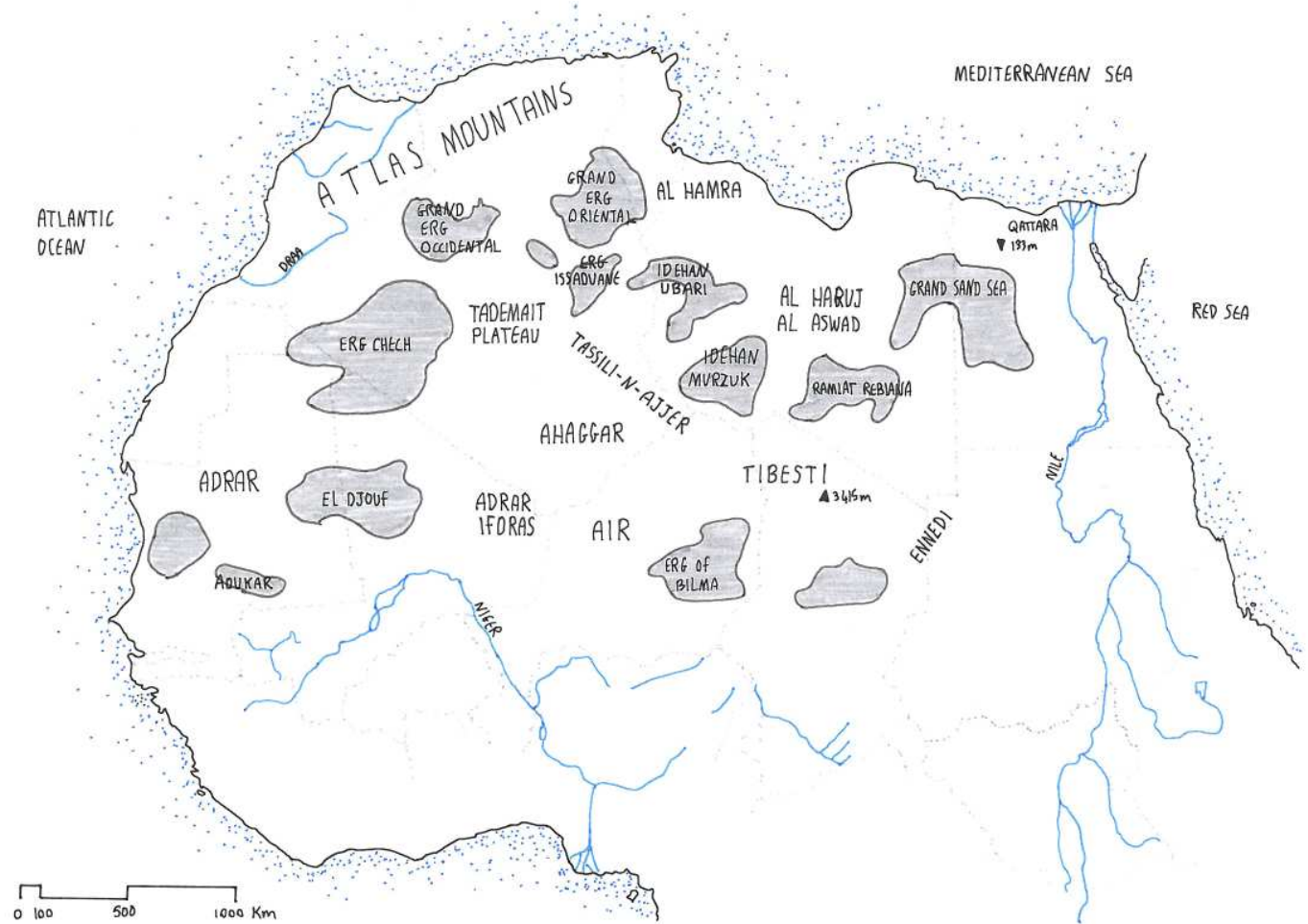
**THE SAHARA DESERT**  
**WHAT IS THE SAHARA?**

**PHYSICAL CHARACTERISTICS**

**PHYSIOGRAPHY:**

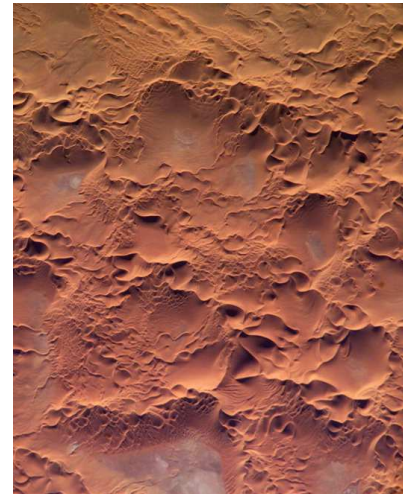
THE PRINCIPAL TOPOGRAPHICAL FEATURES OF THE SAHARA INCLUDE SHALLOW, SEASONALLY INUNDATED BASINS (CHOTTS AND DAYAS) AND LARGE OASIS DEPRESSIONS; EXTENSIVE GRAVEL-COVERED PLAINS (SERIRS OR REGS); ROCK-STREWN PLATEAUS (HAMMADAS); ABRUPT MOUNTAINS; AND SAND SHEETS, DUNES, AND SAND SEAS (ERGS). THE HIGHEST POINT IN THE DESERT IS THE 3415 METRE SUMMIT OF MOUNT KOUSSI IN THE TIBESTI MOUNTAINS IN CHAD; THE LOWEST, 133 METRES BELOW SEA LEVEL, IS IN THE QATTARA DEPRESSION OF EGYPT.

SAND SHEETS AND DUNES COVER APPROXIMATELY 25% OF THE SAHARA'S SURFACE. THE PRINCIPAL TYPES OF DUNES INCLUDE TIED DUNES, WHICH FORM IN THE LEE OF HILLS OR OTHER OBSTACLES; PARABOLIC BLOWOUT DUNES; CRESCENT-SHAPED BARCHANS AND TRANSVERSE DUNES; LONGITUDINAL SEIFS; AND THE MASSIVE, COMPLEX FORMS ASSOCIATED WITH SAND SEAS. SEVERAL PYRAMIDAL DUNES IN THE SAHARA ATTAIN HEIGHTS OF NEARLY 153 METRES, WHILE DRAA, THE MOUNTAINOUS SAND RIDGES THAT DOMINATE THE ERGS, ARE SAID TO REACH 305 METRES. AN UNUSUAL PHENOMENON ASSOCIATED WITH DESERT SANDS IS THEIR "SINGING" OR BOOMING. VARIOUS HYPOTHESES HAVE BEEN ADVANCED TO EXPLAIN THE PHENOMENON, SUCH AS THOSE BASED UPON THE PIEZOELECTRIC PROPERTY OF CRYSTALLINE QUARTZ, BUT THE MYSTERY REMAINS UNSOLVED.



**SOILS:**

THE SOILS OF THE SAHARA ARE LOW IN ORGANIC MATTER, EXHIBIT ONLY SLIGHTLY DIFFERENTIATED HORIZONS (STRATA), AND ARE OFTEN BIOLOGICALLY INACTIVE, ALTHOUGH NITROGEN-FIXING BACTERIA ARE PRESENT IN SOME AREAS. THE SOILS IN DEPRESSIONS ARE FREQUENTLY SALINE. AT THE MARGINS OF THE DESERT ARE SOILS CONTAINING GREATER CONCENTRATIONS OF ORGANIC MATTER. WEATHERABLE MINERALS ARE A PROMINENT CONSTITUENT OF THESE SOILS, AND CHEMICALLY ACTIVE EXPANDING-LATTICE CLAYS ARE COMMON. FREE CARBONATES ARE OFTEN PRESENT, INDICATING THAT LITTLE LEACHING HAS OCCURRED. COMPACT AND INDURATED LAYERS, OR CRUSTS, ARE LARGELY RESTRICTED TO THE NORTHWESTERN SECTION OF THE DESERT IN ASSOCIATION WITH CALCAREOUS BEDROCK. FINE MATERIALS, INCLUDING DEPOSITS OF DIATOMACEOUS EARTH, ARE LIMITED TO BASINS AND DEPRESSIONS.



ERG ISSAOUANE, ALGERIA



GRAND SAND SEA, LYBIA/EGYPT

## THE SAHARA DESERT

### WHAT IS THE SAHARA?

#### CLIMATE

THE SAHARA IS DOMINATED BY TWO CLIMATIC REGIMES: A DRY SUBTROPICAL CLIMATE IN THE NORTH AND A DRY TROPICAL CLIMATE IN THE SOUTH. THE DRY SUBTROPICAL CLIMATE IS CHARACTERIZED BY UNUSUALLY HIGH ANNUAL AND DIURNAL TEMPERATURE RANGES, COLD TO COOL WINTERS AND HOT SUMMERS, AND TWO PRECIPITATION MAXIMUMS. THE DRY TROPICAL CLIMATE IS CHARACTERIZED BY A STRONG ANNUAL TEMPERATURE CYCLE FOLLOWING THE DECLINATION OF THE SUN; MILD, DRY WINTERS; AND A HOT DRY SEASON PRECEDING VARIABLE SUMMER RAINS. A NARROW STRIP OF THE WESTERN COASTAL ZONE HAS A RELATIVELY COOL, UNIFORM TEMPERATURE REFLECTING THE INFLUENCE OF THE COLD CANARY CURRENT.

THE DRY SUBTROPICAL CLIMATE OF THE NORTHERN SAHARA IS CAUSED BY STABLE HIGH-PRESSURE CELLS CENTERED OVER THE TROPIC OF CANCER. THE ANNUAL RANGE OF AVERAGE DAILY TEMPERATURES IS ABOUT 20°C. WINTERS ARE RELATIVELY COLD IN THE NORTHERN REGIONS AND COOL IN THE CENTRAL SAHARA. FOR THE ZONE AS A WHOLE, AVERAGE MONTHLY TEMPERATURES DURING THE COLD SEASON ARE APPROXIMATELY 13°C. THE SUMMERS ARE HOT. DAILY TEMPERATURE RANGES ARE CONSIDERABLE DURING BOTH THE WINTER AND SUMMER MONTHS. ALTHOUGH PRECIPITATION IS HIGHLY VARIABLE, IT AVERAGES ABOUT 76 MM PER YEAR. MOST PRECIPITATION FALLS FROM DECEMBER THROUGH MARCH. ANOTHER MAXIMUM OCCURS IN AUGUST, CHARACTERIZED BY THUNDERSTORMS. THESE STORMS CAN CAUSE TREMENDOUS FLASH FLOODS THAT RUSH INTO AREAS WHERE NO PRECIPITATION HAS FALLEN. LITTLE PRECIPITATION FALLS IN MAY AND JUNE. SNOWFALL OCCURS OCCASIONALLY OVER THE NORTHERN PLATEAUS. ANOTHER FEATURE OF THE DRY SUBTROPICS ARE THE HOT, SOUTHERLY WINDS THAT OFTEN CARRY DUST FROM THE INTERIOR. ALTHOUGH THEY OCCUR AT VARIOUS TIMES OF THE YEAR, THEY ARE ESPECIALLY COMMON DURING THE SPRING. IN EGYPT THEY ARE KNOWN AS THE KHAM SIN, IN LIBYA AS THE GHIBLI, AND IN TUNISIA AS THE CHILI. THE DUST-LADEN HABOOB WINDS OF SUDAN ARE OF SHORTER DURATION, CHIEFLY OCCUR DURING THE SUMMER MONTHS, AND OFTEN USHER IN HEAVY RAINS.

THE DRY TROPICAL CLIMATE TO THE SOUTH IS DOMINATED BY THE SAME HIGH-PRESSURE CELLS, BUT IT IS REGULARLY INFLUENCED BY THE SEASONAL INTERACTION OF A STABLE CONTINENTAL SUBTROPICAL AIR MASS AND A SOUTHERLY, UNSTABLE MARITIME TROPICAL AIR MASS. THE ANNUAL RANGE IN AVERAGE DAILY TEMPERATURES IN THE DRY TROPICAL REGIONS OF THE SAHARA IS APPROXIMATELY 17.5°C. AVERAGE TEMPERATURES FOR THE COLDEST MONTHS ARE ESSENTIALLY THE SAME AS THEY ARE FOR THE SUBTROPICAL ZONE TO THE NORTH, BUT THE DIURNAL RANGE IS MORE MODERATE. IN THE HIGHER ELEVATIONS OF THE ZONE, THE LOWS APPROXIMATE THOSE OF MORE NORTHERLY, SUBTROPICAL REGIONS. FOR EXAMPLE, ABSOLUTE LOWS OF -15°C HAVE BEEN RECORDED IN THE TIBESTI MOUNTAINS. LATE SPRING AND EARLY SUMMER ARE HOT; HIGH TEMPERATURES OF 50°C ARE NOT UNUSUAL. ALTHOUGH THE MASSIFS OF THE DRY TROPICS OFTEN RECEIVE SMALL QUANTITIES OF PRECIPITATION THROUGHOUT THE YEAR, THE LOWLANDS HAVE A SINGLE SUMMER MAXIMUM. AS IN THE NORTH, MUCH OF THIS RAINFALL OCCURS AS THUNDERSTORMS. PRECIPITATION AVERAGES ARE ABOUT 13 CM PER YEAR, OCCASIONALLY INCLUDING SOME SNOWFALL IN THE CENTRAL MASSIFS. IN THE WESTERN MARGIN OF THE DESERT THE COLD CANARY CURRENT REDUCES AIR TEMPERATURES, THEREBY REDUCING CONVECTIONAL RAINFALL, BUT RESULTING IN HIGHER HUMIDITY AND OCCASIONAL FOGS. IN THE SOUTHERN SAHARA THE WINTER IS THE PERIOD OF THE HARMATTAN, A DRY NORTHEASTERLY WIND LADEN WITH SAND AND OTHER EASILY TRANSPORTED DUST PARTICLES.





## THE SAHARA DESERT

### WHAT IS THE SAHARA?

#### LIVING CREATURES

##### THE PEOPLE:

ALTHOUGH AS LARGE AS THE UNITED STATES, THE SAHARA (EXCLUDING THE NILE VALLEY) IS ESTIMATED TO CONTAIN ONLY SOME 2.5 MILLION INHABITANTS—LESS THAN 0.4 PERSON PER SQUARE KILOMETRE. HUGE AREAS ARE WHOLLY EMPTY, BUT WHEREVER MEAGRE VEGETATION CAN SUPPORT GRAZING ANIMALS OR RELIABLE WATER SOURCES OCCUR, SCATTERED CLUSTERS OF INHABITANTS HAVE SURVIVED IN FRAGILE ECOLOGICAL BALANCE WITH ONE OF THE HARSHTEST ENVIRONMENTS ON EARTH.

ARCHAEOLOGICAL EVIDENCE SUGGESTS THAT THE SAHARA WAS INCREASINGLY INHABITED BY DIVERSE POPULATIONS, AND PLANT AND ANIMAL DOMESTICATION LED TO OCCUPATIONAL SPECIALIZATION. WHILE THE GROUPS LIVED SEPARATELY, THE PROXIMITY OF SETTLEMENTS SUGGESTS AN INCREASING ECONOMIC INTERDEPENDENCE. EXTERNAL TRADE ALSO DEVELOPED. COPPER FROM MAURITANIA HAD FOUND ITS WAY TO THE BRONZE AGE CIVILIZATIONS OF THE MEDITERRANEAN BY THE 2ND MILLENNIUM BC. TRADE INTENSIFIED WITH THE EMERGENCE OF THE IRON AGE CIVILIZATIONS OF THE SAHARA DURING THE 1ST CENTURY BC, INCLUDING THE CIVILIZATION CENTERED IN NUBIA.

DESPITE CONSIDERABLE CULTURAL DIVERSITY, THE PEOPLES OF THE SAHARA TEND TO BE CATEGORIZED AS PASTORALISTS, SEDENTARY AGRICULTURALISTS, OR SPECIALISTS (SUCH AS THE BLACKSMITHS VARIOUSLY ASSOCIATED WITH HERDERS AND CULTIVATORS). PASTORALISM, ALWAYS NOMADIC TO SOME DEGREE, OCCURS WHERE SUFFICIENT SCANTY PASTURAGE EXISTS, AS IN THE MARGINAL AREAS, ON THE MOUNTAIN BORDERS, AND IN THE SLIGHTLY MOISTER WEST. CATTLE APPEAR ALONG THE SOUTHERN BORDERS WITH THE SAHEL, BUT SHEEP, GOATS, AND CAMELS ARE THE MAINSTAYS IN THE DESERT. MAJOR PASTORAL GROUPS INCLUDE THE REGEIBAT OF THE NORTHWESTERN SAHARA AND THE CHAAMBA OF THE NORTHERN ALGERIAN SAHARA. HIERARCHICAL IN STRUCTURE, THE LARGER PASTORAL GROUPS FORMERLY DOMINATED THE DESERT. WARFARE AND RAIDS (GHAZW) WERE ENDEMIC, AND IN DROUGHT PERIODS WIDE MIGRATIONS IN SEARCH OF PASTURE TOOK PLACE, WITH HEAVY LOSS OF ANIMALS. THE TUAREG (WHO CALL THEMSELVES KEL TAMASHEQ) WERE RENOWNED FOR THEIR WARLIKE QUALITIES AND FIERCE INDEPENDENCE. ALTHOUGH THEY ARE ISLĀMIC, THEY RETAIN A MATRIARCHAL ORGANIZATION, AND THE WOMEN OF THE TUAREG HAVE AN UNUSUAL DEGREE OF FREEDOM. THE MOORISH GROUPS TO THE WEST FORMERLY POSSESSED POWERFUL TRIBAL CONFEDERATIONS. THE TEDA, OF THE TIBESTI AND ITS SOUTHERN BORDERLANDS, ARE CHIEFLY CAMEL HERDERS, RENOWNED FOR THEIR INDEPENDENCE AND FOR THEIR PHYSICAL ENDURANCE.

##### PLANT LIFE:

SAHARAN VEGETATION IS GENERALLY SPARSE, WITH SCATTERED CONCENTRATIONS OF GRASSES, SHRUBS, AND TREES IN THE HIGHLANDS, IN OASIS DEPRESSIONS, AND ALONG THE VALLEYS. VARIOUS HALOPHYTES (SALT-TOLERANT PLANTS) ARE FOUND IN SALINE DEPRESSIONS. SOME HEAT- AND DROUGHT-TOLERANT GRASSES, HERBS, SMALL SHRUBS, AND TREES ARE FOUND ON THE LESS WELL-WATERED PLAINS AND PLATEAUS OF THE SAHARA.

THE VEGETATION OF THE SAHARA IS PARTICULARLY NOTEWORTHY FOR ITS MANY UNUSUAL ADAPTATIONS TO UNRELIABLE PRECIPITATION. THESE ARE VARIOUSLY SEEN IN MORPHOLOGY—INCLUDING ROOT STRUCTURE, A BROAD RANGE OF

PHYSIOLOGICAL ADAPTATIONS, SITE PREFERENCES, DEPENDENCY AND AFFINITY RELATIONSHIPS, AND REPRODUCTIVE STRATEGIES. MANY OF THE HERBACEOUS PLANTS ARE EPHEMERALS THAT MAY GERMINATE WITHIN THREE DAYS OF ADEQUATE RAINFALL AND SOW THEIR SEEDS WITHIN 10 OR 15 DAYS OF GERMINATION. SHELTERED IN THE SAHARAN MASSIFS ARE OCCASIONAL STANDS OF RELICT VEGETATION, OFTEN WITH MEDITERRANEAN AFFINITIES.

PROMINENT AMONG THE RELICT WOODY PLANTS OF THE SAHARAN HIGHLANDS ARE SPECIES OF OLIVE, CYPRESS, AND MASTIC TREES. OTHER WOODY PLANTS FOUND IN THE HIGHLANDS AND ELSEWHERE IN THE DESERT INCLUDE SPECIES OF ACACIA AND ARTEMISIA, DOUM PALM, OLEANDER, DATE PALM, AND THYME. HALOPHYTES SUCH AS TAMARIX SENEGALENSIS ARE FOUND ALONG THE WESTERN COASTAL ZONE. GRASSES WIDELY DISTRIBUTED IN THE SAHARA INCLUDE SPECIES OF ARISTIDA, ERAGROSTIS, AND PANICUM. AELUROPUS LITTORALIS AND OTHER SALT-TOLERANT GRASSES ARE FOUND ALONG THE ATLANTIC COAST. VARIOUS COMBINATIONS OF EPHEMERALS FORM IMPORTANT SEASONAL PASTURES CALLED ACHEB.

##### ANIMAL LIFE:

RELICT TROPICAL FAUNA OF THE NORTHERN SAHARA INCLUDE TROPICAL CATFISH AND CHROMIDES FOUND AT BISKRA, ALGERIA, AND IN ISOLATED OASIS OF THE SAHARA; COBRAS AND PYGMY CROCODILES MAY STILL EXIST IN REMOTE DRAINAGE BASINS OF THE TIBESTI MOUNTAINS. MORE SUBTLE HAS BEEN THE PROGRESSIVE LOSS OF WELL-ADAPTED, MORE MOBILE SPECIES TO THE ADVANCED FIREARMS AND HABITAT DESTRUCTION OF HUMANS. THE NORTH AFRICAN ELEPHANT BECAME EXTINCT DURING THE ROMAN PERIOD, BUT THE LION, OSTRICH, AND OTHER SPECIES WERE ESTABLISHED IN THE DESERT'S NORTHERN MARGINS AS LATE AS 1830. THE LAST ADDAX IN THE NORTHERN SAHARA WAS KILLED IN THE EARLY 1920S.

AMONG THE MAMMAL SPECIES STILL FOUND IN THE SAHARA ARE THE GERBIL, JERBOA, CAPE HARE, AND DESERT HEDGEHOG; BARBARY SHEEP AND SCIMITAR-HORNED ORYX; DORCAS GAZELLE, DAMA DEER, AND NUBIAN WILD ASS; ANUBIS BABOON; SPOTTED HYENA, COMMON JACKAL, AND SAND FOX; AND LIBYAN STRIPED WEASEL AND SLENDER MONGOOSE. INCLUDING RESIDENT AND MIGRATORY POPULATIONS, THE BIRDLIFE OF THE SAHARA EXCEEDS 300 SPECIES. THE COASTAL ZONES AND INTERIOR WATERWAYS ATTRACT MANY SPECIES OF WATER AND SHORE BIRDS. AMONG THE SPECIES ENCOUNTERED IN THE INTERIOR REGIONS ARE OSTRICHES; VARIOUS RAPTORS; SECRETARY BIRDS, GUINEA FOWL, AND NUBIAN BUSTARDS; DESERT EAGLE OWLS AND BARN OWLS; SAND LARKS AND PALE CRAG MARTINS; AND BROWN-NECKED AND FAN-TAILED RAVENS.

FROGS, TOADS, AND CROCODILES LIVE IN THE LAKES AND POOLS OF THE SAHARA. LIZARDS, CHAMELEONS, SKINKS, AND COBRAS ARE FOUND AMONG THE ROCKS AND DUNES. THE LAKES AND POOLS OF THE SAHARA ALSO CONTAIN ALGAE AND BRINE SHRIMP AND OTHER CRUSTACEANS. THE VARIOUS SNAILS THAT INHABIT THE DESERT ARE AN IMPORTANT SOURCE OF FOOD FOR BIRDS AND ANIMALS.



TUAREG



SAHARA PLANTS



SAHARA FOX

**THE SAHARA DESERT**  
**HOW TO LIVE IN THE SAHARA?**  
**SOCIAL LIFE AND TRADITIONAL BUILDING**

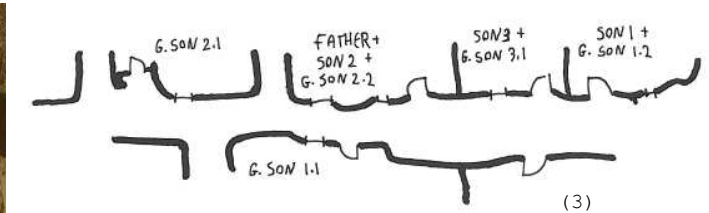
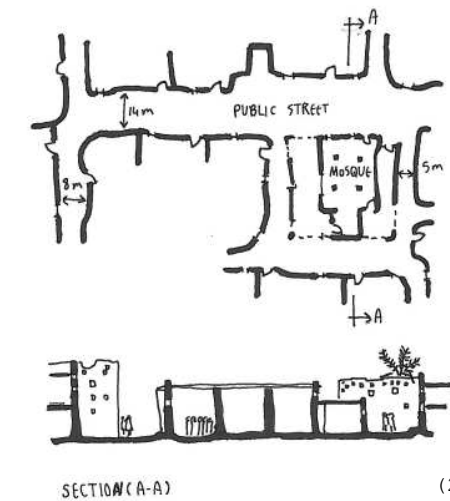
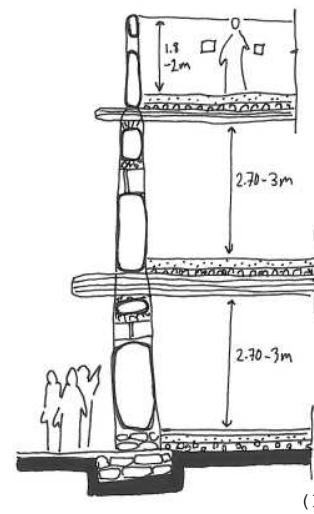
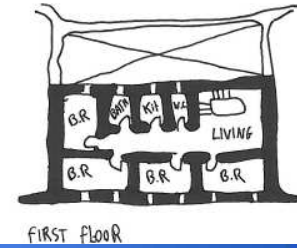
SIWA OASIS, EGYPT:

SIWA OASIS IS ONE OF EGYPT'S MOST ISOLATED SETTLEMENTS, WITH 23,000 PEOPLE, MOSTLY BERBER SPEAKERS WHO SPEAK A DISTINCT LANGUAGE OF THE BERBER FAMILY KNOWN AS SIWI. ITS FAME LIES PRIMARILY IN ITS ANCIENT ROLE AS THE HOME TO AN ORACLE OF AMON, THE RUINS OF WHICH ARE A POPULAR TOURIST ATTRACTION. AGRICULTURE IS THE MAIN ACTIVITY OF MODERN SIWA, PARTICULARLY THE CULTIVATION OF DATES AND OLIVES. HANDICRAFTS LIKE BASKETRY ARE ALSO OF REGIONAL IMPORTANCE. THE ISOLATION OF THE OASIS CAUSED THE DEVELOPMENT OF A UNIQUE CULTURE WHICH WAS SHOWN IN ITS POTTERY, COSTUME, STYLES OF EMBROIDERY AND, MOST NOTABLY, IN THE SILVER JEWELLERY WORN BY WOMEN TO WEDDINGS AND IMPORTANT OCCASIONS. THESE PIECES WERE DECORATED WITH SYMBOLS WHICH RELATED TO SIWA'S HISTORY AND BELIEFS AND ATTITUDES. TOURISM HAS IN RECENT DECADES BECOME A VITAL SOURCE OF INCOME. MUCH ATTENTION HAS BEEN GIVEN TO CREATING HOTELS THAT USE LOCAL MATERIALS AND PLAY ON LOCAL STYLES.

THE MAIN STREETS OF SIWA ARE APPROXIMATELY 14 METRES WIDE; THE SIDE STREETS ARE APPROXIMATELY 8 METRES, WHILE DEAD END STREETS ARE 5 METRES WIDE. THERE ARE ALSO OPEN SQUARES; AND NOBODY WAS ALLOWED TO BUILD A HOUSE OF MORE THAN TWO STOREYS UNTIL THE 1920S (2).

THE CHARACTER OF HOUSING IN SIWA DEVELOPED NOT ONLY FROM THE RELATIONSHIPS OBTAINED WITH THE NATURAL STRUCTURE, BUT ALSO FROM THE SOCIAL STRUCTURE WHICH WAS ESTABLISHED AMONG THE VARIOUS GROUPS OF PEOPLE WHO SETTLED THE OASIS. THE AUTOCHTHONOUS CLANS UNDERPINNED LARGER ECONOMIC, SOCIAL AND POLITICAL UNITS WHICH CAN BE REGARDED AS CONFEDERATIONS. THE ULTIMATE UNITY OF SUCH FAMILIES FORMED A BOND THAT IS APPARENT IN THE ALLOCATION OF HOUSES, WHERE HOUSES OF EACH FAMILY WERE CLUSTERED ADJACENTLY, CREATING FAMILY/ TRIBAL PRECINCTS (3). COLLECTIVELY, THE NATURAL AND SOCIAL ORDERS HAVE INFLUENCED THE DESIGN OF RESIDENTIAL UNITS. TO GRANT MAXIMUM PRIVACY FOR THE HOUSEHOLD, MOST HOUSES HAS TWO FLOORS AND A ROOF TOP TERRACE. THE GROUND FLOOR HELD SEMIPRIVATE ACTIVITIES ENCLOSING THE MAIN STORAGE AREAS AND THE BARN; WHEREAS, THE SECOND FLOOR HAS BEDROOMS, A SITTING ROOM AND A KITCHEN (1).

IN THE SUMMER RESIDENTS SLEEP OR SIT IN THE EVENING FOR DINNERS AND CHATS IN THE OPEN AIR. AND IN THE WINTER, THERE IS THE WINTER ROOM GHARFIT NSHTEE ON THE GROUND FLOOR. IT IS A VERY WARM ROOM BECAUSE IT IS SMALL, DOWN BELOW AND HAS SMALL WINDOWS. ON THE COLD WINTER EVENINGS,



THE WHOLE FAMILY SITS AROUND A HEATH CALLED AL KOR - A PLATE OF GLOWING HOT OLIVE WOOD COALS PLACED IN THE MIDDLE OF THE ROOM. FURTHERMORE, HOUSES ARE BUILT WITH BENT ENTRANCES TO ENSURE TOTAL PRIVACY FOR THE HOUSEHOLD.

DUE TO THE RELATIVE ISOLATION FROM THE OUTSIDE, BUILDING MATERIALS WERE OBTAINED FROM THE SURROUNDING GARDENS OR FROM THE SALT LAKES. HOUSES WERE BUILT BY KARSHEEF, A STONE MADE OF A MIXTURE OF CLAY, SALT AND FINE SAND WHICH IS FORMED AT THE SHORES OF THE SALT LAKES. WHEN BONDED WITH CLAY, KARSHEEF WALLS BECOME A SINGLE, SOLID UNIT AND ARE QUITE STURDY, WITH THICKNESS RANGING FROM 40 TO 80 CM. CEILINGS AND DOORS ARE MADE OF PALM WOOD, AND MUD AND OLIVE LEAVES HELP STRENGTHEN THE ROOF AGAINST THE RAIN. TAKING INTO CONSIDERATION, THE ARID CLIMATE OF THE OASIS WITH THE GREAT VARIATION IN TEMPERATURES BETWEEN DAY AND NIGHT; THESE BUILDING TECHNIQUES PROVIDED THE RESIDENTS A PLEASANT ATMOSPHERE INSIDE THE HOUSES.



## THE SAHARA DESERT

### HOW TO LIVE IN THE SAHARA?

#### SOCIAL LIFE AND TRADITIONAL BUILDING

GHARDAIA, ALGERIA:

GHARDAIA IS IN MID-ALGERIA, HAS A HOT AND DRY CLIMATE. THE NAME GHARDAIA MEANS THE CAVE OF DAIA AND REFERS TO AN ANCIENT LEGEND OF A WOMAN LIVING IN A CAVE IN THE MOUNTAINS OUTSIDE THE PRESENT CITY. GHARDAIA IS TODAY USED AS A NAME FOR ALL FIVE CITIES: GHARDAIA, MELIKA, BENIL IZGUEN, BOUNOURA AND EL ATTEUF IN THE M'ZAB VALLEY SOME 600 KM SOUTH OF THE MEDITERRANEAN. THE AREA WAS OCCUPIED BY THE IBHADITE PEOPLE AFTER THE DESTRUCTION OF THEIR CAPITAL SEDRATA IN THE 11TH CENTURY. THESE PEOPLE TODAY ARE CALLED 'MOZABITES' AFTER THE NAME OF THE VALLEY.

EACH CITY IS LOCATED ON A HILL WITH A CENTRAL MOSQUE AND A SPIDER-WEB-LIKE STREET PATTERN SPREADING FROM THIS CENTRE TO THE WELL-DEFINED LIMIT OF THE ENCLOSURE WALL. THIS LOCATION IS CHOSEN FOR DEFENCE, BUT ALSO TO SAVE AGRICULTURAL LAND AND TO AVOID FLOODS, EVEN IF THEY ARE RARE. THE TRADITIONAL HOUSES ARE ATTACHED TO EACH OTHER WITH ONLY ONE FACADE TOWARDS THE NARROW STREET. THEY ARE BUILT IN 2-3 STOREYS AND OPEN TOWARDS AN INNER COURTYARD. THE BUILDING MATERIALS ARE HEAVY, AND OPENINGS ARE SMALL AS IN MOST TRADITIONAL HOUSES IN DESERT REGIONS. THIS CONSTRUCTION TECHNIQUE MODERATES THE GREAT DIURNAL TEMPERATURE RANGE, AND VENTILATION THROUGH THE SHADED STREETS AND NIGHT LOWERS TEMPERATURES. INTERNAL MOVEMENTS TO SEEK OR AVOID THE HEAT WAS ONE STRATEGY OF CLIMATE ADAPTION; FOR EXAMPLE, SLEEPING ON THE FLAT ROOF IS STILL COMMON DURING THE HOTTEST PERIODS.

SOME TRADITIONAL PLANNING AND BUILDING CODES ISSUED BY THE CITY AND FAMILY COUNCILS: ORIENTATION, HEIGHT AND OPENINGS WERE REGULATED, AND RULES FOR THE BEHAVIOUR APPLIED WHEN PHYSICAL APPLICATIONS COULD NOT BE USED. FOR EXAMPLE, TO AVOID HIGH PARAPET WALLS THAT BLOCKED WIND AND SUNLIGHT FROM ENTERING BUILDINGS AND COURTYARDS, IT WAS PROHIBITED TO LOOK INTO A NEIGHBOUR'S HOUSE.

#### MODERN CONSTRUCTION:

EXCEPT FOR SOME RESTORATION OR IN-FILL, THE STRICTLY LIMITED TRADITIONAL CITY CENTRES OF THE M'ZAB VALLEY REMAIN UNCHANGED. EXPANSION OCCURS OUTSIDE THESE CENTRES. THREE TYPES OF MODERN HOUSES:

1. THE 'FRENCH' TYPE, EMERGING COLONISATION AT THE TURN OF THE CENTURY, IS ONE-STOREY, TWO-SIDED, OFTEN WITH BOTH FRONT AND BACK YARDS. IT IS ORGANISED AROUND A CENTRAL CORRIDOR INSTEAD OF A COURTYARD, MAKING OUTDOOR PRIVACY LIMITED.
  2. THE 'NEW LOCAL' TYPE BUILT BY PEOPLE THEMSELVES IS SIMILAR TO THE TRADITIONAL HOUSE: TWO-STOREY WITH TWO ENTRANCES, A COURTYARD, SOMETIMES A CELLAR, AND OFTEN A FRONT YARD. ATTACHMENT TO OTHER BUILDING ARE INDICATED ON THREE SIDES. MEN'S AND WOMEN'S SPACE ARE WELL SEPARATED.
  3. THE 'NEW DESIGNED' TYPE IS A COPY OF TRADITIONAL HOUSES IN THE ORGANISATION OF SPACE. THE COURTYARD IS ONLY SYMBOLIC AND CONNECTS TO A FRONT GARDEN, AND THE HOUSES IS GENERALLY OUTWARD-LOOKING WITH WINDOWS FACING THE STREETS.
- PASSIVE CLIMATISATION IS SELDOM CONSIDERED IN RECENT CONSTRUCTION SINCE THE ALGERIAN STATE HAS LONG SUBSIDISED ELECTRICITY, AND THUS MINIMISED INTEREST IN STRUCTURAL COOLING AND HEATING.



M'ZAB VALLEY



GHARDAIA



NARROW STREET IN GHARDAIA



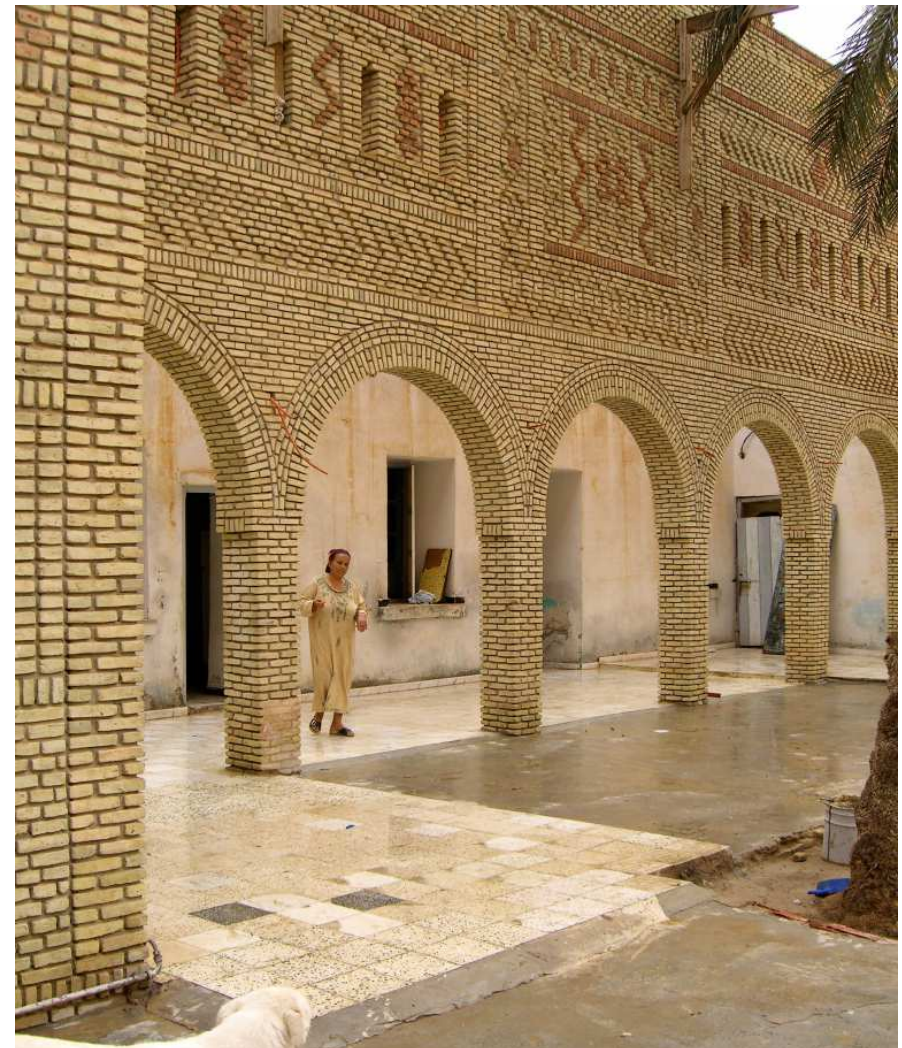
**THE SAHARA DESERT**  
**HOW TO LIVE IN THE SAHARA?**  
**SOCIAL LIFE AND TRADITIONAL BUILDING**

TOZEUR OASIS, TUNISIA:

TOZEUR IS A MILD, MARITIME OASIS. TOZEUR WAS FOUNDED AT THE LARGE OASIS BY THE ROMANS AS A LAST OUT-POST BEFORE THE DESERT. TODAY IT IS THE COUNTRY CAPITAL WITH ITS MAIN INCOME FROM AGRICULTURE AND TOURISM. THE REGION IS KNOWN FOR ITS HAND-MADE, LOW-FIRED, SOLID CLAY BRICKS. IN THE PAST THESE WERE OFTEN MADE AT THE BUILDING SITE, IN A SMALL KILN FIRED WITH PALM LEAVES. TRADITIONAL HOUSES ARE COMMONLY MADE OF SANDWICH WALLS WITH MUD BETWEEN TWO BRICK LAYERS, GIVING A THICKNESS OF ABOUT 70 CM. TODAY THE BRICKS ARE TOO EXPENSIVE TO USE FOR CONSTRUCTION, BUT ARE COMMONLY USED AS DECORATION, A COMPULSORY ELEMENT IN ALL PUBLIC BUILDINGS.

EXCEPT FOR THE PRINCIPAL BUILDING MATERIAL, THE TRADITIONAL TOWN CENTRE OF TOZEUR IS SIMILAR TO GHARDAIA. THE BUILDING MASS IS COMPACT; STREETS ARE NARROW; AND THE HOUSES ARE CLOSED AND INWARD LOOKING. PROXIMITY TO THE OASIS GIVES AN IMPROVED MICRO-CLIMATE, WHICH IS ESSENTIAL SINCE THE INHABITANTS NEVER HAD SUMMER-HOUSES AT THEIR CULTIVATION PLOTS.

NEW LIVING AREAS IN TOZEUR HAVE WIDE STREETS, OFTEN UP TO 10 METRES. MOST SELF-BUILT HOUSES ARE OF 'NEW LOCAL' TYPE WITH AN INNER COURTYARD AND OUTDOOR COMMUNICATION, BUT NORMALLY ONLY ONE STOREY HIGH. 'NEW DESIGNED' TYPES - 'VILLAS' ARE BUILT TODAY, PRINCIPALLY BY SNIT THE NATIONAL HOUSING COMPANY. THESE ARE EXTROVERT WITH INDOOR COMMUNICATIONS AND GARDENS AROUND AND ARE GENERALLY ACCEPTED BY THE UPPER-CLASS AND OFFICERS AND EMPLOYEES FROM THE NORTH. THERE ARE EXAMPLES OF PLOTS WHERE A MODERN 'VILLA' IS BUILT CLOSE TO THE STREET FOR RECEPTION AND PURPOSES, WITH TRADITIONAL BUILDINGS BEHIND FOR LIVING IN.



TOZEUR



SOLID CLAY BUILDING





**THE SAHARA DESERT  
HOW TO LIVE IN THE SAHARA?  
BUILDING TECHNIQUES**

**BUILDING WITH SALT: (SIWA OASIS, EGYPT)**

IN THE BUILDING TECHNIQUE OF THE MASONRIES THE FOLLOWING MATERIALS CAN BE FOUND: SALT BLOCKS UTILIZED AS ASHLARS, SALTY MUD MORTAR, PALM AND OLIVE TREE TRUNKS.

THE SALT BLOCKS, CALLED KARSHIF, ARE MADE OF NACL CRYSTALS WITH A LITTLE AMOUNT OF CLAY AND SAND AND ARE TAKEN FROM THE SHORE AROUND THE SALTY LAKES. THEY ARE EVAPORITIC DEPOSITS WHICH FORM THROUGH PRECIPITATION OF NACL AND OTHER SECONDARY SALTS LIKE KCL DURING EVAPORATION OF WATER FROM THE SALTY LAKES. DURING THIS PROCESS, IN OCCASION OF SANDSTORMS, MINERALS LIKE QUARTZ, FELDSPAR CALCITE AND CLAY MINERALS CAN BE INCLUDED AS IMPURITIES IN THE SALT.

UNTIL THE 19TH CENTURY THE MASONRY MORTAR WAS REALIZED UTILIZING TIIN AS BINDER, AN ARGILLITE PRESENT IN LAYERS INSIDE THE MAMURA FORMATION OF MIOCENIC AGE. THIS FORMATION OUTCROPS EXTENSIVELY ON THE HILLS AROUND AND INSIDE THE OASIS. THE ARGILLITE, IN THE OUTCROP, IS CHARACTERIZED BY A BROWN GREENISH COLOR AND BY THE PRESENCE OF LEVELS AND FISSURES FILLED BY GYPSUM CRYSTALS. EXACTLY THESE LEVELS RICH IN GYPSUM WERE SELECTED TO PRODUCE THE MORTAR AS TESTIFIED BY THE ASPECT OF THE OLD MASONRIES: THE ARGILLITE WAS DISAGGREGATED IN SALTY WATER FOR ABOUT 10 DAYS (ORAL TRADITION) IN ORDER TO REHYDRATE AND TO ACQUIRE A PLASTIC BEHAVIOR. THE QUITE LONG TIME OF REHYDRATION WAS NECESSARY BECAUSE AN ARGILLITE IS A CLAY THAT SUFFERED A DIAGENESIS PROCESS WITH TRANSFORMATION OF THE SEDIMENT IN ROCK. DURING THIS PROCESS THE COMPACTION CAUSES THE LOSS OF ALL THE HYGROSCOPIC WATER WITH THE CONSEQUENCE THAT ALL THE CLAY MINERALS COME IN TIGHT CONTACT AND THEREFORE DECREASING THE POROSITY TO VERY LOW VALUES. THIS IS THE REASON WHY WHEN IN CONTACT WITH WATER, AN ARGILLITE DOES NOT BECOME IMMEDIATELY PLASTIC AS A CLAY.

AT PRESENT IN THE TRADITIONAL KARSHIF ARCHITECTURE THE MORTAR IS REALIZED WITH TAFLA, A CLAY THAT CAN BE FOUND UNDER THE SALT CRUST AROUND THE SALTY LAKES. THIS CLAY IS MIXED WITH SALTY WATER UNTIL REACHING THE SUITABLE WORKABILITY AND UTILIZED DIRECTLY WITHOUT ADDING AGGREGATE.



BUILDING DETAILS



BUILDING PROCESSES



SALTY LAKE



HOTEL BUILT BY KARSHIF



**THE SAHARA DESERT  
HOW TO LIVE IN THE SAHARA?  
BUILDING TECHNIQUES**

BUILDING WITH SAND: (MBERA REFUGEE CAMP, MAURITANIA)

THE MBERA CAMP, LOCATED 50 KM FROM THE MALIAN BORDER IN THE SOUTHEAST CORNER OF MAURITANIA PROVIDES REFUGE TO AROUND 60,000 MALIAN REFUGEES. THE REFUGEES FLED TO THE MBERA CAMP AFTER THE OUTBREAK OF A CONFLICT BETWEEN TUAREG SEPARATISTS AND GOVERNMENT FORCES SOME YEARS AGO IN NORTHERN MALI.

AN ITALIAN NGO, AND THE MAURITANIAN MINISTRY OF EDUCATION TASKED AN ITALIAN ARCHITECTURE FIRM TO PROVIDE 60 TRANSITIONAL CLASSROOMS TO THE MBERA CAMP TO REPLACE THE EXISTING STRUCTURES, WHICH PERFORMED BADLY IN THE WIND.

THE CONCEPT OF THE SEMI-PERMANENT, TRANSITIONAL CLASSROOMS AIMS TO CONNECT DURABLE ARCHITECTURAL SOLUTIONS FOR BUILDING IN THE DESERT WITH EMERGENCY SITUATIONS.

THE SANDBAG BUILDING TECHNIQUE WAS FOUND TO BE THE BEST SOLUTION AS THE TRANSPORT OF OTHER BUILDING MATERIALS LIKE BRICK IS EXPENSIVE WHILE SAND IS LARGELY AVAILABLE AT THE MBERA SITE.

BAGS FILLED WITH SAND WERE USED AS MASONRY, AND CEMENT PLASTER WAS APPLIED ON CHICKEN WIRE TO BOTH SIDES OF EACH WALL. THE THERMAL PERFORMANCE OF THE CLASSROOMS WAS A GREAT CONSIDERATION IN THE DESIGN. THE ARCHITECTS COVERED THE ROOF WITH CURVED METAL TRUSSES (A LOCALLY PRODUCED MATERIAL WIDELY USED IN THE AREA), AIMED AT MINIMISING THE EFFECTS OF WIND AND ASSURING NATURAL VENTILATION AND LIGHTING IN THE CLASSROOM.

REFUGEES LIVING ON THE CAMP WERE EMPLOYED AS UNSKILLED LABOURERS ALONGSIDE SKILLED BRICKLAYERS AND METALWORKERS ON A "CASH FOR WORK" BASIS. THIS ARRANGEMENT GAVE THE REFUGEES AN OPPORTUNITY TO EARN SOME MONEY BY WORKING ON THE STRUCTURES THAT WOULD FORM A PART OF THEIR TEMPORARY HOME.

THE EDUCATION CENTRE BUILDING WAS COMPLETED IN FOUR MONTHS, WITH EACH CLASSROOM COSTING AROUND \$3575.



**THE SAHARA DESERT**  
**HOW TO LIVE IN THE SAHARA?**  
**BUILDING TECHNIQUES**

**BUILDING WITH MUD:**

THERE ARE THREE GENERAL METHODS OF BUILDING IN MUD. IN SOME AREAS, A MIXTURE IS TAMPED IN PLACE USING A LARGE WOODEN FORM, OR COFFER. THE BLOCK IS ALLOWED TO DRY, THE COFFER IS REMOVED AND LIFTED ON TOP OF IT, AND THE PROCESS IS REPEATED. THIS IS PISÉ, OR RAMMED EARTH, CONSTRUCTION.

AS SECOND METHOD, USED IN NORTHERN SUDAN, IS CALLED COURSEING OR PUDDLING. A THIN LAYER OF MUD IS SHAPED BY HAND. AFTER IT DRIES, ANOTHER IS ADDED, AND THE WALL RISES.

BRICK IS THE THIRD TECHNIQUE. DATING FROM BEFORE RECORDED HISTORY, IT IS THE METHOD IN WIDEST USE TODAY. SOMETIMES, HAND MOLDED BRICKS DRY IN THE WALL; MORE FREQUENTLY, CAST ONES ARE LEFT ON THE GROUND TO BAKE IN THE SUN. SET IN PLACE, THE BRICKS ARE USUALLY JOINED BY MUD MORTAR AND COVERED WITH MUD PLASTER. THIS TECHNIQUE IS CALLED ADOBE, A WORD BORROWED FROM SPANISH. STILL EARLIER, SPANISH BORROWED IT FROM ARABIC, IN WHICH AL-TOB IS THE TYPE OF EARTH FROM WHICH SUN-DRIED BRICKS ARE MADE.

ONE OF MUD'S GREAT ADVANTAGES IS THERMAL. USUALLY UP TO 60 CM THICK, MUD WALLS HAVE A HIGH HEAT-RETAINING CAPACITY. DURING THE DAY, ACTING AS PASSIVE-SOLAR COLLECTORS, THEY INSULATE WELL AGAINST HIGH TEMPERATURES, AND AT NIGHT THE HEAT THEY HAVE ABSORBED IS SLOWLY RELEASED. WHILE OUTSIDE TEMPERATURES MAY SOAR OR FALL DRAMATICALLY, INDOOR ONES STAY REMARKABLY CONSTANT.



PUDDLING CONSTRUCTION



PISÉ CONSTRUCTION



SUN BACKED BRICKS

## CHAPTER 3

### VERNACULAR ARCHITECTURE



## VERNACULAR ARCHITECTURE

### VERNACULAR ARCHITECTURE

ARCHITECTURAL HISTORY, AS WRITTEN AND TAUGHT IN THE WESTERN WORLD, HAS NEVER BEEN CONCERNED WITH MORE THAN A FEW SELECT CULTURES. IN TERMS OF SPACE IT COMPRISES BUT A SMALL PART OF THE GLOBE - EUROPE, STRETCHES OF EGYPT AND ANATOLIA - OR LITTLE MORE THAN WAS KNOWN IN THE SECOND CENTURY A.D. MOREOVER, THE EVOLUTION OF ARCHITECTURE IS USUALLY DEALT WITH ONLY IN ITS LATE PHASES. SKIPPING THE FIRST FIFTY CENTURIES, CHRONICLERS PRESENT US WITH A FULL-DRESS PAGEANT OF "FORMAL" ARCHITECTURE. MENTIONING VERNACULAR ARCHITECTURE IS A WAY TO INTRODUCE THE UNFAMILIAR WORLD OF NONPEDIGREED ARCHITECTURE. IT COULD ALSO BE NAMED ANONYMOUS, SPONTANEOUS, INDIGENOUS, RURAL, AS THE CASE MAY BE. IN THIS CHAPTER THERE ARE SOME EXAMPLES OF VERNACULAR ARCHITECTURE AND A GENERAL OVERVIEW ABOUT THE TECHNOLOGY OF BUILDING BY EARTH WHICH IS AN IMPORTANT WAY OF VERNACULAR ARCHITECTURE:

#### THE AMPHITHEATRES OF MUYU-URAY:

ANONYMOUS ARCHITECTURE OF A MONUMENTAL KIND, UNKNOWN TO LAYMAN AND SCHOLAR ALIKE, CAN BE FOUND RIGHT ON THE AMERICAN CONTINENT. IN PERU, HALFWAY CUZCO AND MACHU PICCHU, LIES AN ANCIENT THEATRE THAT HAS NO COUNTERPART ANYWHERE ELSE. BUILT BY THE INCA TRIBE OF THE MARAS, IT COMPRISES FOUR THEATRES IN THE ROUND AND ONE IN THE FORM OF A HORSEHOE. AS MIGHT BE EXPECTED, THE ACOUSTICS OF ALL FIVE THEATRES ARE SUPERB. THE CONTOURS OF THE ARCHITECTURE HAVE BEEN ERODED BY THE ELEMENT, THE SITE TURNED TO PASTURE AND FARMLAND. YET THE BASIC STRUCTURE IS RELATIVELY WELL PRESERVED. THE LARGEST THEATRE - PROBABLY SET INTO A METEORIC CRATER - ACCOMMODATED AS MANY AS 60,000 PEOPLE. TWELVE OF ITS TERRACES, EACH ABOUT 2 METRES HIGH AND 7 METRES WIDE, STILL EXIST. THE LOWEST CIRCULAR PLATFORM OF THE FOUR THEATRES, WHICH CORRESPONDS TO THE GREEK ORCHESTRA, VARIES IN DIAMETRE FROM 24 TO 40 METRES. WATER PIPES, 30 CM WIDE, CARVED INTO STONE MONOLITHS, CARRIED SPRING WATER FROM A NEARBY MOUNTAIN PEAK.

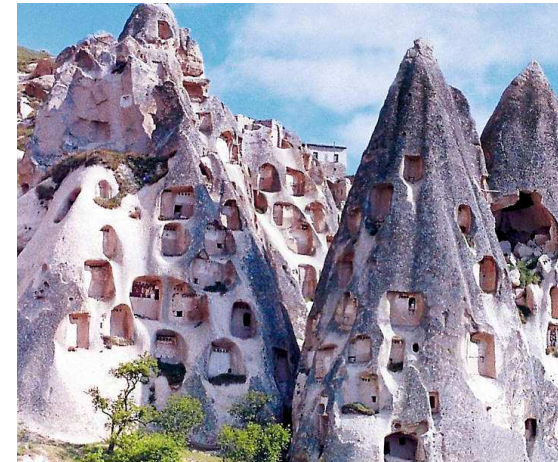
ALTHOUGH NOTHING IS KNOWN ABOUT THE KIND OF SPECTACLES PERFORMED, WE MAY ASSUME THAT ATHLETIC EXHIBITIONS - BOXING, JUMPING, RACING, AND ANIMAL BAITING - OUTWEIGHED TRUE THEATRICALS. PERUVIAN ARCHAEOLOGISTS BELIEVE THAT THE "UNDESCRIBABLE BEAUTY" OF THE LANDSCAPE (ABOUT 3600 METRES ABOVE SEA LEVEL) WAS AN INSPIRATIONAL FACTOR IN THE GRANDIOSE ENTERPRISE.



THE TROGLODYTIC TOWN OF PANTALICA: DURABILITY AND VERSATILITY ARE CHARACTERISTIC OF VERNACULAR ARCHITECTURE. THE RUDE CHAMBERS WHOSE DOORS CAN BE MADE OUT IN THE PICTURE WERE CUT INTO THE NEARLY PERPENDICULAR DECLIVITIES OF THE ANAPO VALLEY BY THE SICULI, WHO INHABITED SICILY ABOUT 3000 YEARS AGO. ORIGINALLY SERVING AS BURIAL GROUNDS FOR AN ADJACENT PREHISTORIC TOWN, THEY WERE CONVERTED INTO DWELLINGS DURING THE MIDDLE AGES. AS A RULE, THEY FORM MULTISTORIED APARTMENTS CONNECTED BY INTERIOR PASSAGES. SIMILAR ESTABLISHMENTS ARE SCATTERED ALL OVER SICILY - NEAR SICULIANO, CATABELOTTA, AND RAFFADALE.



ARCHITECTURE BY SUBTRACTION: OCCASIONALLY, MEN HAVE CARVED ENTIRE TOWNS OUT OF LIVE ROCK ABOVE GROUND. THE RAMPARTS, CASTLE, AND HOUSES OF LES BAUX-EN-PROVENCE WERE CUT TO A GREAT EXTENT FROM THE CALCAREOUS MOUNTAIN ON WHICH THEY STAND. AN IMPORTANT PLACE IN THE MIDDLE AGES, IT HAS LONG BEEN ABANDONED; THE NUMBER OF ITS INHABITANTS HAS DWINDLED TO 250. IN THE PHOTO, A CLOSE-UP OF ONE OF THE GÖREME CONES IN TURKEY, SCULPTED BY NATURE. THEY RANGE FROM THE SIZE OF A TENT TO THAT OF A MINOR SKYSCRAPER WITH AS 16 FLOORS.



#### ITALIAN HILL TOWNS:

THE VERY THOUGHT THAT MODERN MAN COULD LIVE IN ANACHRONISTIC COMMUNITIES LIKE THESE WOULD SEEM ABSURD WERE IT NOT THAT THEY ARE INCREASINGLY BECOMING REFUGES FOR CITY DWELLERS. PEOPLE WHO HAVE NOT YET BEEN REDUCED TO APPENDAGES TO AUTOMOBILES FIND IN THEM A FOUNTAIN OF YOUTH.

POSITANO IN SALERNO CHANGED WITHIN A FEW YEARS FROM A SIMPLE FISHING TOWN - IT WAS AN IMPORTANT HARBOR SOME FIVE HUNDRED YEARS AGO - TO A LUXURIOUS RESORT, WITHOUT DESTROYING THE LOCAL ARCHITECTURE.





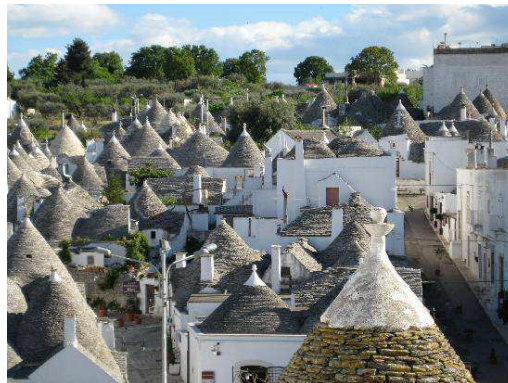
**CLIFF DWELLERS OF THE DOGON:**

AMONG SUDANESE TRIBES, ONE OF THE BEST KNOWN - FOR THEIR ART RATHER THAN FOR THEIR ARCHITECTURE - ARE THE DOGONS. NUMBERING ABOUT A QUARTER OF A MILLION PEOPLE, THEY LIVE ALONG THE PLATEAU OF BANDIAGARA, SOUTH OF TOMBOUCTOU. THE PHOTOGRAPH SHOWS ONE OF A STRING OF VILLAGES BUILT ON ROCKS FALLEN FROM HIGH CLIFFS. WHAT AT FIRST GLANCE APPEARS TO BE MERE DEBRIS, IS A MIXTURE OF FLAT-ROOFED DWELLINGS AND STRAW-HATTED HOUSES. THE ABSENCE OF ANY LARGE BUILDINGS, VEHICLES, OR EVEN STREETS, WOULD SUGGEST TO US BARBARIAN CONDITIONS HAD NOT EXTENSIVE ETHNOGRAPHIC INVESTIGATIONS DISCLOSED A HIGHLY SOPHISTICATED CULTURE. THE DOGONS' ARCHITECTURE EXPRESS COMMUNAL ORGANIZATION; THEIR RELIGIOUSLY INSPIRED SCULPTURE RANKS AMONG THE BEST OF AFRICAN ART. TYPICAL SUBJECTS ARE HUMAN FIGURES SCULPTED FROM TREE TRUNKS THAT FORM AN INTEGRAL PART OF ARCHITECTURE.



**PRIMEVAL FORMS:**

PEASANT HOUSES, CALLED TRULLI, DOT THE ALMOND AND OLIVE GROVES OF SOUTHERN APULIA IN ITALY. THEY ARE BUILT OF ANNULAR LAYERS OF STONE THAT TERMINATE IN A FALSE CONIC CUPOLA CROWNED BY A KEYSTONE. THE ARCHAIC HOUSE FORM OF AN EARLY MEGALITHIC CIVILIZATION, THEY ARE RELATED TO THE BALEARIC TALYOTS, SARDINIAN NURAGHI, AND THE SESI OF PANTELLERIA. DESPITE THE PASSAGE OF A DOZEN NATIONS, THE TYPE HAS SURVIVED ALMOST WITHOUT CHANGE SINCE THE SECOND MILLENNIUM B.C. IT STILL SERVES THE INHABITANTS WELL.



**THE CLASSICAL VERNACULAR:**

RUGGED NATURE SEEMS TO STIMULATE MAN'S ARTISTIC POWERS. THIS REMARKABLE TOWN, WHOSE INHABITANTS COME NEAREST TO LIVING ON A VOLCANO, IS A CASE IN POINT. APANOMERIA IN GREECE IS BUILT ON THE BRINK OF A CRATER, THE LEFTOVERS OF A VOLCANO THAT BLEW UP IN PREHISTORIC TIME. THE HOUSES, BLINDINGLY WHITE AGAINST THE MASSES OF A DARK-COLORED ROCKS, REPRESENT A SORT OF ENDLESS SCULPTURE.

IN THE 1920S, COMMERCIAL ARCHITECTURE WAS ALREADY ON THE MARCH. THE OLD HOUSES, HOWEVER, ARE MODELED ACCORDING TO LOCAL TRADITIONS, THEIR FORMS BEING NO MORE ACCIDENTAL THAN THE VOICES OF A FIGURE. ALL OF THEM ARE VARIATIONS OF A SINGLE DWELLING TYPE, THE VAULTED CELL. THEY CONTAIN NO INTERIOR STAIRCASES, EACH ROOM BEING ACCESSIBLE FROM THE OUTSIDE ONLY. THE SMALL WINDOWS PROVE PERFECTLY ADEQUATE SINCE WALLS AND CEILING - AND OFTEN ALSO THE FLOOR - ARE WHITEWASHED AND THUS REFLECT THE LIGHT. NO OUTSIZE BUILDINGS DISTURB THE GENERAL HARMONY; EVEN THE MANY CHURCHES AND CHAPELS SUBMIT TO THE VERNACULAR.



**LOGGIE:**

THE LOGGIA, AN OLD FIXTURE OF VERNACULAR ARCHITECTURE, RUNS THE ENTIRE GAMUT FROM COVERED WALKWAYS THROUGH MORE OR LESS PROTECTED BALCONIES AND GALLERIES TO COLUMNED HALLS. IN THE PHOTO, A WING OF THE GREEK MONASTERY SIMON PETRA ON MOUNT ATHOS.

**SEMICOVERED STREETS:**

LESS STURDY THAN ARCHADES BUT MORE AIRY ARE THE LACY COVERINGS THAT ARE THE DELIGHT OF ORIENTAL STREETS AND COURTYARDS. THEIR SHADOW-PLAYS ARE STAGED WITH SIMPLE MEANS: CANOPIES OF TRELLISES, MATES, NETS, OR, VINES ARE TURNED TO GOOD ACCOUNT FOR DISTILLING THE RAW SUNLIGHT INTO A SORT OF OPTICAL LIQUEUR. IN THE PHOTO, CANVAS AWNINGS SPREAD ACROSS A STREET IN SEVILLA.



#### FERTILIZER PLANTS:

IN THE WESTERN WORLD, PIGEONS TAKE THEIR PLACE SOMEWHERE AMONG SUCH PESTS AS HOUSEFLIES OR CHIGGERS; WHETHER NUISANCE OR MENACE, MOST PEOPLE LOOK FORWARD TO THEIR EXTINCTION. NOT SO IN EASTERN COUNTRIES, WHERE PIGEONRY IS HELD IN THE HIGHEST ESTEEM. THE BIRDS' DROPPINGS ARE COLLECTED IN SPECIAL TOWERS THAT WORK ON THE PRINCIPLE OF A PIGGY-BANK. WHEN FILLED, THEY ARE SMASHED AND THEIR PRECIOUS CONTENTS PUT TO USE. IN THE PHOTO, PIGEONCOTS IN THE NILE VALLEY IN EGYPT.



#### WOOD IN VERNACULAR ARCHITECTURE:

LOG CABINS ARE NOT THE ONLY ARCHITECTURE THAT ONE CAN MAKE UNSAWED TREE TRUNKS. IN THE EXAMPLE SHOWN, THIS MATERIAL ACHIEVES MONUMENTALITY, TEMPERED BY ELEGANCE. A ROW OF TORII FLANKING THE APPROACH TO THE INARI SHRINE IN KYOTO IN JAPAN. A TORII IS A KIND OF SQUARE ARCH, ACCESSORY TO SHINTO SHRINES; ITS ORIGIN IS UNKNOWN.



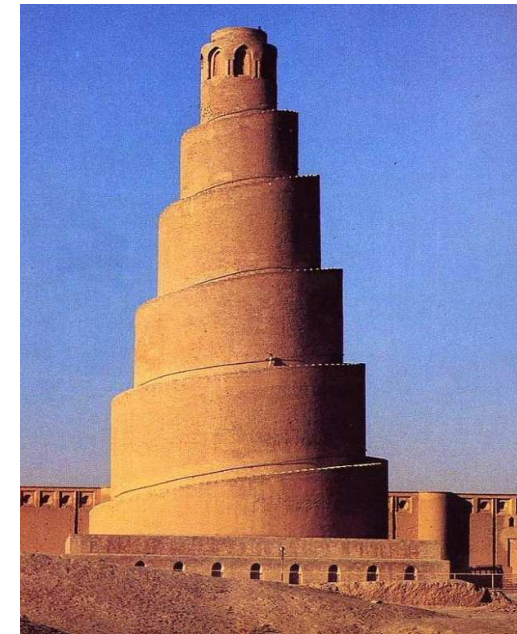
#### THE AIR-CONDITIONERS OF HYDERABAD SIND:

THESE UNUSUAL ROOFSCAPES ARE A PROMINENT FEATURE OF THE LOWER SIND DISTRICT IN WEST PAKISTAN. FROM APRIL TO JUNE, TEMPERATURES RANGE ABOVE 48°C, LOWERED BY AN AFTERNOON BREEZE TO A PLEASANT 35°C. TO CHANNEL THE WIND INTO EVERY BUILDING, "BAD-GIR", WINDSCOOPS, ARE INSTALLED ON THE ROOFS, ONE TO EACH ROOM. SINCE THE WIND ALWAYS BLOWS FROM THE SAME DIRECTION, THE POSITION OF THE WINDSCOOPS IS PERMANENTLY FIXED. IN MULTISTORIED HOUSES THEY REACH ALL THE WAY DOWN, DOUBLING AS INTRAMURAL TELEPHONES. ALTHOUGH THE ORIGIN OF THIS CONTRAPTION IS UNKNOWN, IT HAS BEEN IN USE FOR AT LEAST FIVE HUNDRED YEARS.



#### SYMBOLIC VERNACULAR:

ONLY IN OUR TIME ARE TOWERS BUILT FOR PROFIT AND USURY. IN THE PAST THEIR SIGNIFICANCE WAS MAINLY SYMBOLIC. APART FROM THE FUNCTIONAL DEFENSIVE TOWERS, THEY USUALLY EXPRESSED RELIGIOUS SENTIMENTS - FAITH, HOPE, GRIEF, AND THE LIKE. SPIRES, MINARETS, AND PAGODAS WERE, OR ARE, ESSENTIAL PARTS OF BUILDING INTENDED FOR LAUNCHING PRAYERS; ONLY THE NOTORIOUS TOWER OF BABEL SPELLED, UNACCOUNTABLY, BLASPHEMY. IN THE PHOTO, THE TOWER OF SAMARRA IN IRAQ, BUILT ELEVEN CENTURIES AGO. THE 42 METRES ASCENT HAS TO BE MADE WITHOUT BENEFIT OF RAILINGS.





**VERNACULAR ARCHITECTURE**  
**BUILDING WITH EARTH**  
**THE TECHNOLOGY OF EARTH BUILDING**

**INTRODUCTION**

IN NEARLY ALL HOT-ARID AND TEMPERATE CLIMATES, EARTH HAS ALWAYS BEEN THE MOST PREVALENT BUILDING MATERIAL. EVEN TODAY, ONE THIRD OF THE HUMAN POPULATION RESIDES IN EARTHEN HOUSES; IN DEVELOPING COUNTRIES THIS FIGURE IS MORE THAN ONE HALF. IT HAS PROVEN IMPOSSIBLE TO FULFIL THE IMMENSE REQUIREMENTS FOR SHELTER IN THE DEVELOPING COUNTRIES WITH INDUSTRIAL BUILDING MATERIALS, I.E. BRICK, CONCRETE AND STEEL, NOR WITH INDUSTRIALISED CONSTRUCTION TECHNIQUES. WORLDWIDE, NO REGION IS ENDOWED WITH THE PRODUCTIVE CAPACITY OR FINANCIAL RESOURCES NEEDED TO SATISFY THIS DEMAND. IN THE DEVELOPING COUNTRIES, REQUIREMENTS FOR SHELTER CAN BE MET ONLY BY USING LOCAL BUILDING MATERIALS AND RELYING ON DO-IT-YOURSELF CONSTRUCTION TECHNIQUES.

EARTH IS THE MOST IMPORTANT NATURAL BUILDING MATERIAL, AND IT IS AVAILABLE IN MOST REGIONS OF THE WORLD. IT IS FREQUENTLY OBTAINED DIRECTLY FROM THE BUILDING SITE WHEN EXCAVATING FOUNDATIONS OR BASEMENTS. IN THE INDUSTRIALISED COUNTRIES, CARELESS EXPLOITATION OF RESOURCES AND CENTRALISED CAPITAL COMBINED WITH ENERGY-INTENSIVE PRODUCTION IS NOT ONLY WASTEFUL; IT ALSO POLLUTES THE ENVIRONMENT AND INCREASES UNEMPLOYMENT. IN THESE COUNTRIES, EARTH IS BEING REVIVED AS A BUILDING MATERIAL.

INCREASINGLY, PEOPLE WHEN BUILDING HOMES DEMAND ENERGY- AND COST-EFFECTIVE BUILDINGS THAT EMPHASISE A HEALTHY, BALANCED INDOOR CLIMATE. THEY ARE COMING TO REALISE THAT MUD, AS A NATURAL BUILDING MATERIAL, IS SUPERIOR TO INDUSTRIAL BUILDING MATERIALS SUCH AS CONCRETE, BRICK AND LIME-SANDSTONE.

NEWLY DEVELOPED, ADVANCED EARTH BUILDING TECHNIQUES DEMONSTRATE THE VALUE OF EARTH NOT ONLY IN DO-IT-YOURSELF CONSTRUCTION, BUT ALSO FOR INDUSTRIALISED CONSTRUCTION INVOLVING CONTRACTORS.

**HISTORY:**

EARTH CONSTRUCTION TECHNIQUES HAVE BEEN KNOWN FOR OVER 9000 YEARS. MUD BRICK (ADOBE) HOUSES DATING FROM 8000 TO 6000 BC HAVE BEEN DISCOVERED IN RUSSIAN TURKESTAN. RAMMED EARTH FOUNDATIONS DATING FROM CA. 5000 BC HAVE BEEN DISCOVERED IN ASSYRIA. EARTH WAS USED AS THE BUILDING MATERIAL IN ALL ANCIENT CULTURES, NOT ONLY FOR HOMES, BUT FOR RELIGIOUS BUILDINGS AS WELL. (1) SHOWS VAULTS IN THE TEMPLE OF RAMSES II AT GOURNA, EGYPT, BUILT FROM MUD BRICKS 3200 YEARS AGO. (2) SHOWS THE CITADEL OF BAM IN IRAN, PARTS OF WHICH ARE CA. 2500 YEARS OLD; (3) SHOWS A FORTIFIED CITY IN THE DRAA VALLEY IN MOROCCO, WHICH IS AROUND 250 YEARS OLD. THE 4000-YEAR-OLD GREAT WALL OF CHINA WAS ORIGINALLY BUILT SOLELY OF RAMMED EARTH; ONLY A LATER COVERING OF STONES AND BRICKS GAVE IT THE APPEARANCE OF A STONE WALL. THE CORE OF THE SUN PYRAMID IN TEOTIHUACAN, MEXICO, BUILT BETWEEN THE 300 AND 900 AD, CONSISTS OF APPROXIMATELY 2 MILLION TONS OF RAMMED EARTH.

MANY CENTURIES AGO, IN DRY CLIMATIC ZONES WHERE WOOD IS SCARCE, CONSTRUCTION TECHNIQUES WERE DEVELOPED IN WHICH BUILDINGS WERE COVERED WITH MUD BRICK VAULTS OR DOMES WITHOUT FORMWORK OR SUPPORT DURING CONSTRUCTION. (4) SHOWS THE BAZAAR QUARTER OF SIRDJAN IN PERSIA, WHICH

IS COVERED BY SUCH DOMES AND VAULTS. IN CHINA, TWENTY MILLION PEOPLE LIVE IN UNDERGROUND HOUSES OR CAVES THAT WERE DUG IN THE SILTY SOIL. BRONZE AGE DISCOVERIES HAVE ESTABLISHED THAT IN GERMANY EARTH WAS USED AS AN INFILL IN TIMBER-FRAMED HOUSES OR TO SEAL WALLS MADE OF TREE TRUNKS. WATTLE AND DAUB WAS ALSO USED. THE OLDEST EXAMPLE OF MUD BRICK WALLS IN NORTHERN EUROPE, FOUND IN THE HEUNEURG FORT NEAR LAKE CONSTANCE, GERMANY (6) DATES BACK TO THE 6TH CENTURY BC. WE KNOW FROM THE ANCIENT TEXTS OF PLINY THAT THERE WERE RAMMED EARTH FORTS IN SPAIN BY THE END OF THE YEAR 100 BC.

IN MEXICO, CENTRAL AMERICA AND SOUTH AMERICA, ADOBE BUILDINGS ARE KNOWN IN NEARLY ALL PRE-COLUMBIAN CULTURES. THE RAMMED EARTH TECHNIQUE WAS ALSO KNOWN IN MANY AREAS, WHILE THE SPANISH CONQUERORS BROUGHT IT TO OTHERS. (5) SHOWS A RAMMED EARTH FINCA IN THE STATE OF SÃO PAULO, BRAZIL, WHICH IS 250 YEARS OLD.



(1)



(2)



(3)



(4)



(5)



(6)

IN AFRICA, NEARLY ALL EARLY MOSQUES ARE BUILT FROM EARTH. (9) SHOWS ONE FROM THE 12TH CENTURY, (7 AND 8) SHOW LATER EXAMPLES IN MALI AND IRAN. IN THE MEDIEVAL PERIOD (13TH TO 17TH CENTURIES), EARTH WAS USED THROUGHOUT CENTRAL EUROPE AS INFILL IN TIMBER-FRAMED BUILDINGS, AS WELL AS TO COVER STRAW ROOFS TO MAKE THEM FIRE-RESISTANT. IN FRANCE, THE RAMMED EARTH TECHNIQUE, CALLED TERRE PISÉ, WAS WIDESPREAD FROM THE 15TH TO THE 19TH CENTURIES. NEAR THE CITY OF LYON, THERE ARE SEVERAL BUILDINGS THAT ARE MORE THAN 300 YEARS OLD AND ARE STILL INHABITED. THE TECHNIQUE CAME TO BE KNOWN ALL OVER GERMANY AND IN NEIGHBOURING COUNTRIES THROUGH COINTERAUX, AND THROUGH DAVID GILLY, WHO WROTE THE FAMOUS HANDBUCH DER LEHMBAUKUNST, WHICH DESCRIBES THE RAMMED EARTH TECHNIQUE AS THE MOST ADVANTAGEOUS EARTH CONSTRUCTION METHOD. IN GERMANY, THE OLDEST INHABITED HOUSE WITH RAMMED EARTH WALLS DATES FROM 1795 (10). ITS OWNER, THE DIRECTOR OF THE FIRE DEPARTMENT, CLAIMED THAT FIRE-RESISTANT HOUSES COULD BE BUILT MORE ECONOMICALLY USING THIS TECHNIQUE, AS OPPOSED TO THE USUAL TIMBER FRAME HOUSES WITH EARTH INFILL.

THE TALLEST HOUSE WITH SOLID EARTH WALLS IN EUROPE IS AT WEILBURG, GERMANY. COMPLETED IN 1828, IT STILL STANDS (11). ALL CEILINGS AND THE ENTIRE ROOF STRUCTURE REST ON THE SOLID RAMMED EARTH WALLS THAT ARE 75 CM THICK AT THE BOTTOM AND 40 CM THICK AT THE TOP FLOOR (THE COMPRESSIVE FORCE AT THE BOTTOM OF THE WALLS REACHES 7,5 KG/CM<sup>2</sup>). (12) SHOWS THE FACADES OF OTHER RAMMED EARTH HOUSES AT WEILBURG, BUILT AROUND 1830.



(7)



(8)



(9)



(10)



(11)



(12)

#### EARTH AS A BUILDING MATERIAL:

EARTH, WHEN USED AS A BUILDING MATERIAL, IS OFTEN GIVEN DIFFERENT NAMES. REFERRED TO IN SCIENTIFIC TERMS AS LOAM, IT IS A MIXTURE OF CLAY, SILT (VERY FINE SAND), SAND, AND OCCASIONALLY LARGER AGGREGATES SUCH AS GRAVEL OR STONES.

WHEN SPEAKING OF HANDMADE UNBAKED BRICKS, THE TERMS "MUD BRICKS" OR "ADOBES" ARE USUALLY EMPLOYED; WHEN SPEAKING OF COMPRESSED UNBAKED BRICKS, THE TERM "SOIL BLOCKS" IS USED. WHEN COMPACTED WITHIN A FORMWORK, IT IS CALLED "RAMMED EARTH".

LOAM HAS THREE DISADVANTAGES WHEN COMPARED TO COMMON INDUSTRIALISED BUILDING MATERIALS:

##### 1. LOAM IS NOT A STANDARDISED BUILDING MATERIAL

DEPENDING ON THE SITE WHERE THE LOAM IS DUG OUT, IT WILL BE COMPOSED OF DIFFERING AMOUNTS AND TYPES OF CLAY, SILT, SAND AND AGGREGATES. ITS CHARACTERISTICS, THEREFORE, MAY DIFFER FROM SITE TO SITE, AND THE PREPARATION OF THE CORRECT MIX FOR A SPECIFIC APPLICATION MAY ALSO DIFFER. IN ORDER TO JUDGE ITS CHARACTERISTICS AND ALTER THESE, WHEN NECESSARY, BY APPLYING ADDITIVES, ONE NEEDS TO KNOW THE SPECIFIC COMPOSITION OF THE LOAM INVOLVED.

##### 2. LOAM MIXTURES SHRINK WHEN DRYING

DUE TO EVAPORATION OF THE WATER USED TO PREPARE THE MIXTURE (MOISTURE IS REQUIRED TO ACTIVATE ITS BINDING STRENGTH AND TO ACHIEVE WORKABILITY), SHRINKAGE CRACKS WILL OCCUR. THE LINEAR SHRINKAGE RATIO IS USUALLY BETWEEN 3% AND 12% WITH WET MIXTURES (SUCH AS THOSE USED FOR MORTAR AND MUD BRICKS), AND BETWEEN 0.4% AND 2% WITH DRIER MIXTURES (USED FOR RAMMED EARTH, COMPRESSED SOIL BLOCKS). SHRINKAGE CAN BE MINIMISED BY REDUCING THE CLAY AND THE WATER CONTENT, BY OPTIMISING THE GRAIN SIZE DISTRIBUTION, AND BY USING ADDITIVES.

##### 3. LOAM IS NOT WATER-RESISTANT

LOAM MUST BE SHELTERED AGAINST RAIN AND FROST, ESPECIALLY IN ITS WET STATE. EARTH WALLS CAN BE PROTECTED BY ROOF OVERHANGS, DAMPPROOF COURSES, APPROPRIATE SURFACE COATINGS ETC.

ON THE OTHER HAND, LOAM HAS MANY ADVANTAGES IN COMPARISON TO COMMON INDUSTRIAL BUILDING MATERIALS:

##### 1. LOAM BALANCES AIR HUMIDITY

LOAM IS ABLE TO ABSORB AND DESORB HUMIDITY FASTER AND TO A GREATER EXTENT THAN ANY OTHER BUILDING MATERIAL, ENABLING IT TO BALANCE INDOOR CLIMATE. EXPERIMENTS AT THE FORSCHUNGLABOR FÜR EXPERIMENTELLES BAUEN (BUILDING RESEARCH LABORATORY, OR BRL) AT THE UNIVERSITY OF KASSEL,

GERMANY, DEMONSTRATED THAT WHEN THE RELATIVE HUMIDITY IN A ROOM WAS RAISED SUDDENLY FROM 50% TO 80%, UNBAKED BRICKS WERE ABLE, IN A TWODAY PERIOD TO ABSORB 30 TIMES MORE HUMIDITY THAN BAKED BRICKS. EVEN WHEN STANDING IN A CLIMATIC CHAMBER AT 95% HUMIDITY FOR SIX MONTHS, ADOBES DO NOT BECOME WET OR LOSE THEIR STABILITY; NOR DO THEY EXCEED THEIR EQUILIBRIUM MOISTURE CONTENT, WHICH IS ABOUT 5% TO 7% BY WEIGHT. (THE MAXIMUM HUMIDITY A DRY MATERIAL CAN ABSORB IS CALLED ITS "EQUILIBRIUM MOISTURE CONTENT").

MEASUREMENTS TAKEN IN A NEWLY BUILT HOUSE IN GERMANY, ALL OF WHOSE INTERIOR AND EXTERIOR WALLS ARE FROM EARTH, OVER A PERIOD OF EIGHT YEARS, SHOWED THAT THE RELATIVE HUMIDITY IN THIS HOUSE WAS A NEARLY CONSTANT 50% THROUGHOUT THE YEAR. IT FLUCTUATED BY ONLY 5% TO 10%, THEREBY PRODUCING HEALTHY LIVING CONDITION WITH REDUCED HUMIDITY IN SUMMER AND ELEVATED HUMIDITY IN WINTER.

## 2. LOAM STORES HEAT

LIKE ALL HEAVY MATERIALS, LOAM STORES HEAT. AS A RESULT, IN CLIMATIC ZONES WITH HIGH DIURNAL TEMPERATURE DIFFERENCES, OR WHERE IT BECOMES NECESSARY TO STORE SOLAR HEAT GAIN BY PASSIVE MEANS, LOAM CAN BALANCE INDOOR CLIMATE.

## 3. LOAM SAVES ENERGY AND REDUCES ENVIRONMENTAL POLLUTION

THE PREPARATION, TRANSPORT AND HANDLING OF LOAM ON SITE REQUIRES ONLY CA. 1% OF THE ENERGY NEEDED FOR THE PRODUCTION, TRANSPORT AND HANDLING OF BAKED BRICKS OR REINFORCED CONCRETE. LOAM, THEN, PRODUCES VIRTUALLY NO ENVIRONMENTAL POLLUTION.

## 4. LOAM IS ALWAYS REUSABLE

UNBAKED LOAM CAN BE RECYCLED AN INDEFINITE NUMBER OF TIMES OVER AN EXTREMELY LONG PERIOD. OLD DRY LOAM CAN BE REUSED AFTER SOAKING IN WATER, SO LOAM NEVER BECOMES A WASTE MATERIAL THAT HARMS THE ENVIRONMENT.

## 5. LOAM SAVES MATERIAL AND TRANSPORTATION COSTS

CLAYEY SOIL IS OFTEN FOUND ON SITE, SO THAT THE SOIL EXCAVATED FOR FOUNDATIONS CAN THEN BE USED FOR EARTH CONSTRUCTION. IF THE SOIL CONTAINS TOO LITTLE CLAY, THEN CLAYEY SOIL MUST BE ADDED, WHEREAS IF TOO MUCH CLAY IS PRESENT, SAND IS ADDED.

THE USE OF EXCAVATED SOIL MEANS GREATLY REDUCED COSTS IN COMPARISON WITH OTHER BUILDING MATERIALS. EVEN IF THIS SOIL IS TRANSPORTED FROM OTHER CONSTRUCTION SITES, IT IS USUALLY MUCH CHEAPER THAN INDUSTRIAL BUILDING MATERIALS.

## 6. LOAM IS IDEAL FOR DO-IT-YOURSELF CONSTRUCTION

PROVIDED THE BUILDING PROCESS IS SUPERVISED BY AN EXPERIENCED INDIVIDUAL, EARTH CONSTRUCTION TECHNIQUES CAN USUALLY BE EXECUTED BY NON-PROFESSIONALS. SINCE THE PROCESSES INVOLVED ARE LABOUR-INTENSIVE AND REQUIRE ONLY INEXPENSIVE TOOLS AND MACHINES, THEY ARE IDEAL FOR DO-IT-YOURSELF BUILDING.

## 7. LOAM PRESERVES TIMBER AND OTHER ORGANIC MATERIALS

OWING TO ITS LOW EQUILIBRIUM MOISTURE CONTENT OF 0.4% TO 6% BY WEIGHT AND ITS HIGH CAPILLARITY, LOAM CONSERVES THE TIMBER ELEMENTS THAT REMAIN IN CONTACT WITH IT BY KEEPING THEM DRY. NORMALLY, FUNGI OR INSECTS WILL NOT DAMAGE SUCH WOOD, SINCE INSECTS NEED A MINIMUM OF 14% TO 18% HUMIDITY TO MAINTAIN LIFE, AND FUNGI MORE THAN 20% (MÖHLER 1978). SIMILARLY, LOAM CAN PRESERVE SMALL QUANTITIES OF STRAW THAT ARE MIXED INTO IT.

HOWEVER, IF LIGHTWEIGHT STRAW LOAM WITH A DENSITY OF LESS THAN 500 TO 600 KG/M<sup>3</sup> IS USED, THEN THE LOAM MAY LOSE ITS PRESERVATIVE CAPACITY DUE TO THE HIGH CAPILLARITY OF THE STRAW WHEN USED IN SUCH HIGH PROPORTIONS. IN SUCH CASES, THE STRAW MAY ROT WHEN REMAINING WET OVER LONG PERIODS.

## 8. LOAM ABSORBS POLLUTANTS

IT IS OFTEN MAINTAINED THAT EARTH WALLS HELP TO CLEAN POLLUTED INDOOR AIR, BUT THIS HAS YET TO BE PROVEN SCIENTIFICALLY. IT IS A FACT THAT EARTH WALLS CAN ABSORB POLLUTANTS DISSOLVED IN WATER. FOR INSTANCE, A DEMONSTRATION PLANT EXISTS IN RUHLEBEN, BERLIN, WHICH USES CLAYEY SOIL TO REMOVE PHOSPHATES FROM 600 M<sup>3</sup> OF SEWAGE DAILY. THE PHOSPHATES ARE BOUND BY THE CLAY MINERALS AND EXTRACTED FROM THE SEWAGE. THE ADVANTAGE OF THIS PROCEDURE IS THAT SINCE NO FOREIGN SUBSTANCES REMAIN IN THE WATER, THE PHOSPHATES ARE CONVERTED INTO CALCIUM PHOSPHATE FOR REUSE AS A FERTILISER.

## THE PROPERTIES OF EARTH AS A BUILDING MATERIAL

LOAM IS A PRODUCT OF EROSION FROM ROCK IN THE EARTH'S CRUST. THIS EROSION OCCURS MAINLY THROUGH THE MECHANICAL GRINDING OF ROCK VIA THE MOVEMENT OF GLACIERS, WATER AND WIND, OR THROUGH THERMAL EXPANSION AND CONTRACTION OF ROCK, OR THROUGH THE EXPANSION OF FREEZING WATER IN THE CREVICES OF THE ROCK. DUE TO ORGANIC ACIDS PREVALENT IN PLANTS, MOREOVER, CHEMICAL REACTIONS DUE TO WATER AND OXYGEN ALSO LEAD TO ROCK EROSION. THE COMPOSITION AND VARYING PROPERTIES OF LOAM DEPEND ON LOCAL CONDITIONS. GRAVELLY MOUNTAINOUS LOAMS, FOR INSTANCE, ARE MORE SUITABLE FOR RAMMED EARTH (PROVIDED THEY CONTAIN SUFFICIENT CLAY), WHILE RIVERSIDE LOAMS ARE OFTEN SILTY AND ARE THEREFORE LESS WEATHERRESISTANT AND WEAKER IN COMPRESSION.

LOAM IS A MIXTURE OF CLAY, SILT AND SAND, AND SOMETIMES CONTAINS LARGER AGGREGATES LIKE GRAVEL AND STONES. ENGINEERING SCIENCE DEFINES ITS PARTICLES ACCORDING TO DIAMETER: PARTICLES WITH DIAMETERS SMALLER THAN 0.002 MM ARE TERMED CLAY, THOSE BETWEEN 0.002 AND 0.06 MM ARE CALLED SILT, AND THOSE BETWEEN 0.06 AND 2 MM ARE CALLED SAND. PARTICLES OF LARGER DIAMETER ARE TERMED GRAVELS AND STONES.

LIKE CEMENT IN CONCRETE, CLAY ACTS AS A BINDER FOR ALL LARGER PARTICLES IN THE LOAM. SILT, SAND AND AGGREGATES CONSTITUTE THE FILLERS IN THE LOAM. DEPENDING ON WHICH OF THE THREE COMPONENTS IS DOMINANT, WE SPEAK OF A CLAYEY, SILTY OR SANDY LOAM. IN TRADITIONAL SOIL MECHANICS, IF THE CLAY CONTENT IS LESS THAN 15% BY WEIGHT, THE SOIL IS TERMED A LEAN CLAYEY SOIL. IF IT IS MORE THAN 30% BY WEIGHT, IT IS TERMED A RICH CLAYEY SOIL. COMPONENTS THAT FORM LESS THAN 5% OF THE TOTAL BY WEIGHT ARE NOT MENTIONED WHEN NAMING THE SOILS. THUS, FOR INSTANCE, A RICH SILTY, SANDY, LEAN CLAYEY SOIL CONTAINS MORE THAN 30% SILT, 15% TO 30% SAND, AND LESS THAN 15% CLAY WITH LESS THAN 5% GRAVEL OR ROCK. HOWEVER, IN EARTH CONSTRUCTION ENGINEERING, THIS METHOD OF NAMING SOILS IS LESS ACCURATE BECAUSE, FOR EXAMPLE, A LOAM WITH 14% CLAY WHICH WOULD BE CALLED LEAN CLAYEY IN SOIL MECHANICS, WOULD BE CONSIDERED A RICH CLAYEY SOIL FROM THE POINT OF VIEW OF EARTH CONSTRUCTION.

## RAMMED EARTHWORKS

ON ALL FIVE CONTINENTS, RAMMED EARTH HAS BEEN WELL-KNOWN FOR CENTURIES AS A TRADITIONAL WALL CONSTRUCTION TECHNIQUE. IN FACT, RAMMED EARTH FOUNDATIONS FOUND IN ASSYRIA DATE BACK AS FAR AS 5000 BC.

WITH RAMMED EARTH TECHNIQUES, MOIST EARTH IS POURED INTO A FORMWORK IN LAYERS OF TO 15 CM THICK, AND THEN COMPACTED BY RAMMING. THE FORMWORK USUALLY CONSISTS OF TWO PARALLEL WALLS SEPARATED AND INTERCONNECTED BY SPACERS (1). THIS TECHNIQUE IS CALLED PISÉ DE TERRE OR TERRE PISÉ IN FRENCH; THE SPANISH NAMES IS BARRO APISONADO OR TAPIAL; AND THE GERMAN WORDS IS STAMPFLEHMBAU.

TRADITIONAL RAMMED EARTH TECHNIQUES ARE STILL USED IN MANY DEVELOPING COUNTRIES. REFINED FORMWORK SYSTEMS AND ELECTRICAL OR PNEUMATIC RAMMING REDUCES LABOUR INPUT SIGNIFICANTLY AND MAKES RAMMED EARTH TECHNIQUES RELEVANT IN SOME INDUSTRIALISED COUNTRIES AS WELL. FOR ECOLOGICAL, AND SOMETIMES FOR ECONOMIC REASONS AS WELL, MECHANISED RAMMED EARTH TECHNOLOGY MAY BE A VIABLE ALTERNATIVE TO CONVENTIONAL MASONRY ESPECIALLY IN THOSE INDUSTRIALISED COUNTRIES WHERE HIGH STANDARDS OF THERMAL INSULATION ARE NOT REQUIRED. MANY FIRMS EMPLOY THIS TECHNOLOGY IN THE SOUTHWESTERN USA AND IN AUSTRALIA.

IN COMPARISON WITH WET LOAM TECHNIQUES, THE SHRINKAGE RATIO OF RAMMED EARTH IS MUCH LOWER, AND STRENGTH MUCH HIGHER. IN COMPARISON WITH ADOBE MASONRY, RAMMED EARTH - SINCE IT IS MONOLITHIC - PROVIDES THE ADVANTAGE OF LONGER LIFE.

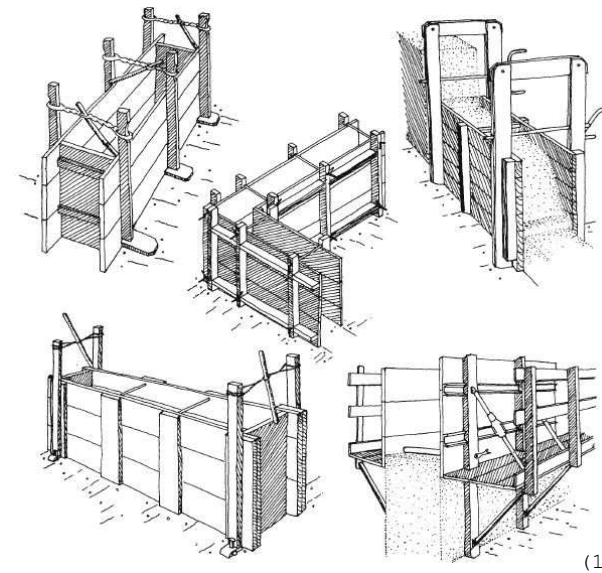
TECHNIQUES FOR RAMMED EARTH WALL AND DOME CONSTRUCTION ARE DESCRIBED IN THE FOLLOWING SECTIONS.

### FORMWORK:

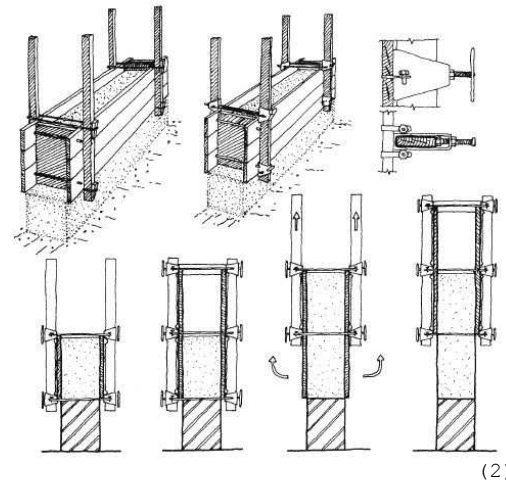
WITH TRADITIONAL FORMWORKS, THE BOARDS ON BOTH SIDES ARE HELD APART AND KEPT TOGETHER BY SPACERS (1). THESE SPACERS PIERCE THE WALL, CAUSING OPENINGS THAT MUST BE FILLED IN AFTER REMOVAL OF FORMWORK. A SYSTEM WITH VERY THIN TENSILE SPACERS (4 X 6 MM) PENETRATING THE WALL HAS BEEN DEVELOPED AT THE BUILDING RESEARCH LABORATORY (BRL) (2). IN ORDER TO COMPLETELY ELIMINATE THIS DISADVANTAGE, SPACER-FREE SYSTEMS HAVE BEEN DEVELOPED. AS SHOWN IN (3), FORMWORKS WITHOUT INTERMEDIARY SPACERS WHICH ARE BRACED ON BOTH SIDES REQUIRE A LOT OF SPACE AND HINDER SITE MOVEMENT CONSIDERABLY.

WITH A SPECIAL FORMWORK, ROUNDED CORNERS AND CURVED WALLS CAN ALSO BE FORMED (5). A CIRCULAR BARN BUILT IN 1831 IN BOLLBRÜGGE, GERMANY, WITH 90-CM-THICK RAMMED EARTH WALLS IS SHOWN IN (4).

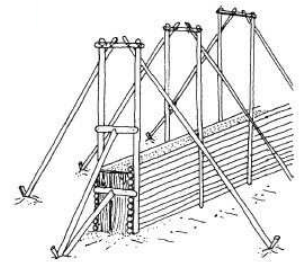
COMMON FORMWORK SYSTEMS USED IN CONCRETE TECHNOLOGY CAN ALSO BE USED FOR RAMMED EARTH, BUT USUALLY TURN OUT TO BE TOO HEAVY AND EXPENSIVE. IN EUROPE, TIMBER PANELS OF 19 MM THICKNESS ARE COMMONLY USED. THEY NEED TO BE STIFFENED BY VERTICAL MEMBERS AT APPROXIMATELY 75 CM INTERVALS. IF THIS IS NOT DONE, THEY WILL BEND OUTWARDS DURING RAMMING. THEREFORE, IT MIGHT BE MORE ECONOMICAL TO CHOOSE THICKER BOARDS OF 30 TO 45 MM THICKNESS, WHICH NEED STIFFENING ONLY AT INTERVALS OF 100 TO 150 CM. IF THE SOIL IS VERY CLAYEY, THE FORM SHOULD NOT BE WRENCHED OFF, BUT INSTEAD SLIPPED OFF THE RAMMED EARTH SMOOTHLY ALONG THE SURFACE, THUS PREVENTING IT FROM BEING SPOILED BY CLAYEY PARTICLES STICKING TO THE FORM. FURTHERMORE, IT IS NEITHER DESIRABLE TO HAVE A SURFACE THAT IS TOO ROUGH (SUCH AS SAW-CUT TIMBER), NOR ONE THAT IS TOO SMOOTH (SUCH AS VARNISHED AND PLANED TIMBER).



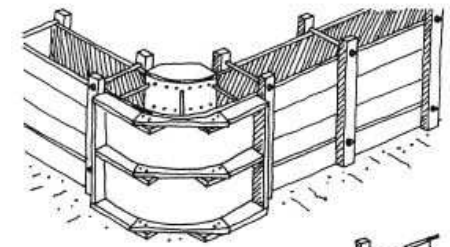
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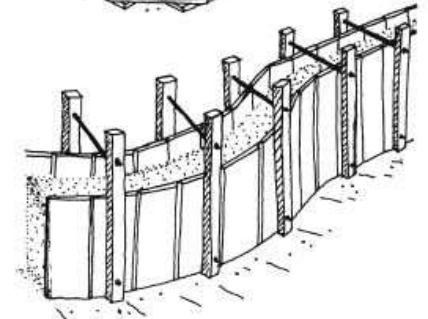
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IF THE FORMWORK IS NOT OPTIMISED FOR THIS TECHNIQUE, THEN UP TO 30% OF TOTAL LABOUR INPUT COULD BE INVESTED SIMPLY IN ERECTING, ADJUSTING, AND DISMANTLING THE FORMWORK. THEREFORE, THE FOLLOWING POINTS SHOULD BE BORNE IN MIND:

- BOARDS MUST BE STIFF SO THAT THEY DO NOT BEND OUTWARDS WHILE RAMMING IS UNDERWAY.
  - ALL PARTS MUST BE LIGHT ENOUGH TO BE CARRIED BY TWO WORKERS.
  - THE FORMWORK SHOULD BE EASY TO ADJUST IN BOTH VERTICAL AND HORIZONTAL DIRECTIONS.
  - VARIATIONS IN THE THICKNESS OF THE WALL MUST BE CONTROLLABLE WITHIN A SPECIFIED TOLERANCE.
  - IT IS PREFERABLE THAT THE EDGES REQUIRE NO SPECIAL FORMWORK.
- THEREFORE, THE FORMWORK SHOULD ALLOW VARYING LENGTHS OF WALL TO BE CAST.

**TOOLS:**

IN FORMER TIMES, EARTH WAS RAMMED MANUALLY, USING RAMS WITH CONICAL, WEDGE-SHAPED OR FLAT BASES (6).

IF CONICAL OR WEDGE-SHAPED RAMS ARE USED, THE DIFFERENT LAYERS ARE BETTER MIXED AND, PROVIDED THERE IS SUFFICIENT MOISTURE, A BETTER BOND IS OBTAINED. HOWEVER, THIS TAKES MORE TIME THAN RAMMING WITH FLAT-BASED RAMS. WALLS RAMMED WITH FLAT-BASED RAMS SHOW LESS LATERAL SHEAR RESISTANCE AND THEREFORE SHOULD ONLY BE LOADED VERTICALLY.

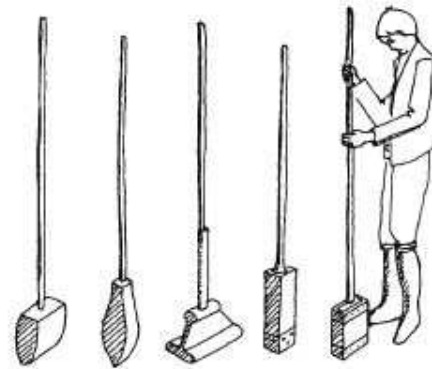
THE BASE OF THE RAM SHOULD NOT BE TOO SHARP, SO THAT THE FORMWORK, IF MADE OF TIMBER, IS NOT DAMAGED. THE BASE SHOULD BE NO SMALLER THAN 60 CM<sup>2</sup>, AND NO LARGER THAN 200 CM<sup>2</sup>. THE WEIGHT OF THE RAM SHOULD BE BETWEEN 5 AND 9 KG. IT IS PREFERABLE TO USE A TWO-HEADED RAM WITH A ROUND HEAD ON ONE SIDE AND A SQUARE ONE ON THE OTHER. THIS ALLOWS THE RAM TO BE USED WITH THE ROUND SIDE FOR GENERAL WORK, AND WITH THE SQUARE EDGE TO COMPACT CORNERS EFFECTIVELY. SUCH A RAM IS USED EVEN TODAY IN ECUADOR (7).

ELECTRIC AND PNEUMATIC RAMS WERE USED AS EARLY AS THE SECOND QUARTER OF THE 20TH CENTURY IN GERMANY, FRANCE AND AUSTRALIA. THE ELECTRICAL RAM SHOWN IN (8), BUILT BY THE GERMAN FIRM WACKER, WAS OFTEN USED IN FORMER TIMES FOR RAMMED EARTH WORK, AND HAS BEEN WRITTEN ABOUT EXTENSIVELY. IT HAS A HAMMERLIKE ACTION WITH A LIFT OF 33 MM, AND A FREQUENCY OF 540 STROKES PER MINUTE. THE RAM IS VERY EFFECTIVE; ITS ONLY DISADVANTAGE BEING DIFFICULT IN HANDLING, SINCE IT WEIGHS 24 KG. IT IS NO LONGER MANUFACTURED.

IN AUSTRALIA IN THE 1950S, A PNEUMATIC RAM WAS USED (9). THIS ACTS LIKE A JACKHAMMER, HAS A FREQUENCY OF 160 STROKES PER MINUTE, AND WEIGHS 11 KG.

NORMALLY, SOIL COMPACTION TOOLS OF THE TYPE USED IN ROAD CONSTRUCTION ARE UNSUITABLE FOR RAMMED EARTHWORK, BECAUSE THEIR FREQUENCY IS TOO HIGH AND THEIR LIFT TOO LOW. TOOLS WHICH ONLY VIBRATE MIGHT BE SUITABLE FOR SANDY SOILS, BUT NOT FOR CLAYEY ONES.

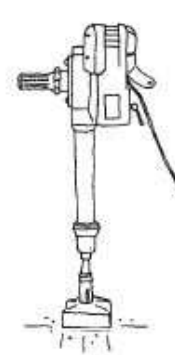
THE PNEUMATIC RAMS SHOWN IN (10) ARE EXTREMELY EFFECTIVE FOR RAMMED EARTHWORK. THE RAM II G, PRODUCED BY THE FIRM ATLAS- COPCO, IS FAIRLY SUITABLE BECAUSE A SPECIAL FEATURE PREVENTS ITS HEAD ROTATING, THUS ENSURING THAT SQUARE HEADS CAN ALSO BE CONVENIENTLY USED. ALL THE RAMS ILLUSTRATED REQUIRE A PRESSURE OF 6 BAR AND AN AIR FLOW RATE OF 0.4 TO 0.9 M<sup>3</sup>/MIN. DUE TO THEIR HIGH COSTS AND THE INFRASTRUCTURE AND ENERGY REQUIRED TO RUN THEM, THESE RAMS ARE USED ONLY FOR LARGER PROJECTS.



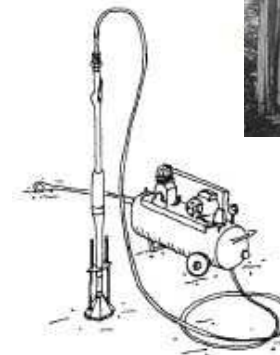
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(7)



(8)



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(10)

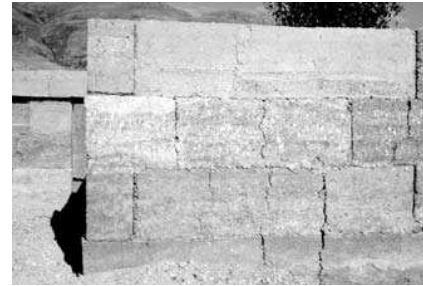
**METHOD OF CONSTRUCTION:**

IN NEARLY ALL TRADITIONAL RAMMED EARTH TECHNIQUES, THE FORMWORK IS REMOVED AND RE-ERECTED HORIZONTALLY STEP BY STEP. THIS MEANS THAT EARTH IS RAMMED IN LAYERS FROM 50 TO 80 CM HIGH, FORMING COURSES OF THAT HEIGHT BEFORE THE FORMWORK IS MOVED.

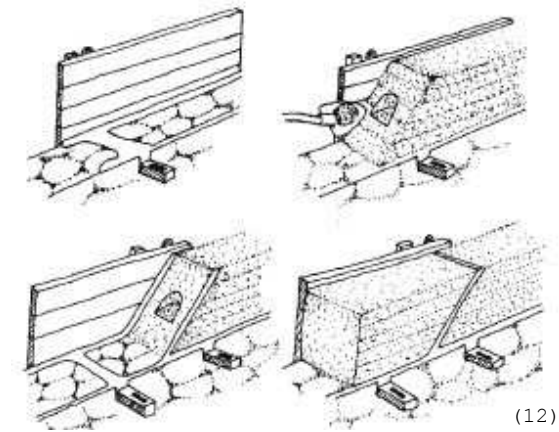
WHEN ONE COURSE IS COMPLETE, THE NEXT COURSE THAT IS RAMMED IS MOISTER THAN THE ONE ALREADY IN PLACE, WHICH IS PARTIALLY DRIED OUT. THEREFORE, THERE IS A HIGHER SHRINKAGE IN THE UPPER COURSE THAN IN THE LOWER, LEADING TO HORIZONTAL SHRINKAGE CRACKS AT THE JOINT (11). THIS CAN BE DANGEROUS, SINCE CAPILLARY WATER CAN ENTER THIS JOINT AND REMAIN, CAUSING SWELLING AND DISINTEGRATION. AS CAN BE SEEN IN THE SAME FIGURE, VERTICAL CRACKS CAN ALSO OCCUR IN SUCH WALLS.

WITH THE FRENCH PISÉ TECHNIQUE, THIS PROBLEM WAS SOLVED BY USING A LAYER OF LIME MORTAR ABOVE EACH COURSE BEFORE LAYING A NEW ONE. A LIME MORTAR CURES OVER SEVERAL WEEKS AND REMAINS PLASTIC UNTIL THE LOAM HAS STOPPED SHRINKING; SOMETIMES EVEN THE SIDE JOINT BETWEEN SECTIONS OF THE COURSE IS MADE WITH MORTAR AT AN INCLINE (12).

ANOTHER METHOD TO AVOIDING HORIZONTAL SHRINKAGE CRACKS IS TO RAM IN A WAY THAT THE WALL IS PRODUCED VERTICALLY.



(11)



(12)

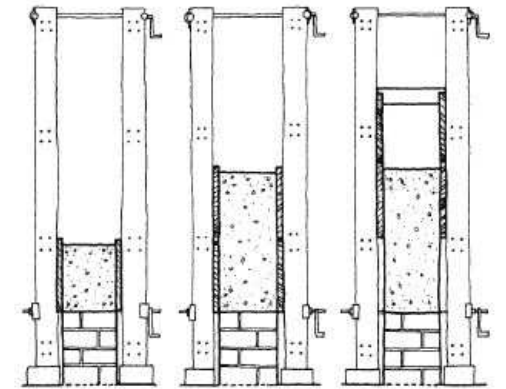
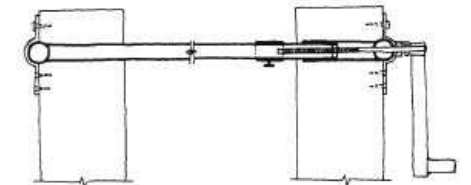
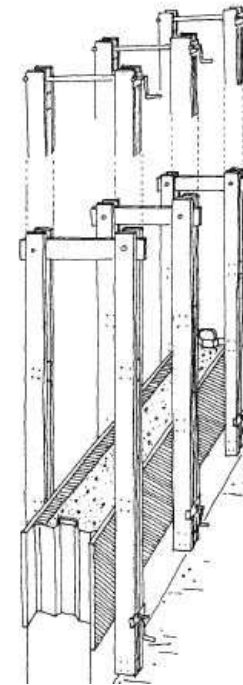
**NEW WALL CONSTRUCTION TECHNIQUES:**

**RAMMED EARTH PANELS:**

IN ORDER TO PREVENT HORIZONTAL SHRINKAGE CRACKS AT THE VERTICAL JOINTS IN TRADITIONAL RAMMED EARTH CONSTRUCTION, A NEW TECHNIQUE WAS DEVELOPED AT THE BRL FOR PRODUCING ONE-STOREY-HEIGHT PANELS, WITH WIDTHS OF UP TO 2.4 M, IN A CONTINUOUS RAMMING PROCESS. THIS TECHNIQUE AVOIDS HORIZONTAL JOINTS, AND THE VERTICAL JOINTS THAT OCCUR ARE CLOSED ONLY AFTER THE SHRINKAGE IS COMPLETE. FOR LATERAL STABILITY, THE VERTICAL JOINTS ARE MADE IN A TONGUE-IN-GROOVE PATTERN. NO SHRINKAGE CRACKS OCCUR WITHIN THE PANELS FOR THESE SIZES. THE REDUCTION OF LENGTH DUE TO SHRINKAGE IS ONLY VISIBLE AT THE JOINT. (THE JOINT ACTS LIKE A PRE-DESIGNED CONTRACTION JOINT). IN ORDER TO AVOID A FORMWORK THAT WOULD HAVE TO BE AN ENTIRE STOREY IN HEIGHT, A SLIP FORM WAS DEVELOPED AT THE BRL. (15) SHOWS THE DESIGN IN STEEL, WHILE (13) AND (14) SHOW A LATER DESIGN IN WOOD (WHICH PROVED EASIER TO WORK WITH).

THE FORMWORK IS SPACED AT THE BOTTOM WITH ONLY A STEEL BAR, WHICH LEAVES A VERY SMALL HOLE AFTER DISMANTLING. THE TOP SPACE IS POSITIONED ABOVE THE TOP LEVEL OF THE WALL AND DOES NOT INTERFERE WITH THE PROCESS. AS THE FIGURES SHOW, IT IS POSSIBLE TO USE EITHER A SIMPLER SOLUTION WITH A TIMBER SPACER ON TOP FIXED TO THE VERTICAL MEMBERS, THUS FORMING A YOKE, OR A MORE SOPHISTICATED VERSION MADE FROM STEEL, WHICH ALSO ALLOWS FINE ADJUSTMENTS OF DISTANCE AT THE TOP.

THE FIRST BUILDING USING THIS TECHNIQUE WAS BUILT AT THE UNIVERSITY OF KASSEL IN 1982 (16). THE SOIL CONTAINED ABOUT 10% CLAY AND ABOUT 50% SAND.



(13)



(16)



(14)



(15)

## WORKING WITH EARTHEN BLOCKS

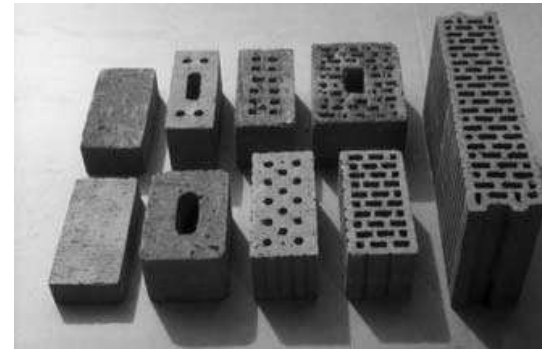
BLOCKS OF EARTH PRODUCED MANUALLY BY THROWING WET EARTH INTO A FORMWORK ARE CALLED "ADOBES" OR "MUD BRICKS" OR "SUNDRIED EARTH BLOCKS." WHEN MOIST EARTH IS COMPACTED IN A MANUAL OR POWERED PRESS, THE COMPRESSED ELEMENTS SO FORMED ARE CALLED "SOIL BLOCKS." IN THEIR UNBAKED STATE, BRICKS PRODUCED BY AN EXTRUDER IN A BRICK PLANT ARE CALLED "GREEN BRICKS." THESE THREE TYPES OF BLOCKS ARE USUALLY THE SAME SIZE AS BAKED BRICKS. LARGER BLOCKS, COMPACTED IN A FORMWORK BY RAMMING, ARE CALLED "RAMMED EARTH BLOCKS."

SOME COUNTRIES HAVE STANDARDISED MEASUREMENTS FOR THESE BLOCKS. THE TWO SIZES USED MOST COMMONLY IN GERMANY, FOR EXAMPLE, ARE:

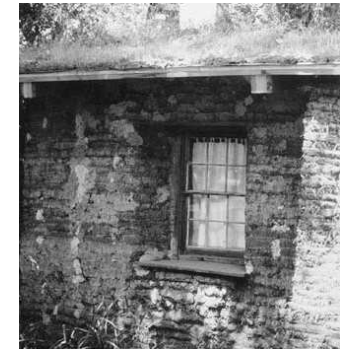
NF (NORMAL FORMAT) = 71 X 115 X 240 MM

2DF (DOUBLE THIN FORMAT) = 113 X 115 X 240 MM.

(1) SHOWS DIFFERENT SHAPES AND SIZES OF GREEN BRICKS PRODUCED INDUSTRIALLY BY AN EXTRUSION PROCESS COMMON IN THE GERMAN MARKET.



(1)



(2)

## HISTORY:

BUILDING WITH EARTHEN BLOCKS IS WIDESPREAD IN ALL HOT-DRY, SUBTROPICAL AND MODERATE CLIMATES. EARTH BLOCK BUILDINGS DATING FROM 8000 TO 6000 BC HAVE BEEN FOUND IN TURKESTAN, AND ONES FROM CA. 4000 BC IN ASSYRIA. VISIBLE EVEN TODAY IN UPPER EGYPT ARE MONUMENTAL STRUCTURES ABOUT 3200 YEARS OLD, SUCH AS THE HUGE EARTH BLOCK FORTIFICATION WALL OF MEDINET HABU AND THE VAULTS OF THE STORAGE ROOMS IN THE TEMPLE AREA OF RAMSES II NEAR GOURNA (1, P.55).

THE TECHNIQUE OF MAKING VAULTS AND DOMES FROM EARTH BLOCKS WITHOUT SUPPORTS DURING CONSTRUCTION (CENTRING OR SHUTTERING) WAS KNOWN TO MANY CULTURES. FOR CENTURIES, PUEBLO INDIANS IN TAOS, NEW MEXICO, BUILT THEIR HOUSES USING THE EARTH FROM THE SITES THEMSELVES, THE WATER FROM NEARBY STREAMS, AND STRAW FROM THE FIELDS (4).

THE HISTORICAL CORE OF THE CITY OF SHIBAM, YEMEN, COVERING ABOUT 20,000 M<sup>2</sup> AND ACCESSIBLE ONLY THROUGH A SINGLE GATEWAY, WAS BUILT ENTIRELY IN ADOBE. MANY HOUSES RESEMBLE SKYSCRAPERS, AND DATE FROM THE 15TH CENTURY (3).



(3)

IN SCANDINAVIA AND IN ENGLAND, BUILDING WITH SOD WAS COMMON IN THE 17TH AND 18TH CENTURIES. THESE HOUSES WERE CONSTRUCTED OF BLOCKS CUT FROM THE TOP LAYER OF LOAMY SOIL TOGETHER WITH THE GRASS GROWING ON IT. THE BLOCKS WERE INVERTED AND USED AS BRICKS TO FORM WALLS WITHOUT MORTAR. EUROPEAN IMMIGRANTS BROUGHT THIS TECHNIQUE TO THE USA, WHERE A LARGE NUMBER OF SOD HOUSES WERE BUILT IN THE 18TH AND 19TH CENTURIES (2). SOME SETTLERS ALSO ADAPTED THE SAME IDEA FROM NORTH AMERICAN INDIAN NATIONS SUCH AS THE OMAHA AND PAWNEE, WHO FOR CENTURIES HAD USED THE METHOD TO COVER THEIR ROUND HUTS WITH SOD.



(4)

IN NEW MEXICO, SILTY SOIL BLOCKS CUT FROM RIVERBEDS, AND CONTAINING A NETWORK OF ROOTS WHICH ACT AS REINFORCEMENT, WERE USED FOR BUILDING WALLS. THESE BLOCKS ARE CALLED TERRONIS OR TERRONES, AND WERE SOMETIMES USED IN MEXICO AND CENTRAL AMERICA AS WELL. IT IS INTERESTING TO NOTE THAT BUILDING CODES IN NEW MEXICO STILL PERMIT BUILDING WITH TERRONIS. IN GERMANY, EARTH BLOCK WORK WAS USED IN THE 6TH CENTURY BC; ADOBE BLOCKS 40 X 40 CM AND 6 TO 8 CM HIGH WERE USED IN THE FORT OF HEUNEURG NEAR LAKE CONSTANZE. AROUND 140,000 BLOCKS AND 400 M<sup>3</sup> OF MORTAR WERE USED TO CONSTRUCT ITS 3-M-HIGH WALLS. AN OFFICIAL CIRCULAR INTRODUCING THE USE OF ADOBES IN WALLS WAS PUBLISHED IN 1764.

PRODUCTION OF EARTH BLOCKS:

ADOBES ARE MADE EITHER BY FILLING MOULDS WITH A PASTY LOAM MIXTURE OR BY THROWING MOIST LUMPS OF EARTH INTO THEM. DIFFERENT TYPES OF MOULDS CAN BE USED; SOME OF THESE ARE SHOWN IN (5). THEY ARE USUALLY MADE FROM TIMBER. THE THROWING TECHNIQUE IS COMMONLY USED IN ALL DEVELOPING COUNTRIES (6). HERE, A SANDY LOAM IS MIXED WITH WATER, AND CUT STRAW IS USUALLY ADDED AND THE WHOLE FORMED INTO A PASTE THAT IS THROWN INTO WOODEN MOULDS. THE GREATER THE FORCE WITH WHICH THE LOAM IS THROWN, THE BETTER ITS COMPACTION AND DRY STRENGTH. THE SURFACE IS SMOOTHED EITHER BY HAND OR BY A TIMBER PIECE, TROWEL OR WIRE (7).

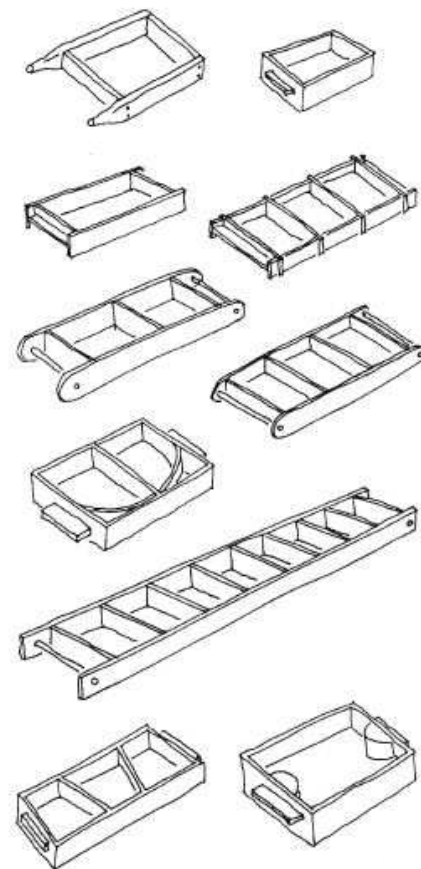
ONE PERSON CAN PRODUCE ABOUT 300 BLOCKS PER DAY (INCLUDING PREPARATION OF MIX, TRANSPORTATION AND STACKING). IN INDIA, ONE PERSON CAN PRODUCE AS MANY AS 500 BLOCKS PER DAY USING A DOUBLE MOULD DESIGNED FOR A SMALLER BRICK. IN ORDER TO FACILITATE WORK, BRICKS CAN BE MOULDED ON A TABLE, AS WAS TRADITIONALLY THE CASE IN GERMANY (8). ANOTHER EASY METHOD USES MOULDS WITH HANDLES 80 CM IN LENGTH, WHICH ENABLES WORKERS TO MANUFACTURE BRICKS WHILE STANDING (9).

TECHNIQUES FOR PRODUCING COMPRESSED SOIL BLOCKS WERE KNOWN IN EUROPE IN THE 18TH CENTURY. IN 1789, THE FRENCH ARCHITECT FRANÇOIS COINTREUX DEVELOPED A MANUALLY OPERATED SOIL BLOCK PRESS. SINCE THEN, NUMEROUS MANUALLY OPERATED PRESSES HAVE BEEN DEvised. THE BEST-KNOWN PRESS WORLDWIDE IS THE CINVA RAM, DEVELOPED IN COLOMBIA BY THE CHILEAN ENGINEER RAMIREZ (10). (11) SHOWS THE CETA RAM IN OPERATION. IT IS SIMILAR TO THE CINVA RAM, AND WAS DEVELOPED IN PARAGUAY. IT PERMITS SIMULTANEOUS PRODUCTION OF THREE BLOCKS. MANUALLY OPERATED PRESSES OF THIS TYPE PRODUCE PRESSURES UP TO 5 TO 25 KG/CM<sup>2</sup>, AND REQUIRE THREE TO FIVE PERSONS FOR OPTIMUM OPERATION. DESPITE MECHANISED PRODUCTION OF SOIL BLOCKS USING PRESSES, THE OUTPUT PER PERSON PER DAY IS ONLY 150 TO 200 BLOCKS, CONSIDERABLY LESS THAN THAT OF THE PRIMITIVE METHOD INVOLVING THROWING LOAM INTO MOULDS.

THE ADVANTAGE OF THESE MECHANISED PRESSES, HOWEVER, IS THAT LOAMS WITH LOWER WATER CONTENTS CAN BE USED. THIS MAKES IT POSSIBLE TO STACK BLOCKS IMMEDIATELY AFTER PRODUCTION. THE DISADVANTAGE IS THAT THE BLOCKS ARE USUALLY STABILISED WITH A 4% TO 8% CEMENT CONTENT IN ORDER TO ENDOW THEM WITH SUFFICIENT STRENGTH. THIS IS NECESSARY BECAUSE OF THE ABSENCE OF EITHER SUFFICIENT WATER OR ADEQUATE DYNAMIC IMPACT CAPABLE OF SIGNIFICANTLY ACTIVATING THE BINDING FORCES OF THE CLAY MINERALS. WITHOUT CEMENT, PRESSED BLOCKS USUALLY HAVE DRY A COMPRESSIVE STRENGTH LOWER THAN THAT OF HANDMADE ADOBES.

ANOTHER DISADVANTAGE OF SUCH PRESSES IS THAT THE SOIL MIX MUST BE KEPT AT A CONSTANT LEVEL OF MOISTURE AND COMPOSITION. IF COMPOSITIONS VARY, THEN BOTH THE VOLUME OF THE MATERIAL TO BE FILLED AND THE PRESSURE CHANGES. THIS LEADS TO VARIATIONS IN THE HEIGHTS AND STRENGTHS OF THE BLOCKS.

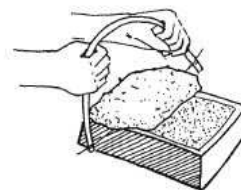
FULLY AUTOMATIC BLOCK-MAKING PRESSES SUCH AS THOSE SHOWN IN (12) CAN PRODUCE 1500 TO 4000 BLOCKS DAILY. HOWEVER, THEY REQUIRE LARGE INVESTMENTS AND MAY BE DIFFICULT TO MAINTAIN, ESPECIALLY IN DEVELOPING COUNTRIES. TO ASSURE EVEN LOAM CONSISTENCIES, SUCH MACHINES OFTEN REQUIRE SEPARATE CRUSHERS AND MIXERS. FULLY AUTOMATIC PRESSES ARE ONLY ECONOMICAL IF THEY HAVE LONG LIVES, ARE UTILISED EXTENSIVELY ON A DAILY BASIS, AND IF RAW MATERIAL OF EVEN CONSISTENCY IS AVAILABLE LOCALLY AND IN SUFFICIENT QUANTITIES. OTHERWISE, CAPITAL, MAINTENANCE AND REPAIR



(5)



(6)



(7)



(8)



(9)



COSTS QUICKLY DIMINISH ANY POTENTIAL ECONOMIC ADVANTAGES. IN LOW-WAGE COUNTRIES, MANUAL ADOBE PRODUCTION IS USUALLY MORE ECONOMICAL, AS IS THE PRODUCTION OF GREEN BRICKS IN BRICK PLANTS IN INDUSTRIALISED COUNTRIES. IN INDUSTRIALISED COUNTRIES, BRICK PRODUCTION USING SUCH MACHINES WOULD BE ECONOMICAL ONLY IF TRANSPORTATION COSTS WERE HIGH. THE PRODUCTION METHOD DEVELOPED IN THE USA BY HANS STUMPF AND PATENTED IN 1946, AND CONSISTING OF A BLOCK MAKING APPARATUS, SEEMS COMPARATIVELY MORE EFFICIENT (13 AND 14). WITH THIS METHOD, LOAM IS PREPARED TO A PASTY CONSISTENCY IN A FORCED MIXER AND THEN Poured INTO A LARGE FUNNEL THAT MOVES OVER A GRID OF MOULDS. THE MOULDS ARE FILLED, AND THE TOP AND THE BLOCKS ARE THEN SMOOTHED MECHANICALLY. A LEVER LIFTS THIS GRID, LEAVING THE SEPARATED BLOCKS TO DRY ON THE GROUND. AFTER A PRELIMINARY DRYING PERIOD, THE BLOCKS CAN BE TURNED ON THEIR EDGES FOR EVEN DRYING. IN MECHANISED BRICK PLANTS, CRUSHED SOIL IS MIXED AND PUSHED BY ROLLERS INTO AN EXTRUDER, WHERE IT IS AGAIN MIXED AND PRESSED THROUGH A VACUUM-OPERATED MOUTHPIECE INTO LONG PROFILES, WHICH ARE THEN SLICED BY A WIRE. DRYING IS ACCOMPLISHED IN OVENS USING COMMERCIAL ENERGY. SINCE THIS ENTIRE PROCESS IS COMPUTERISED IN INDUSTRIALISED BRICK PLANTS, IT MAY BE DIFFICULT TO ORDER GREEN BRICKS, AND THE PRICES QUOTED ARE SOMETIMES MORE THAN THOSE FOR ORDINARY FIRED BRICKS. WITH SIMPLER PRODUCTION PROCESSES AND OPEN-AIR DRYING, ON THE OTHER HAND, IT WAS POSSIBLE IN AT LEAST ONE GERMAN CASE, TO OBTAIN GREEN BRICKS THAT ARE 40% CHEAPER THAN THE PRICE OF REGULAR FIRED BRICKS.



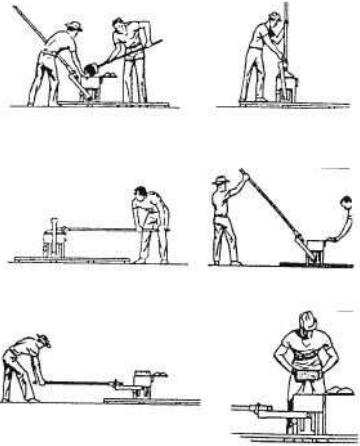
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### LARGE BLOCKS AND PREFABRICATED PANELS

WITH MONOLITHIC RAMMED EARTH WALLS, OR EVEN WITH SMALL-SIZED BRICK MASONRY, MANPOWER IS HIGH AND DRYING TIME CAN DELAY CONSTRUCTION WORK DUE TO THE INHERENT WATER. THEREFORE, SEVERAL IDEAS INVOLVING LARGER PREFABRICATED ELEMENTS HAVE BEEN DEVELOPED.



(11)



MAKING LIGHTWEIGHT STRAW LOAM BLOCKS



EXTERIOR WALL MADE OF LARGE BLOCKS OF LIGHTWEIGHT STRAW LOAM



(12)



STRUCTURAL ELEMENTS FILLED WITH LIGHT WEIGHT LOAM

**DIRECT FORMING WITH WET LOAM**

UNLIKE OTHER BUILDING MATERIALS, WET LOAM HAS THE CAPACITY TO BE FORMED INTO ANY SHAPE. IT THEREFORE PRESENTS A CREATIVE CHALLENGE TO DESIGNERS AND BUILDERS. THE MANUAL SHAPING OF WALLS FROM LUMPS OF WET LOAM OR THICK LOAM PASTE IS WIDESPREAD IN AFRICA AND ASIA, AND IS ALSO KNOWN IN EUROPE AND AMERICA. SINCE NO TOOLS ARE REQUIRED TO WORK WITH EARTH, IT IS THE SIMPLEST AND MOST PRIMITIVE TECHNIQUE. THE PREPARED MIXTURE IS USED DIRECTLY (WITHOUT INTERMEDIATE PRODUCTS BEING FORMED OR INTERMEDIATE PROCESSES). ITS DISADVANTAGE IS THAT EVEN LEAN LOAM OF ONLY 10% TO 15% CLAY SHOWS LINEAR SHRINKAGE OF 3% TO 6% WHEN DRYING. THE HIGHER THE CLAY CONTENT AND THE MORE WATER EMPLOYED, THE GREATER THE SHRINKAGE. THICK LOAM PASTE WITH HIGH CLAY CONTENT MAY EVEN HAVE A LINEAR SHRINKAGE RATIO OF ABOVE 10%. (1) AND (2) SHOW A BENCH FORMED WITH WET LOAM ELEMENTS WHERE SHRINKAGE WAS NOT TAKEN INTO ACCOUNT. THE FOLLOWING TECHNIQUES EXPLAIN HOW PRE DESIGNED SHRINKAGE CRACKS OF SMALLER DIMENSIONS, OR THE USE OF CURVED ELEMENTS CAN HELP TO REDUCE OR EVEN AVOID SUCH CRACKS.



(1)



(2)

**TRADITIONAL WET LOAM TECHNIQUES:**

WHILE IN THE CASE OF EARTH BLOCK WORK, DRY ELEMENTS ARE BUILT UP WITH MORTAR JOINTS, NO MORTAR IS USED WITH WET LOAM WORK. PLASTIC LOAM IS BOUND SIMPLY BY RAMMING, BEATING, PRESSING OR THROWING.



MAKING WALLS USING BALLS OF WET EARTH, GHANA



CONSTRUCTION OF A LOAM WALL, USING THE ZABUR TECHNIQUE, YEMEN

**THE "DÜNNE LOAM LOAF" TECHNIQUE:**

TECHNIQUES SIMILAR TO THE ONES USED IN SLOVAKIA AND YEMEN, WERE KNOWN IN NORTH AFRICA. THEY INSPIRED GUSTAV VON BODELSCHWINGH, A GERMAN MISSIONARY, TO ADAPT THEM TO GERMAN CONDITIONS. THE RESULTING TECHNIQUE DERIVES ITS NAME FROM THE SMALL TOWN OF DÜNNE, WHERE IT WAS FIRST USED. HERE, WET LOAVES OF LOAM ARE STACKED IN MASONRY PATTERNS, BUT WITHOUT MORTAR. IN ORDER TO PROVIDE BETTER BONDING TO THE PLASTER THAT IS APPLIED LATER, A CONICAL HOLE IS MADE ON THE OUTER FACE OF EACH LOAF USING THE FINGER (3). THREE TO FIVE LAYERS ARE LAID PER DAY. A LIME PLASTER SEVERAL LAYERS THICK IS USED AFTER THE WALL IS DRY. THE FIRST SUCH HOUSE WAS BUILT IN 1925 (4). WITHIN THE NEXT FIVE YEARS, MORE THAN 300 HOUSES WERE BUILT BY CO-OPERATIVES, FORMED BY UNEMPLOYED WORKERS ON THE INITIATIVE OF VON BODELSCHWINGH. THE ENTIRE FAMILIES OF THE MEMBERS PARTICIPATED IN PRODUCTION AND CONSTRUCTION.



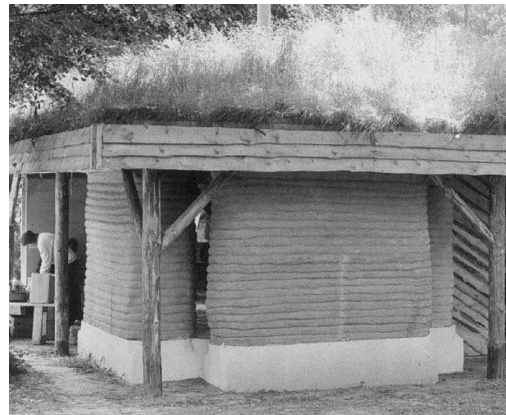
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(4)

**THE STRANGLEHM TECHNIQUE:**

AT THE BUILDING RESEARCH LABORATORY (BRL) A NEW WET LOAM TECHNIQUE, TERMED THE STRANGLEHM ("LOAM STRAND") TECHNIQUE, WAS DEVELOPED IN 1982. WALLS, VAULTS AND DOMES CAN BE BUILT WITH THIS TECHNIQUE. EVEN BUILTIN FURNITURE AND SANITARY ITEMS CAN BE FORMED.



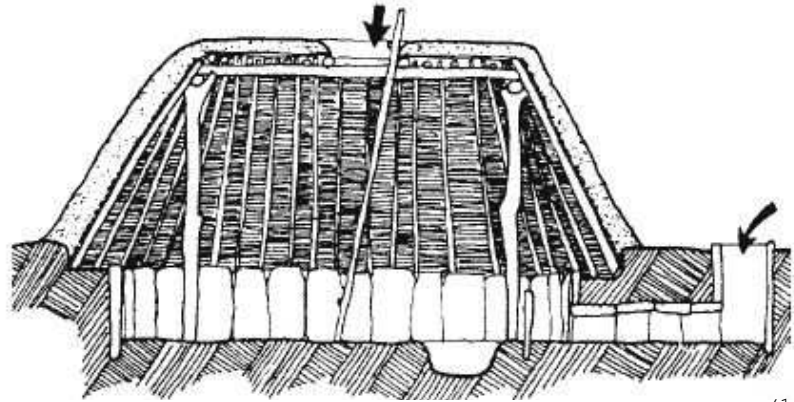
WALLS OF EXTRUDED LOAM PROFILES, TEST HOUSE, UNIVERSITY OF KASSEL, 1982



SCULPTURED INTERIOR WALL MADE OF EXTRUDED LOAM PROFILES

**WET LOAM INFILL IN SKELETON STRUCTURES**

PLASTIC LOAM HAS BEEN USED FOR THOUSANDS OF YEARS TO FILL GAPS IN LOG HOUSES WHERE THE LOGS ARE LAID HORIZONTALLY, AS WELL AS IN PALISADES (WHERE THE TREE TRUNKS ARE POSITIONED VERTICALLY). IN TRADITIONAL EUROPEAN FACHWERK (TIMBER-FRAMED) HOUSES, AS WELL AS IN AMERICAN, AFRICAN AND ASIAN WATTLE-AND-DAUB STRUCTURES, WET LOAM (USUALLY CONTAINING CUT STRAW) IS THROWN ON AN INTERWOVEN MESH OF TWIGS, BRANCHES, BAMBOO STICKS AND THE LIKE (1). THERE EXIST MANY VARIATIONS OF THIS TECHNIQUE. MODERN TECHNIQUES OF INFILL THAT USE MECHANICAL DEVICES TO REDUCE LABOUR INPUT ALSO EXISTS.



(1)

**THROWN LOAM:**

THROWN LOAM TECHNIQUES HAVE BEEN USED IN ALL TROPICAL, SUB-TROPICAL AND MODERATE CLIMATES OF THE WORLD, AND ARE PROBABLY OLDER THAN RAMMED EARTH AND EARTH BLOCK PRACTICES.



TRADITIONAL WATTLE-AND-DAUB BUILDING, VENEZUELA



PREFABRICATED WATTLE-AND-DAUB SYSTEM, BRAZIL

**SPRAYED LOAM:**

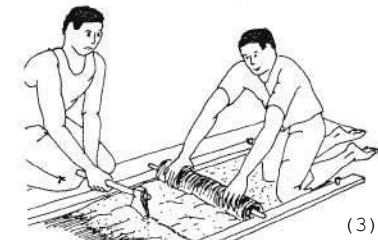
SINCE WATTLE-AND-DAUB TECHNIQUES ARE VERY LABOUR-INTENSIVE, VARIOUS ATTEMPTS HAVE BEEN MADE TO USE SPRAYING MACHINES TO APPLY MIXTURES. THE MAIN PROBLEM WITH ALL OF THESE TECHNIQUES HAS BEEN THE COMMON OCCURRENCE OF SHRINKAGE CRACKS.



SPRAYING LIGHTWEIGHT LOAM

**ROLLS AND BOTTLES OF STRAW LOAM:**

IN GERMANY AND FRANCE, OPENINGS IN THE FRAMEWORKS OF TRADITIONAL TIMBER-FRAMED HOUSES ARE SOMETIMES FILLED IN WITH ELEMENTS FORMED BY ROLLING STRAW LOAM AROUND A WOODEN BATTEN, AS SEEN IN (2) AND (3). THIS IS LESS LABOUR-INTENSIVE THEN THE WATTLEAND-DAUB TECHNIQUE, AND HAS THE ADDED ADVANTAGE THAT HARDLY ANY SHRINKAGE CRACKS OCCUR.



(2)

(3)



**VERNACULAR ARCHITECTURE  
BUILDING WITH EARTH  
BUILT EXAMPLES**



TWO SEMI-DETACHED HOUSES, KASSEL, GERMANY



FARMHOUSE, WAZIRPUR, INDIA

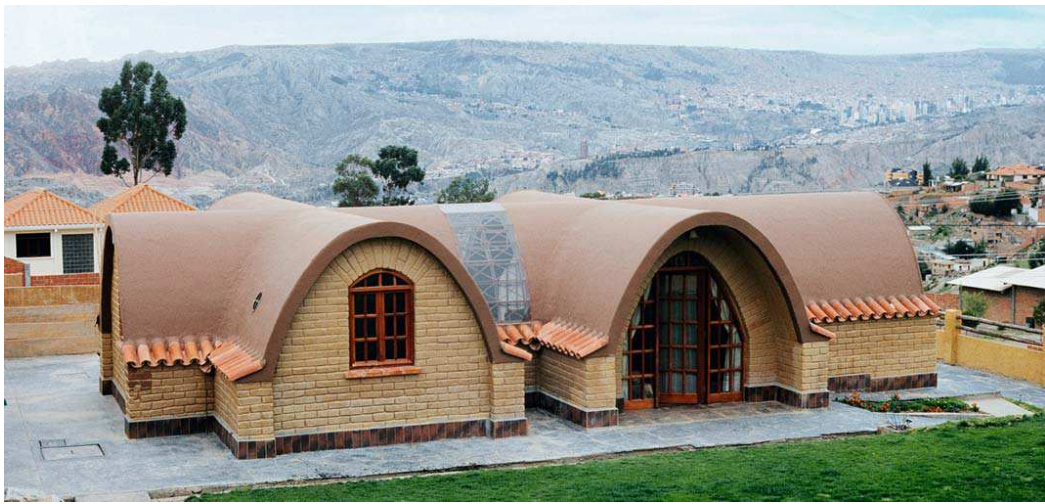


VINEYARD RESIDENCE AT MORNINGTON PENINSULA, VICTORIA, AUSTRALIA



SCHOOL AT SOLVIG, JÄRNA, SWEDEN





RESIDENCE, LA PAZ, BOLIVIA



CHAPEL OF RECONCILIATION, BERLIN, GERMANY



RESIDENCE, TURKU, FINLAND



CASITA NUAANARPOQ AT TAOS, NEW MEXICO, USA

**CHAPTER 4**

**EXTREME ARCHITECTURE**



## EXTREME ARCHITECTURE INFRA-FREE SYSTEMS

THE FASCINATION OF ARCHITECTURE IN EXTREME ENVIRONMENTS IS THAT IT IS SO DEMANDING TECHNICALLY, YET OFFERS SO MUCH POTENTIAL. THE GREATEST CONSTRAINTS USUALLY COME FROM THE NEED NOT TO SPOIL THE NATURAL ENVIRONMENT, AND THAT DEMANDS FAR MORE JUDGMENT, AND IS FAR MORE OPEN, THAN THE NEED TO MATCH THE BRICKWORK OF AN ADJOINING BUILDING, OR KEEP TO A PLANNER'S HEIGHT RESTRICTION.

INSTEAD, ARCHITECTS HAVE TO DEAL WITH MORE FUNDAMENTAL QUESTIONS. HOW DO YOU MAKE A BUILDING LIVEABLE IN BRUTAL CLIMATE? HOW DO YOU TRANSPORT MATERIALS AND MANAGE THE BUILDING PROCESS? AND, IN MANY CASES, HOW DO YOU PROVIDE ENERGY AND POWER AND DISPOSE OF WASTE WHEN IT IS NOT SIMPLY A MATTER OF PLUGGING IN TO THE ELECTRICITY GRID, TO MAINS WATER AND TO AN INFRASTRUCTURE OF WASTE DISPOSAL?

NON-CONNECTED BUILDINGS CAN BE DESCRIBED AS 'INFRA-FREE', A TERM THAT IS SUBTLY DIFFERENT FROM THE 'OFF-GRID' BELOVED OF SOME EVANGELICAL ENVIRONMENTS. BEING OFF-GRID IS UNUSUALLY A CONSCIOUS CHOICE; WITH INFRA-FREE BUILDINGS THERE IS NORMALLY NO INFRASTRUCTURE TO WHICH ONE COULD CONNECT. STUDIES ON 'INFRA-FREE SYSTEMS' WERE LAUNCHED IN 2006 IN AN INTERNATIONAL CONFERENCE. SPEAKERS INCLUDED POETIC JAPANESE ARCHITECT KENGO KUMA, WHO IS CONCERNED WITH DESIGNING IN HARMONY WITH NATURE, AND ARCHITECTS WORKING ON PROJECTS IN THE ANTARCTIC AND IN SPACE.

WHAT IS DRIVING THOSE PROJECTS AND THE OTHERS IN EXTREME ENVIRONMENTS? PART OF IT IS TECHNOLOGICAL - WE CAN LAUNCH INTO SPACE, WE CAN MAKE HOT PLACES LIVEABLE, AND WE CAN SUPPORT SCIENTISTS WORKING IN THE ANTARCTIC. ARCHITECTURE OFTEN FOLLOWS ENGINEERING AS A SECOND WAVE. WHEREAS THE IMPORTANCE OF ARCHITECTURE HAS BEEN ACKNOWLEDGED FOR CENTURIES IN URBAN CENTRES, SOME OF THESE EXTREME ENVIRONMENTS SEEMED AT FIRST SO DEMANDING THAT THEY WERE TREATED PURELY AS ENGINEERING PROBLEMS. AS LONG AS PEOPLE DIDN'T DIE ON THEIR JOURNEYS INTO SPACE, OR WHILE CUT OFF AND LIVING IN THE EXTREME COLD, WHAT DID IT MATTER WHAT THESE PLACES LOOKED LIKE? MOUNTAIN DWELLINGS AND TROPICAL SCHOOLS COULD SURELY BE LEFT TO AGELESS VERNACULAR TECHNIQUES?

BELATEDLY, THERE IS A REALIZATION THAT ARCHITECTURE HAS A CRUCIAL ROLE TO PLAY. AS PLANNED SPACE JOURNEYS BECAME LONGER, DECENT LIVING CONDITIONS WILL NOT JUST BE AN INDULGENCE BUT MAY BE THE KEY TO STAYING SANE. THE ANTARCTIC MAY BE FREEZING COLD, BUT IT IS A HOthouse ENVIRONMENT FOR SCIENTISTS THERE, WHO WILL BE HAPPIER AND MORE PRODUCTIVE IF THEY INHABIT SOME LIVEABLE SPACES THAT ACKNOWLEDGE THEIR SOCIAL NEEDS. THE EVER MORE COMPETITIVE TOURIST INDUSTRY DEMANDS NOVELTY AND LUXURY IN THE MOST BEAUTIFUL AND, IRONICALLY, UNSPOILT PLACES, AND THE WORLD'S TOP ARCHITECTS ARE BEST PLACED TO MEET THESE DEMANDS. MANY OF THESE PROJECTS ARE NOT JUST EXCITING IN THEIR OWN RIGHT, BUT ARE IN ENVIRONMENTS THAT OFFER LESSONS FOR THE FUTURE. UNDERSTANDING THE HORRIFIC CONSEQUENCES THAT WILL ENSURE OF THEIR MISSIONS GO WRONG PART-WAY THROUGH, SPACE AGENCIES ARE TRYING TO LEARN AS MUCH AS THEY CAN THROUGH SIMULATION - BY ISOLATING POTENTIAL ASTRONAUTS UNDER WATER, IN THE DESERT, NEAR THE POLES AND AT ALTITUDE.

EXTREME ARCHITECTURE ON EARTH WILL HAVE LESSONS FOR THE EVEN MORE EXTREME ARCHITECTURAL CONDITIONS IN SPACE. AND IT MAY TRANSFORM THE CV OF THE HIGH-ACHIEVING ARCHITECT. THE NEXT GENERATION MAY BECOME FAMOUS

NOT FOR ANYTHING ON EARTH BUT FOR BUILDINGS ON MARS AND THE MOON, OR EVEN IN ORBIT.



FOSTER + PARTNERS HAS DESIGNED AN ICONIC BUILDING FOR THE REMOTE SIBERIAN CITY OF KHANTY-MANSIYSK



VIRGIN GALACTIC'S SPACEPORT AMERICA UNDER CONSTRUCTION IN THE DESERT OF NEW MEXICO DESIGNED BY NORMAN FOSTER



## EXTREME ARCHITECTURE BUILDING IN HOT WEATHER

IN THE 1980S AIR CONDITIONING SEEMED AN OBVIOUS SOLUTION. FOR PERMANENT ACCOMMODATION IN HOT COUNTRIES (AS, INDEED, AT THE UNIVERSITY ITSELF) ENLIGHTENED ARCHITECTS USED SHADE AND ENCOURAGED CROSS BREEZES AS FAR AS POSSIBLE TO INCREASE THE LEVELS OF COMFORT. BUT THE USE OF AIR CONDITIONING TO AMELIORATE THE HEAT JUST MADE SENSE. FOR THE FIRST TIME, AREAS OF THE WORLD THAT HAD BEEN EITHER UNCOMFORTABLE OR UNINHABITABLE COULD BE BROUGHT UP TO THE STANDARDS OF COMFORT THAT WERE THE NORM IN TEMPERATURE CLIMES. THE WHOLE OF THE GULF BOOM WAS BUILT ON AIR CONDITIONING.

FAST-FORWARD TO TODAY AND IT ALL LOOKS VERY DIFFERENT. RISING ENERGY COSTS AND CONCERN ABOUT CARBON EMISSIONS MAKE AIR CONDITIONING UNDESIRABLE (ALTHOUGH CHINESE, WITH THEIR GROWING AFFLUENCE, ARE STILL RETROFITTING IT LIKE MAD TO SUBSTANDARD ACCOMMODATION IN HOT CITIES). IN TEMPERATE CLIMATES, WE CAN COUPLE CLEVER DESIGN WITH A TOLERANCE OF A FEW UNCOMFORTABLE DAYS, AND DECIDE THAT WE CAN MANAGE. IN HOT COUNTRIES THIS IS NOT ENOUGH.

THE CASE STUDIES SHOWN IN THIS CHAPTER IN BURKINA FASO ARE FOR A COUNTRY SO POOR THAT ANY INCREASE IN COMFORT PROVIDED BY THE ARCHITECTURE WILL BE WELCOMED. BUT THE BUILDINGS, ADMIRABLE THOUGH THEY ARE, WOULD PROBABLY NOT BE CONSIDERED AS OFFERING ADEQUATE THERMAL COMFORT IN MORE AFFLUENT COUNTRIES.

THE KOUDOUGOU MARKET IN BURKINA FASO WON AN AGA KHAN AWARD IN 2007. ANOTHER AGA KHAN AWARD THAT YEAR WENT TO WOHA ARCHITECTS FOR THE MOULMEIN RISE RESIDENTIAL TOWER IN SINGAPORE. THIS 28-STORY BUILDING IS REMARKABLE LARGELY FOR ITS REINTERPRETATION OF THE TRADITIONAL MONSOON WINDOW, AN OPENING THAT ALLOWS BREEZES IN WHILE KEEPING OUT THE RAIN. ON A FAR MORE AMBITIOUS SCALE IS FOSTER + PARTNERS' MASTERPLAN FOR THE CITY OF MASDAR IN ABU DHABI, WHICH AIMS TO BE THE WORLD'S FIRST ZERO-CARBON, ZERO- WASTE CITY. A DENSE, WALLED, CAR-FREE CITY, IT WILL BE BUILT IN TWO PHASES, THE FIRST PHASE BEING A LARGE PHOTOVOLTAIC POWER PLANT THAT WILL BE USED TO POWER NOT ONLY THE FINISHED CITY BUT ALSO THE CONSTRUCTION PROCESS. FOSTER'S CITY HAS HEAVILY SHADED STREETS, WITH PEOPLE RARELY EXPERIENCING DIRECT SUNLIGHT. ONE COULD ARGUE THAT THIS COMPACT APPROACH IS NOT A GOOD IDEA. AFTER ALL, IN TEMPERATURE CITIES DENSE LIVING LEADS TO AN 'URBAN HEAT ISLAND' EFFECT. COULD THIS ALSO HAPPEN IN THE DESERT?

THE ANSWER IS NOT OBVIOUS, AS THERE ARE CONFLICTING FACTORS TO DO WITH MOVEMENT OF AIR AND BUILD-UP OF HEAT. DAVID PEARLMUTTER, A RESEARCHER, STUDIED THESE IN DEPTH. IN 2000, HE WROTE: 'WHAT EMERGES FROM THIS CASE STUDY, THEN, IS EVIDENCE THAT A COMPACT URBAN FABRIC IN THE DESERT CAN IN FACT CONTRIBUTE TO A RELATIVE "COOL ISLAND", IN SHARP CONTRAST TO WHAT IS SO OFTEN EMPHASIZED IN NON-ARID CITIES. LIKE THE URBAN HEAT ISLAND IN GENERAL, THE MICRO-SCALE HEATING EFFECT SHOWN HERE IS PRIMARILY A NOCTURNAL PHENOMENON, AND HAS FAR LESS RELEVANCE THAN IT WOULD IN MORE TROPICAL REGIONS. (IT IS INTERESTING TO NOTE THAT IN WINTER, WHEN THE HEAT ISLAND EFFECT IS DESIRABLE, THE COMPACT STREET CANYON WAS SEEN TO REDUCE HEAT LOSS FROM THE BODY DURING NEARLY ALL HOURS - PRIMARILY DUE TO PROTECTION FROM COLD WINDS.)'



IN DESERT ENVIRONMENTS, DENSE SETTLEMENTS SUCH AS MASDAR IN ABU DHABI, PRODUCE AN 'URBAN COOL ISLAND' EFFECT



THE TRADITIONAL MONSOON WINDOW AT THE MOULMEIN RISE RESIDENTIAL TOWER IN SINGAPORE



THE MOULMEIN RISE RES. TOWER IN SINGAPORE



THERE IS AN ENORMOUS DIFFERENCE BETWEEN DESIGNING FOR DESERT AND HUMID TROPICAL ENVIRONMENTS. ALTHOUGH BOTH CAN EXPERIENCE VERY HIGH TEMPERATURES IN DAYTIME, AND SHADING FROM THE HEAT OF THE SUN IS ESSENTIAL IN BOTH, THEY DEMAND ALMOST OPPOSING APPROACHES. DESERTS HAVE HIGH DAYTIME TEMPERATURES, WITH VERY LOW HUMIDITY, AND COLD NIGHTS. THERMALLY MASSIVE BUILDINGS CAN THEREFORE BE USED TO MODULATE THE TEMPERATURE, HEATING UP SLOWLY IN THE DAY AND COOLING IN THE EVENING. IN SOME AREAS THERE WILL BE COLD DESERT WINTERS, IN WHICH CASE THIS CYCLING OF TEMPERATURES CAN WORK SEASONALLY AS WELL AS DIURNALLY. BUT IN THE TROPICS, OR IN COUNTRIES THAT HAVE A HOT RAINY SEASON, THE OPPOSITE IS THE CASE. IF HEAT BUILDS UP DURING THE DAY, THERE IS NO TIME AT WHICH IT CAN DISSIPATE, SINCE THE NIGHTS ARE ALSO HOT. INSTEAD, LIGHTNESS AND VENTILATION ARE KEY - SHELTER RATHER THAN ENCLOSURE - UNLESS THE ARCHITECT GOES TO THE EXTREME OF THE AIR-CONDITIONED SEALED BOX. HOUSES SUCH AS HOUSE RR IN BRAZIL EPITOMIZE AN APPROACH TO LIVING WITH HUMID WEATHER RATHER THAN FIGHTING AGAINST IT. OF COURSE, GENERATION OF ENERGY IS ANOTHER ROUTE TOWARDS SUSTAINABILITY, ALTHOUGH IT CAN STILL RARELY JUSTIFY ITS RECKLESS DISSIPATION. ON SMALLER BUILDINGS, ANY APPROACH BEYOND USING THE SUN TO HEAT WATER IS LIKELY TO BE TOKENISTIC, BUT AT THE SCALE OF MASDAR IT IS CERTAINLY WORTHWHILE. THE HUGE WORLD TRADE CENTRE IN BAHRAIN, DESIGNED BY GLOBAL CONSULTANCY ATKINS, HAS THREE 29 METRE DIAMETER WIND TURBINES SITTING BETWEEN THE TWO TOWERS OF ACCOMMODATION, GENERATING BETWEEN 10-15% OF THE BUILDING'S TOTAL ENERGY REQUIREMENT. A PROPOSED INTERNATIONAL LEARNING CENTRE, CALLED BRIDGING THE RIFT, DESIGNED BY AMERICAN PRACTICE SOM, WILL SIT IN THE DESERT IN THE ISRAEL-JORDAN BORDER. IT WILL USE UNDERGROUND AQUIFERS TO HELP IN A COOLING STRATEGY, AND SOLAR POWER TO GENERATE HEAT AND ELECTRICITY. THIS WILL ALLOW IT TO OPERATE INDEPENDENTLY OF BOTH NEIGHBOURING COUNTRIES. DESERTS OFFER WONDERFUL OPPORTUNITIES TO GENERATE POWER. AS WELL AS THE POTENTIAL FOR LARGE SOLAR ARRAYS, THERE ARE PROPOSALS SUCH AS THAT BY THE GERMAN ENGINEERING PRACTICE, SCHLAICH BERGERMANN, FOR A 'SOLAR UPDRAFT TOWER'. EFFECTIVELY A LARGE GLAZED ROOF THAT SLOPES UP GENTLY TO A CENTRAL GIANT CHIMNEY, THIS WOULD OPERATE BY CONVERTING THE WIND ENERGY OF HOT AIR RUSHING UP THE TOWER INTO ELECTRICITY. A PROTOTYPE WAS CONSTRUCTED IN MANZANARES IN SPAIN, BUT SO FAR, DESPITE MUCH DISCUSSION, ESPECIALLY IN AUSTRALIA, A FULL-SCALE VERSION HAS NOT YET BEEN BUILT. BUT FOR THE ARCHITECT OF A NORMAL-SIZED INDIVIDUAL BUILDING, SUCH SOLUTIONS ARE LIKELY TO BE BEYOND REACH. INSTEAD, WORKING INTELLIGENTLY TO AMELIORATE THE EXTREMES OF HEAT WILL BE THE MOST REWARDING SOLUTION.



HOUSE RR, UBATUBA , BRAZIL



WIND TURBINES ON ATKINS' WORLD TRADE CENTRE IN BAHRAIN GENERATE BETWEEN 10-15% OF THE TOTAL ENERGY REQUIREMENT



SOM HAS DESIGNED BRIDGING THE RIFT, ON THE ISRAEL-JORDAN BORDER, TO PRODUCE ITS OWN ENERGY



**EXTREME ARCHITECTURE**  
**BUILDING IN HOT WEATHER CASE STUDIES**

SCHOOL BUILDINGS, GRADO AND DANO, BURKINA FASO  
DIÉBÉDO FRANCIS KÉRÉ

BURKINA FASO IS ONE OF THE POOREST COUNTRIES IN THE WORLD, BUT ONE THAT IS MAKING ENORMOUS EFFORTS TO BETTER ITSELF. LEVELS OF LITERACY, FOR EXAMPLE, WHILE STILL FAR TOO LOW AT ONLY ABOUT 25%, HAVE DOUBLED SINCE 1990. DIÉBÉDO FRANCIS KÉRÉ EPITOMIZES THIS MOVE TOWARDS BETTERMENT, NOT ONLY FOR THE INDIVIDUAL BUT ALSO FOR THE SOCIETY. TRAINED AS AN ARCHITECT IN BERLIN, HE COMES FROM THE 3000-STRONG VILLAGE OF GANDO, WHICH IS ABOUT 200 KM FROM THE CAPITAL OUGADOUGOU. KÉRÉ WAS THE FIRST PERSON FROM GANDO TO STUDY ABROAD, AND HE RESOLVED TO CREATE A SCHOOL FOR THE VILLAGE, SETTING UP A FUND-RAISING ORGANIZATION CALLED SCHILBAUSTEINE FÜR GANDO (BRICKS FOR THE GANDO SCHOOL) WITH GERMAN FRIENDS. THE INTENTION WAS NOT JUST TO FUND A SCHOOL, BUT ALSO TO SHOW WHAT COULD BE DONE WITH LOCAL MATERIALS TO CREATE SUSTAINABLE, APPROPRIATE ARCHITECTURE AND TO TRANSFER SKILLS. BURKINA FASO HAS A DRY AND A WET SEASON, THE LATTER LASTING ABOUT FOUR MONTHS, AND PUNISHINGLY HIGH TEMPERATURES. SHADE AND VENTILATION WERE THEREFORE ESSENTIAL.

THE THREE CLASSROOMS ARE ARRANGED IN A LINE, SEPARATED BY COVERED OUTDOOR AREAS THAT CAN BE USED EITHER FOR TEACHING OR FOR PLAY. STABILIZED COMPRESSED-EARTH BLOCKS ARE USED FOR THE WALLS AND ALSO, SUPPORTED ON A GRID OF CONCRETE BEAMS AND STEEL BARS, FOR THE CEILING. THE HIGH THERMAL MASS OF THE BLOCKS HELPS TO MODERATE THE TEMPERATURE. ALSO CRUCIAL IS THE LOW MONOPITCHED CORRUGATED STEEL ROOF, SUPPORTED ON STEEL TRUSSES. THE SPACE BETWEEN THE ROOF AND THE CEILING IS USED FOR VENTILATION, AND THE ROOF ALSO PROJECTS TO PROVIDE SHADE. IT WAS NECESSARY TO BUILD UP THE ROOF FROM RELATIVELY SMALL ELEMENTS, SINCE THE TRANSPORT INFRASTRUCTURE MEANT THAT LARGE ITEMS COULD NOT BE BROUGHT IN, AND NEITHER COULD A CRANE. THE ROOF WAS THEREFORE CONSTRUCTED FROM STEEL BARS WELDED ON SITE, WITH THE SHEETING LAID ON TOP ON SITE. THE ARCHITECT TAUGHT LOCAL PEOPLE TO USE A HANDSAW AND A SMALL WELDING MACHINE.

THE PROJECT WON AN AGA KHAN AWARD FOR ARCHITECTURE IN 2004, AN INTERNATIONAL AWARD THAT AIMS TO "ENHANC THE UNDERSTANDING AND APPRECIATION OF ISLAMIC CULTURES AS EXPRESSED THROUGH ARCHITECTURE'. IN THEIR CITATION, THE JUDGES CALLED THE PROJECT 'A STRUCTURE OF GRACE, WARMTH AND SOPHISTICATION, IN SYMPATHY WITH THE LOCAL CLIMATE AND CULTURE. THE PRACTICAL AND THE POETIC ARE FUSED. THE PRIMARY SCHOOL IN GANDO INSPIRES PRIDE AND INSTILS HOPE IN ITS COMMUNITY, LAYING THE FOUNDATIONS FOR THE ADVANCEMENT OF A PEOPLE.'



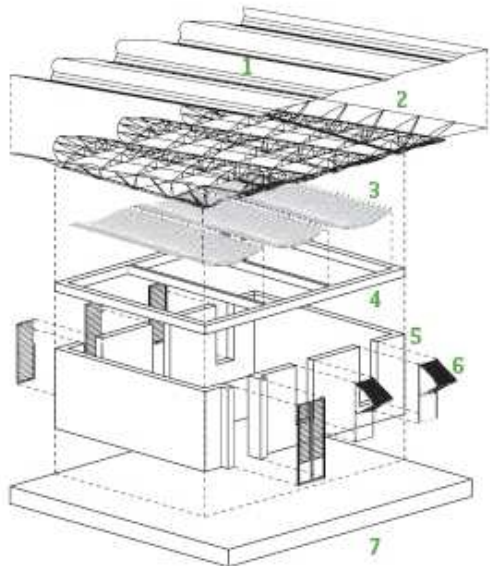
GANDO PRIMARY SCHOOL



INSIDE THE CLASSROOM IN GANDO, MUD BLOCKS FROM BOTH THE WALLS AND THE CEILINGS



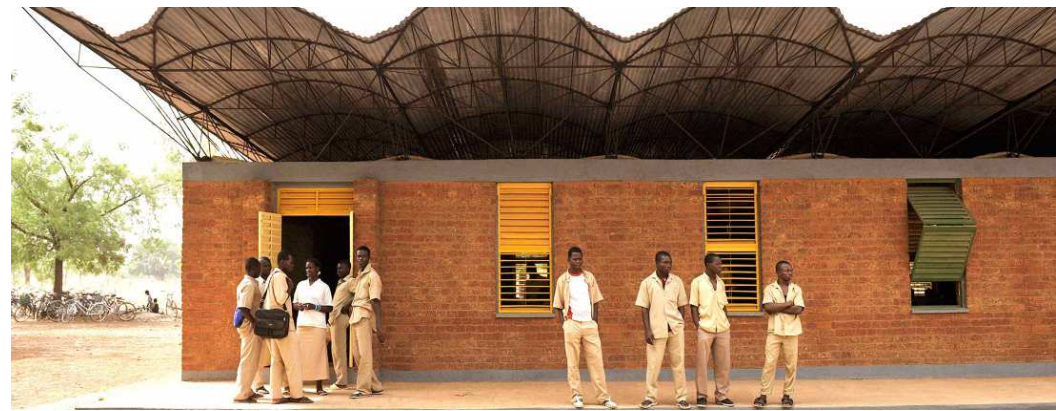
THERE ARE NOW MORE THAN 450 STUDENTS AT THE SCHOOL, AND AN EXTENSION WAS RECENTLY COMPLETED. IN ADDITION, KÉRÉ HAS TAKEN HIS IDEAS FORWARD TO ANOTHER PROJECT 600 KM AWAY, AT DANO, CAPITAL OF THE PROVINCE OF LOBA. AN EXTENSION TO A SCHOOL, FOR THE DREYER FOUNDATION, IT WAS BUILT BY YOUNG WORKERS FROM GANDO WHO KÉRÉ HAD TRAINED. THIS TIME THE MAIN BUILDING MATERIAL WAS NOT COMPRESSED EARTH BUT LOCAL LATERITE BRICKSTONE, A PRODUCT FORMED BY THE WEATHERING OF UNDERLYING ROCK. SINCE THIS STONE IS NOT PARTICULARLY RESISTANT TO WATER, IT WAS PLACED ON A FOUNDATION LAYER OF GRANITE TO ENABLE IT TO ENDURE THE RAINY SEASON. AGAIN, SHADING AND VENTILATION WERE PARAMOUNT. THE BUILDING IS ORIENTED EAST-WEST TO REDUCE SOLAR GAIN, AND THERE ARE SHUTTERS AND ANOTHER OVERSAILING ROOF, THIS TIME WITH A SCALLOPED OUTLINE. UNDULATING IN BOTH THE VERTICAL AND THE HORIZONTAL PLANE, THE ROOF ASSISTS RAINWATER RUN-OFF. AS WITH THE ROOF AT GANDO, IT WAS BUILT UP FROM STANDARD REINFORCING BARS ON SITE. AMONG THE SHADED EXTERNAL SPACES IS AN 'AMPHITHEATRE', A LARGE GATHERING PLACE FOR THE STUDENTS. THE SCHOOL ALSO HAS COFFERED SUSPENDED CEILING OF TIMBER AND CONCRETE. THERE IS AN ADDED CONFIDENCE TO THIS PROJECT, COMPARED TO THE EARLIER ONE AT GANDO. WHERE THE GANDO SCHOOL HAS THE DIGNITY OF ITS UTTER SIMPLICITY, AT DANO THE ARCHITECT, WHILE STILL EAGER TO USE MATERIALS ECONOMICALLY AND APPROPRIATELY, HAS ALSO BEHAVED MORE FREELY, WITH VAULTED CEILING AND VARIATIONS IN THE COLOUR FOR THE SHUTTERS GIVING THE BUILDING MORE PERSONALITY. INTERNALLY, THE SHALLOW VAULTS OF THE SUSPENDED CEILING ECHO THE REGULAR ARRANGEMENTS OF THE DESKS. THE LEVEL OF CONTROL IS IMPRESSIVE, AND HAS AN ELEGANT AUSTERITY THAT WOULD BE DESERVING OF APPLAUSE ON A PROJECT THAT HAD TEN TIMES THE BUDGET.



- 1 Metal roof cladding
- 2 Metal beam construction
- 3 Hanging brick ceiling, plastered
- 4 Reinforced concrete beams
- 5 Laterite stone walls
- 6 Lamella windows
- 7 Granite basement



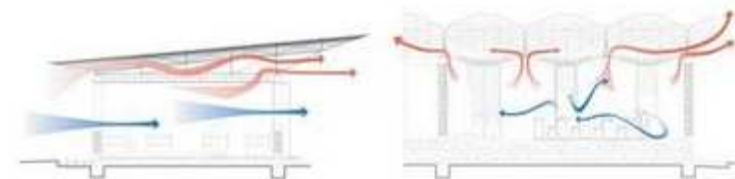
THE STRUCTURE AT DANO WAS BUILT UP FROM SMALL, EASILY TRANSPORTED ELEMENTS



DANO SECONDARY SCHOOL



SHADED AREAS AT THE DANO SCHOOL INCLUDE A LARGE GATHERING SPACE



THE RED AND BLUE ARROWS ILLUSTRATE ENVIRONMENTAL STRATEGIES FOR THE GANDO SCHOOL (LEFT) AND DANO SCHOOL (RIGHT)



**EXTREME ARCHITECTURE**  
**BUILDING IN HOT WEATHER CASE STUDIES**

CENTRAL MARKET, KOUDOUGOU, BURKINA FASO  
LAURENT SÉCHAUD AND PIERRE JÉQUIER

IF YOU GO TO KOUDOUGOU IN BURKINA FASO, YOU ARE LIKELY TO GRAVITATE TO THE CENTRAL MARKET. FIRST, YOU WILL BE IMPRESSED BY JUST HOW BUSY IT IS, AND THEN YOU MAY WONDER WHEN IT WAS BUILT. THERE IS A GREAT REGULARITY AND FRESHNESS TO THE SUGGESTS IT IS RELATIVELY RECENT - IT HAS NOT HAD TIME FOR ALL THOSE ACCRETIONS AND AD HOC CHANGES THAT COME TO ANY STRUCTURE USED BY LARGE NUMBERS OF PEOPLE - AND YET THERE IS SOMETHING SEEMINGLY TIMELESS IN THE REDDISH MUD BLOCKS THAT HAVE BEEN USED TO BUILD IT. BUT THEN AGAIN, IF YOU KNOW ANYTHING ABOUT BUILDING TRADITIONS IN BURKINA FASO, YOU WILL KNOW THAT THOSE BRICKS HAVE TRADITIONALLY ONLY BEEN USED FOR WALLS. HERE THEY ARE USED FOR ROOFS AS WELL.

THIS MARKET IS THE PRODUCT OF A GOVERNMENT PROGRAMME TO PROTECT AND PROMOTE THE LIFE IN BURKINA FASO'S SMALLER TOWNS, COUPLED WITH AN AID PROGRAMME FROM SWITZERLAND.

BURKINA FASO IS A COUNTRY UNDERGOING TRANSFORMATION FROM AN ALMOST ENTIRELY RURAL POPULATION, THROUGH RAPID URBANIZATION. THE PULL HAS NOT JUST BEEN TO ANY TOWN BUT TO THE CAPITAL OUAGADOUGOU AND TO THE SECOND CITY, AND FORMER CAPITAL, BOBO-DIOULASSO. TO STEM THE EXODUS, NOT ONLY FROM VILLAGES BUT ALSO FROM THE SMALLER TOWNS, THE GOVERNMENT LAUNCHED THE PROGRAMME DE DÉVELOPPEMENT DES VILLES MOYENNES (PROGRAMME FOR THE DEVELOPMENT OF MEDIUM-SIZED TOWNS) IN 1990. ITS AIM WAS TO STRENGTHEN THE INFRASTRUCTURE OF THOSE MID-SIZED TOWNS BY PROVIDING ELEMENTS SUCH AS MARKETS, BUS STATIONS AND SLAUGHTERHOUSES AS A BASIS FOR SUSTAINABLE DEVELOPMENT. THIS PROJECT HAS THE BACKING OF THE SWISS AGENCY FOR DEVELOPMENT AND COOPERATION (SDC).

AS THE COUNTRY'S THIRD CITY, AND SITUATED ONLY 75 KM WEST OF THE HONEYPOT OF OUAGADOUGOU, KOUDOUGOU WAS A PRIME TARGET FOR HELP. REVITALIZING AND REHOUSING THE EXISTING MARKET WAS ONE OF THE KEY PROJECTS, AND THIS HAS BEEN ACHIEVED THROUGH A LOCAL COMMITTEE, WORKING WITH SDC ARCHITECTS LAURENT SÉCHAUD AND PIERRE JÉQUIER. AS WELL AS REHOUSING THE MARKET, BY USING MUD BRICKS THE PROJECT SHOWS THAT THERE IS A FUTURE FOR THIS TRADITIONAL BUILDING MATERIAL. IT HAD BEEN LARGELY SUPERSEDED BY CONCRETE-BLOCK CONSTRUCTION, USING IMPORTED MATERIALS. SIMILARLY, STRAW ROOFS HAD BEEN REPLACED BY CORRUGATED ZINC SHEETS. THE AIM WAS TO SHOW THAT EARTH BLOCKS COULD BE USED IN SOPHISTICATED WAYS AND THAT THEY HAVE A BETTER ENVIRONMENTAL PERFORMANCE THAN CONCRETE - A REAL GAIN IN THIS HOT AND, IN THE WET SEASON, HUMID ENVIRONMENT.



SHUTTERS THAT CLOSE THE STALLS AT NIGHT ACT AS SHADINGS DURING THE DAY



THE MARKET'S VAULTED DOMES FORM A RECTANGULAR GRID



SHOPKEEPERS WANTED TO STAY ON THEIR EXISTING SITE, AND IT WAS THEREFORE NECESSARY TO MAKE THE MARKET VERY COMPACT. IN AN AREA OF JUST UNDER 80,000 M<sup>2</sup>, IT ACCOMMODATES 1155 SHOPS, 624 STALLS AND TWO ADMINISTRATIVE BUILDINGS.

THE PROJECT STARTED WITH THE BUILDING OF A PROTOTYPE SHOP TO TEST DESIGN, AND AS A RESULT SEVERAL IMPORTANT MODIFICATIONS WERE MADE. THE REAL CONSTRUCTION TOOK PLACE IN TWO PHASES. IT USED EARTH BLOCKS, CUT FROM A HILLSIDE ONLY 2 KM AWAY AND EMPLOYED IN LOAD-BEARING WALLS 29.5 CM THICK. THE BLOCKS WERE CAST IN HAND PRESSES ON SITE, AND MADE TO THE DIMENSIONS OF EITHER THE LOAD-BEARING WALLS OR NARROWER PARTITION WALLS. THE CENTRAL MARKET IS A RECTANGULAR AREA OF VAULTED DOMES, BROKEN UP BY THE OPEN AREA SURROUNDING AN OFF-CENTRE ADMINISTRATION BUILDING. THIS AREA IS SURROUNDED BY THE SHOPS, AGAIN ON A REGULAR GRID, OF DIFFERENT DIMENSIONS IN EACH DIRECTION. ON PLAN THIS COULD LOOK OPPRESSIVE, BUT IT OFFERS CLEAR VIEWS AND BREEZES. AND THERE IS A GREAT TRADITION OF BUILDING MARKETS IN THIS WAY SUCH AS THE GRAND BAZAAR IN ISTANBUL. THE ANIMATION AND VARIETY COMES FROM THE PEOPLE AND THE GOODS ON DISPLAY. THERE ARE CLEVER TOUCHES. FOR EXAMPLE, METAL SHUTTERS CLOSE DOWN THE STALLS AT NIGHT BUT WHEN OPEN ALSO ACT AS AWNINGS, PROVIDING SHADE. VAULTS WERE BUILT WITHOUT USING FORMWORK, AS TIMBER IS SCARCE IN THE COUNTRY. SIMILARLY, THERE WAS ALMOST NO TIMBER USED IN THE CONSTRUCTION. THERE IS, HOWEVER, CORRUGATED METAL ON THE ROOFS TO PROVIDE PROTECTION IN THE RAINY SEASON. BY DESIGNING A GAP BETWEEN THE DOMES AND THE METAL ROOFS OF ABOUT 35 CM, MORE AIR CAN CIRCULATE.

THIS WAS A DELIBERATELY LABOUR-INTENSIVE METHOD OF BUILDING, AND ALSO PROVIDED TRAINING. AS A RESULT OF WORKING ON THE PROJECT, 140 MASONS OBTAINED CERTIFICATION IN THE TECHNIQUES USED.

KOUDOUGO HAS ENDED UP WITH A THRIVING MARKET, IN A DIGNIFIED SPACE THAT SHOWS THE VALUE OF TRADITIONAL BUILDING TECHNIQUES AND HAS PROVIDED EMPLOYMENT AND TRAINING FOR LOCAL PEOPLE. IT IS NOT SURPRISING THAT IN 2007 THIS PROJECT, LIKE THE GANDO SCHOOL IN 2004, RECEIVED A COVETED AGA KHAN AWARD FOR ARCHITECTURE.



THE CENTRAL MARKET IS ON A REPEATING PATTERN, THE INDIVIDUALITY COMING FROM THE ANIMATION SELLERS PROVIDE



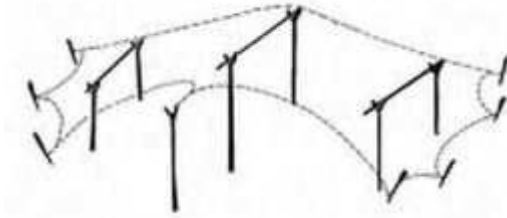
**CHAPTER 5**

**MIGRATION**



**MIGRATION**  
**NOMADIC ARCHITECTURE**

TENTS AND PAVILIONS, "THE MAGNIFICENT STRUCTURES THAT HAVE BEEN THE PRIDE OF THE MONARCHS OF WESTERN ASIA FOR THOUSANDS OF YEARS, FABRICATIONS HUGE IN SIZE, VERY COSTLY, AND EVEN IF NOT PERMANENT, OFTEN OF EXTRAORDINARY BEAUTY," HAVE NEVER BEEN SERIOUSLY CONSIDERED ARCHITECTURE BY ART HISTORIANS, COMPLAINS HISTORIAN ARTHUR UPHAM POPE. THE CHINESE PAINTING (1) MORE THAN HINTS AT THE SATISFACTORY COMBINATION OF AUSTERITY AND POMP. THE GEOMETRIC SCREENS OF SILK, SET AT RIGHT ANGLES, LEND GRANDEUR TO THE BARREN CAMPING SITE. PHOTOS (2,3), A HOLIDAY ENCAMPMENT ON THE AJDIR PLATEAU IN THE MIDDLE ATLAS. THE TENTS ARE MADE FROM BLACK GOATS' WOOL.



THE DIAGRAM OF A TENT STRUCTURE IS FROM  
J. CHAPPELLE, NOMADES NOIRS DU SAHARA



(1)



(2)



(3)

**MIGRATION**  
**MOVABLE ARCHITECTURE**

MANY SO-CALLED PRIMITIVE PEOPLES DEPLORE OUR HABIT OF MOVING (WITH ALL OUR BELONGINGS) FROM ONE HOUSE, OR APARTMENT, TO ANOTHER. MOREOVER, THE THOUGHT OF HAVING TO LIVE IN ROOMS THAT HAVE BEEN INHABITED BY STRANGERS SEEMS TO THEM AS HUMILIATING AS BUYING SECOND HAND OLD CLOTHES FOR ONE'S WARDROBE. WHEN THEY MOVE, THEY PREFER TO BUILD NEW HOUSES OR TO TAKE THEIR OLD ONES ALONG.

MOVING DAY IN GUINEA (1), AND IN VIETNAM (5). IN THE PHOTO (2), TWO DONKEYS CARRYING STRUCTURAL ELEMENTS, TO BE ASSEMBLED INTO HUTS.

RENDILLE NOMADS, KENYA.

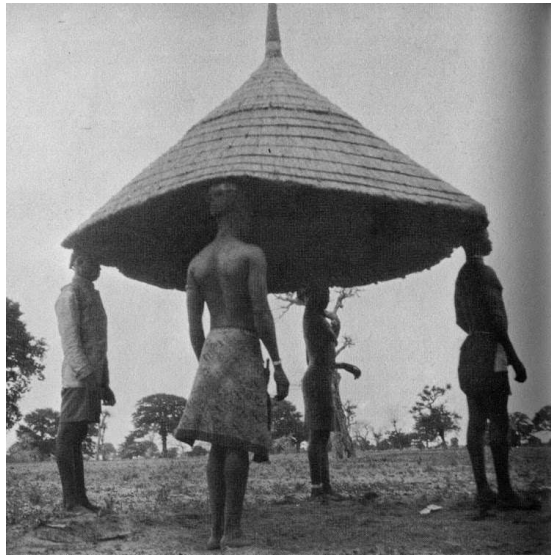
SOMETIMES THE BORDERLINE BETWEEN CLOTHES AND HABITATION BECOMES BLURRED, AS BETWEEN A RAINCOAT AND A PUP TENT. EMPTY BASKETS (3,4) MAY DOUBLE AS COVER AGAINST THE ELEMENTS, PORTABLE ROOFS BECOME UMBRELLAS, AND VICE VERSA. CHERRAPUNJI, INDIA.



(3)



(4)



(1)



(2)



(5)



**MIGRATION**  
**FORCED MIGRATION CASE STUDIES**

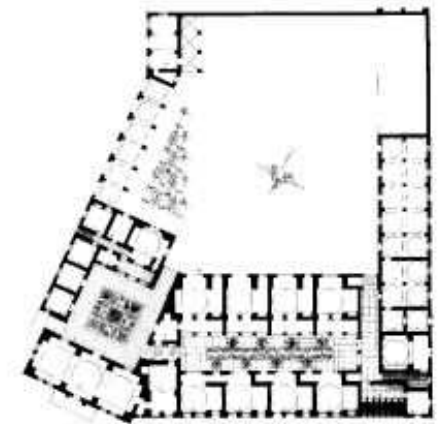
NEW GOURNA VILLAGE, LUXOR, EGYPT  
HASSAN FATHY

THE VILLAGE OF NEW GOURNA, WHICH WAS PARTIALLY BUILT BETWEEN 1945 AND 1948, IS POSSIBLY THE MOST WELL KNOWN OF ALL OF FATHY'S PROJECTS BECAUSE OF THE INTERNATIONAL POPULARITY OF HIS BOOK, "ARCHITECTURE FOR THE POOR", PUBLISHED NEARLY TWENTY YEARS AFTER THE EXPERIENCE AND CONCENTRATING PRIMARILY ON THE ULTIMATELY TRAGIC HISTORY OF THIS SINGLE VILLAGE. WHILE THE ARCHITECT'S EXPLANATIONS OFFERED IN THE BOOK ARE EXTREMELY COMPELLING AND ULTIMATELY PERSUASIVE, NEW GOURNA IS STILL MOST SIGNIFICANT FOR THE QUESTIONS IT RAISES RATHER THAN THE PROBLEMS IT TRIED TO SOLVE, AND THESE QUESTIONS STILL AWAIT A THOROUGH, OBJECTIVE ANALYSIS.

THE IDEA FOR THE VILLAGE WAS LAUNCHED BY THE EGYPTIAN DEPARTMENT OF ANTIQUITIES AS A POTENTIALLY COST-EFFECTIVE SOLUTION TO THE PROBLEM OF RELOCATING AN ENTIRE ENTRENCHED COMMUNITY OF ENTREPRENEURIAL EXCAVATORS THAT HAD ESTABLISHED ITSELF OVER THE ROYAL NECROPOLIS IN LUXOR. THE VILLAGE OF NEW GOURNA ALSO SEEMED TO OFFER FATHY A PERFECT OPPORTUNITY TO FINALLY TEST THE IDEAS UNVEILED AT MANSOURIA ON A LARGE SCALE AND TO SEE IF THEY REALLY COULD OFFER A VIABLE SOLUTION TO THE RURAL HOUSING PROBLEM IN EGYPT.



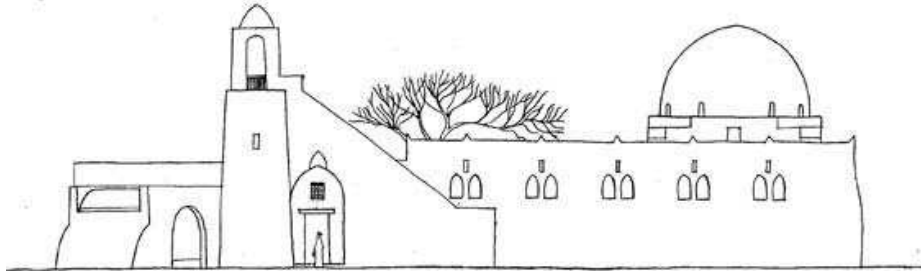
THE VILLAGE WAS MEANT TO BE A PROTOTYPE BUT RATHER THAN SUBSCRIBING TO THE CURRENT IDEA OF USING A LIMITED NUMBER OF UNIT TYPES, FATHY TOOK THE UNPRECEDENTED APPROACH OF SEEKING TO SATISFY THE INDIVIDUAL NEEDS OF EACH FAMILY IN THE DESIGN. AS HE SAID IN ARCHITECTURE FOR THE POOR, "IN NATURE, NO TWO MEN ARE ALIKE. EVEN IF THEY ARE TWINS AND PHYSICALLY IDENTICAL, THEY WILL DIFFER IN THEIR DREAMS. THE ARCHITECTURE OF THE HOUSE EMERGES FROM THE DREAM; THIS IS WHY IN VILLAGES BUILT BY THEIR INHABITANTS WE WILL FIND NO TWO HOUSES IDENTICAL. THIS VARIETY GREW NATURALLY AS MEN DESIGNED AND BUILT THEIR MANY THOUSANDS OF DWELLINGS THROUGH THE MILLENNIA. BUT WHEN THE ARCHITECT IS FACED WITH THE JOB OF DESIGNING A THOUSAND HOUSES AT ONE TIME, RATHER THAN DREAM FOR THE THOUSAND WHOM HE MUST SHELTER, HE DESIGNS ONE HOUSE AND PUTS THREE ZEROS TO ITS RIGHT, DENYING CREATIVITY TO HIMSELF AND HUMANITY TO MAN. AS IF HE WERE A PORTRAITIST WITH A THOUSAND COMMISSIONS AND PAINTED ONLY ONE PICTURE AND MADE NINE HUNDRED AND NINETY NINE PHOTOCOPIES. BUT THE ARCHITECT HAS AT HIS COMMAND THE PROSAIC STUFF OF DREAMS. HE CAN CONSIDER THE FAMILY SIZE, THE WEALTH, THE SOCIAL STATUS, THE PROFESSION, THE CLIMATE, AND AT LAST, THE HOPES AND ASPIRATIONS OF THOSE HE SHALL HOUSE. AS HE CANNOT HOLD A THOUSAND INDIVIDUALS IN HIS MIND AT ONE TIME, LET HIM BEGIN WITH THE COMPREHENSIBLE, WITH A HANDFUL OF PEOPLE OR A NATURAL GROUP OF FAMILIES WHICH WILL BRING THE DESIGN WITHIN HIS POWER. ONCE HE IS DEALING WITH A MANAGEABLE GROUP OF SAY TWENTY OR THIRTY FAMILIES, THEN THE DESIRED VARIETY WILL NATURALLY AND LOGICALLY FOLLOW IN THE HOUSING."



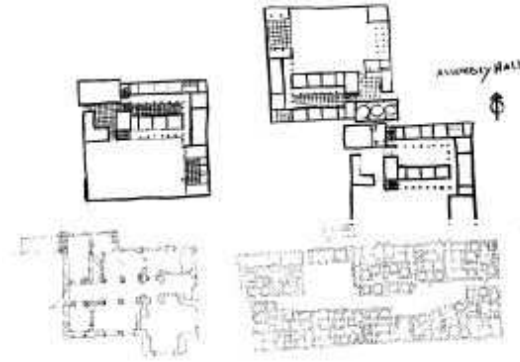


ALL OF THE ARCHITECT'S BEST INTENTIONS, HOWEVER, WERE NO MATCH FOR THE AVARICIOUSNESS OF THE GOURNIS THEMSELVES, WHO TOOK EVERY OPPORTUNITY POSSIBLE TO SABOTAGE THEIR NEW VILLAGE IN ORDER TO STAY WHERE THEY WERE AND TO CONTINUE THEIR OWN CRUDE BUT LUCRATIVE VERSION OF AMATEUR ARCHAEOLOGY. TYPICALLY BUT MISTAKENLY MISREADING THE RELUCTANCE OF THE PEOPLE TO COOPERATE IN THE DESIGN BUILDING OF THE VILLAGE AS A SURE SIGN OF THE INAPPROPRIATENESS OF BOTH PROGRAMMING AND FORM, MANY CONTEMPORARY CRITICS FAIL TO PENETRATE DEEPER INTO THE RELEVANT ISSUES RAISED BY THIS PROJECT. THESE ISSUES NOW, AS AT THE TIME OF CONSTRUCTION HALF A CENTURY AGO, REVOLVE AROUND THE EXTREMELY IMPORTANT QUESTION OF HOW TO CREATE A CULTURALLY AND ENVIRONMENTALLY VALID ARCHITECTURE THAT IS SENSITIVE TO ETHNIC AND REGIONAL TRADITIONS WITHOUT ALLOWING SUBJECTIVE VALUES AND IMAGES TO INTERVENE IN THE DESIGN PROCESS. IN THE FINAL ANALYSIS, THE PORTION OF NEW GOURNA THAT WAS COMPLETED MUST BE JUDGED ON THIS BASIS.

مسجد اوراق  
قرية الغورنا



THE VILLAGE'S MOSQUE



THE VILLAGE'S THEATRE





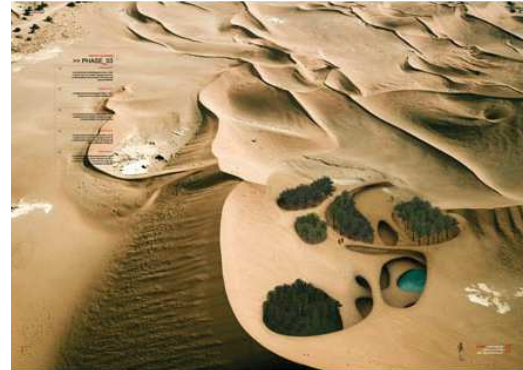
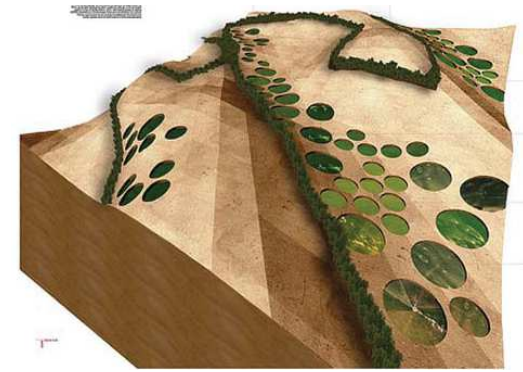
**MIGRATION**  
**FORCED MIGRATION CASE STUDIES**

DUNE, SAHEL REGION, AFRICA  
 MAGNUS LARSSON, AA THESIS 07-08

A 6000 KM LONG STRETCH OF SOLIDIFIED SAND DUNES IS PROPOSED, WHICH WILL ARCHITECTURALLY SUPPORT THE GREEN WALL SAHARA INITIATIVE: 24 AFRICAN COUNTRIES COMING TOGETHER TO PLANT A SHELTERBELT OF TREES RIGHT ACROSS THE CONTINENT, FROM MAURITANIA IN THE WEST TO DJIBOUTI IN THE EAST, IN ORDER TO MITIGATE AGAINST THE ENCROACHING DESERT.

SAND IS SOLIDIFIED INTO A HABITABLE STRUCTURE THAT PROTECTS FROM SAND; A PERMACULTURAL ANTI-DESERTIFICATION NETWORK MADE FROM THE DESERT ITSELF. A PARTICULAR MICROORGANISM, BACILLUS PASTEURII, IS FLUSHED THROUGH THE DUNESCAPE (AN ANALOGY COULD BE MADE TO AN OVERSIZED 3D PRINTER), WHICH CAUSES A BIOLOGICAL REACTION THAT TURNS THE SAND INTO SOLID SANDSTONE. THE INITIAL REACTIONS FINISH WITHIN 24 HOURS; IT WOULD TAKE ABOUT A WEEK TO SATURATE THE SAND ENOUGH TO MAKE THE STRUCTURE HABITABLE. THE BACTERIA ARE NON-PATOGENIC AND DIE IN THE PROCESS OF SOLIDIFYING THE SAND. THIS PART OF THE PROJECT RELIES UPON RESEARCH CARRIED OUT BY PROFESSOR JASON DE JONG'S TEAM AT THE SOIL INTERACTIONS LABORATORY, UC DAVIS, AS WELL AS CONVERSATIONS WITH PROFESSOR STEFANO CIURLI AT THE UNIVERSITY OF BOLOGNA.

THE ARCHITECTURAL FORM IS DERIVED FROM TAFONI, A CAVERNOUS ROCK STRUCTURE THAT FORMALLY TIES THE PROJECT BACK TO NOTIONS OF AGGREGATION AND EROSION. THESE FORMS ARE POROUS AND HAVE A LARGE SURFACE AREA. THE TEMPERATURE DIFFERENCE BETWEEN THE INTERIOR OF THE SOLIDIFIED DUNES AND THE EXTERIOR DUNE SURFACE MAKES IT POSSIBLE TO CREATE NODAL POINTS THAT COULD BOTH SUPPORT WATER HARVESTING AND INHABITABLE THERMAL COMFORT ZONES. IN THIS WAY, WE CAN START 'GROWING' CONTROLLED OASES IN THE DESERT, AND STOP THE SAND FROM PUSHING PEOPLE AWAY FROM THEIR HOMES AND VILLAGES, WHICH, IN THE WORST-CASE SCENARIO, MAY LEAD TO HUGE MIGRATION FLOODS, FOOD SHORTAGES, WARS, AND OTHER HORRIBLE SITUATIONS.



**CHAPTER 6**

**THE POSSIBLE SOLUTION**



**THE POSSIBLE SOLUTION  
A PROPOSED PROJECT**

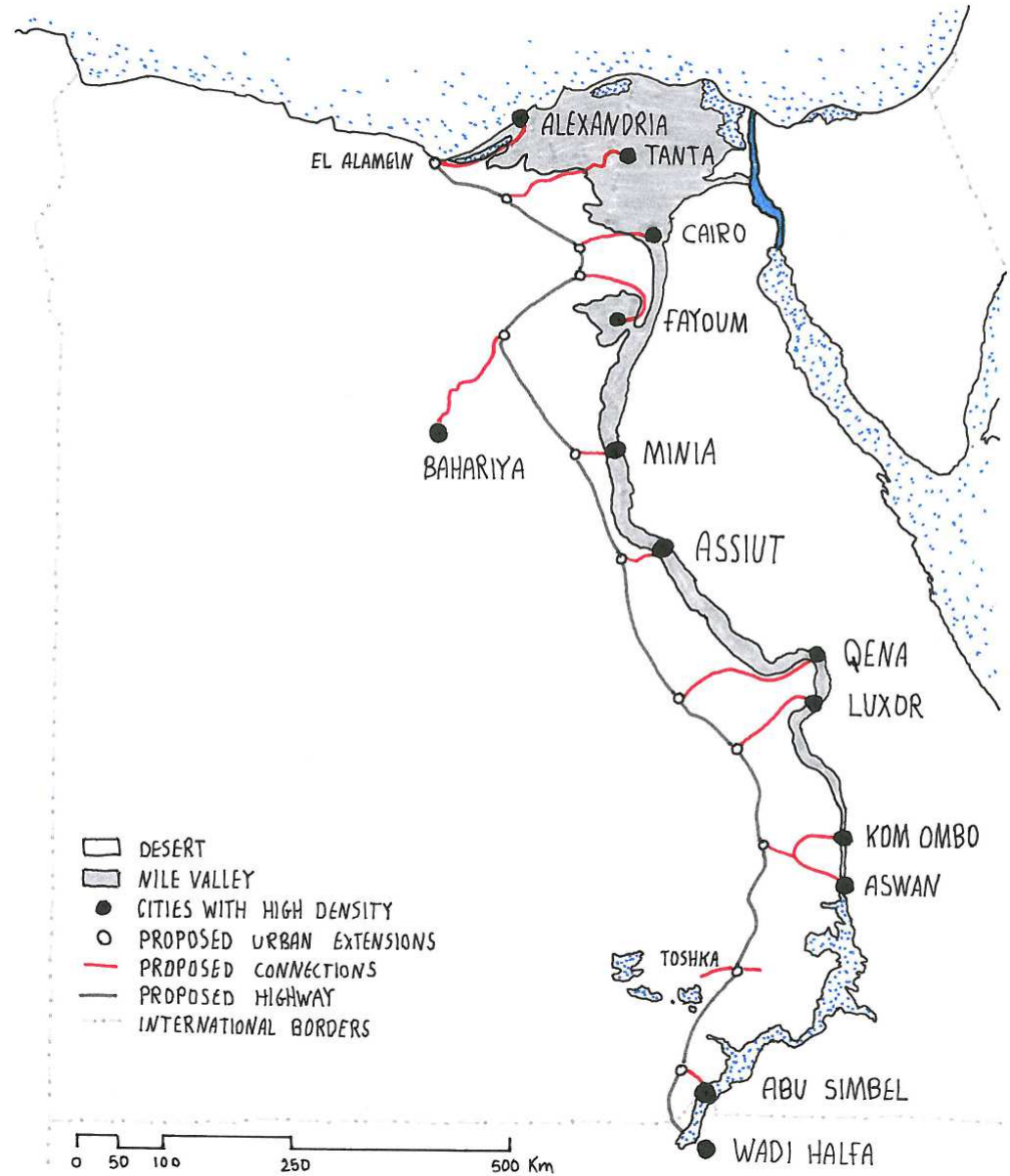
THE "DEVELOPMENT CORRIDOR" IS A PROPOSED PROJECT TO THE EGYPTIAN GOVERNMENT. A PROPOSED SUPERHIGHWAY WEST OF THE NILE FROM THE MEDITERRANEAN SEA COASTLINE TO LAKE NASSER. THE PROPOSAL WOULD PROVIDE NUMEROUS OPPORTUNITIES FOR THE DEVELOPMENT OF NEW COMMUNITIES, AGRICULTURE, INDUSTRY, TRADE AND TOURISM AROUND A 2000 KM STRIP OF THE WESTERN DESERT.

IT IS NOT POSSIBLE TO FORESEE ESTABLISHMENT OF A MODERN NETWORK OF TRANSPORTATION SYSTEMS WITHIN THE CONFINES OF THE NILE VALLEY AND ITS DELTA, BECAUSE THAT WOULD REDUCE AGRICULTURAL LAND. THE FERTILE SOIL WITHIN THE INHABITED STRIP OF EGYPT WAS DEPOSITED BY THE NILE RIVER OVER MILLIONS OF YEARS, AND IT IS IRREPLACEABLE. IN THE MEANTIME, THE GROWTH OF POPULATION NEGATES THE POTENTIAL OF CONTINUING TO LIVE ON AND UTILIZE ONLY 5% OF THE LAND AREA OF EGYPT. THUS, IT IS IMPERATIVE TO OPEN NEW VISTAS FOR EXPANSION OUTSIDE OF THE INHABITED STRIP. THIS PROPOSAL PROVIDES AN INNOVATIVE SOLUTION TO THE NUMEROUS PROBLEMS THAT FACE EGYPT TODAY.

IN ADDITION TO FACILITATING TRANSPORT THROUGHOUT EGYPT, THE PROPOSED SUPERHIGHWAY WOULD LIMIT URBAN ENCROACHMENT OVER AGRICULTURAL LAND AND OPENS MYRIAD OPPORTUNITIES FOR NEW COMMUNITIES CLOSE TO OVER-POPULATED TOWNS. IT ALSO AFFORDS UNLIMITED POTENTIAL FOR NEW SCHOOLS AND TRAINING CENTERS, INDUSTRIAL ZONES, TRADE CENTRES, TOURISM; PROVIDING VIRGIN TERRITORY FOR DEVELOPMENT INITIATIVES IN EVERY FIELD. THIS IN ITSELF GIVES HOPE TO THE NEW GENERATIONS OF EGYPTIANS FOR A BETTER FUTURE. IT REPRESENTS THE BEST POSSIBLE USE OF ONE OF EGYPT'S NATURAL RESOURCES -- THE STRIP OF THE WESTERN DESERT THAT PARALLELS THE NILE AND IS CLOSE TO ITS HIGH-DENSITY POPULATION CENTERS. THIS PARTICULAR STRIP OF LAND WAS CHOSEN BECAUSE OF ITS UNIQUE NATURAL CHARACTERISTICS. IT IS BASICALLY FLAT WITH A GENTLE NORTHWARD SLOPE FROM WEST OF ASWAN TO THE COAST OF THE MEDITERRANEAN SEA; THE LACK OF TOPOGRAPHIC PROMINENCES MAKES IT EASY TO PAVE. THIS STRIP IS ALSO DEVOID OF EAST-WEST CROSSING VALLEYS THAT ARE PRONE TO FLASHFLOODS AS IN THE CASE OF THE EASTERN DESERT. IT PASSES CLOSE TO VAST TRACTS OF FERTILE SOILS THAT ARE AMENABLE TO RECLAMATION; MOST OF SUCH REGIONS HAVE POTENTIAL FOR GROUNDWATER RESOURCES. THE STRIP IS ALSO COMPARATIVELY FREE OF SANDY AREAS; IT IS NOT CROSSED BY LINES OF SHIFTING DUNES AS IN THE CASE OF REGIONS FARTHER TO THE WEST. FURTHERMORE, THE REGION IS ENDOWED WITH PLENTIFUL SUNLIGHT AND PERSISTENT NORTHERLY WIND. THESE CONDITIONS ALLOW THE USE OF RENEWABLE SOLAR AND WIND ENERGY IN THE FUTURE.

BASED ON THE ABOVE, THE PROPOSED PROJECT INCLUDES THE ESTABLISHMENT OF THE FOLLOWING:

1. A SUPERHIGHWAY TO BE BUILT USING THE HIGHEST INTERNATIONAL STANDARDS, 1200 KM IN LENGTH, FROM WEST OF ALEXANDRIA TO THE SOUTHERN BORDER OF EGYPT.
2. 12 EAST-WEST BRANCHES, WITH THE TOTAL LENGTH OF APPROXIMATELY 800 KM, TO CONNECT THE HIGHWAY TO HIGH-DENSITY POPULATION CENTERS ALONG THE WAY.
3. A RAILROAD FOR FAST TRANSPORT PARALLEL TO THE SUPERHIGHWAY.
4. A WATER PIPELINE FROM THE TOSHA CANAL TO SUPPLY FRESHWATER.
5. AN ELECTRICITY LINE TO SUPPLY ENERGY DURING THE EARLY PHASES OF DEVELOPMENT.

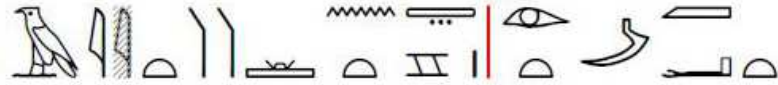


**THE POSSIBLE SOLUTION  
 THESIS PROPOSAL**

THE INFRASTRUCTURE OF THE DENSE CITIES SURROUNDING THE SAHARA DESERT IN NORTHERN AFRICA IS MOSTLY OLD AND RUNDOWN, AND THE GROWTH RATE IS RELATIVELY HIGH - ESPECIALLY IN THE NILE VALLEY, IN ADDITION TO THE FLOODING THREATS FOR THE COASTAL CITIES. THE THESIS PROPOSES MOVING TO THE SAHARA DESERT -INSTEAD OF CROSSING THE MEDITERRANEAN- AND CREATE NEW PEASANT COMMUNITIES.

EVERY MAN HAS THE RIGHT TO HAVE A PLOT OF LAND TO BUILD HIS OWN HOUSE AND IMPLANT HIS FOOD AND USE THE RESOURCES OF THIS LAND TO REALIZE THIS, SO HE CAN BE INDEPENDENT WITHOUT ASKING A GOVERNMENT OR RISK HIS LIFE SEARCHING FOR A JOB OVERSEAS. JUSTICE IS DISTRIBUTING THE LAND FOR THE PEOPLE TO LIVE, EAT, WORK AND PRODUCE.

THE THESIS IS PROPOSING CONCEPTS, STRATEGIES AND GUIDELINES FOR THE USAGE OF THE LOCAL RESOURCES OF THE SAHARA DESERT TO CREATE NEW PEASANT COMMUNITIES FOR IMPLANTING THE LAND WITHIN A PROPER ECOLOGY SYSTEM TO PRODUCE FOOD FOR THEMSELVES AND ALSO FOR THEIR PEOPLE, THIS WILL REALIZE THE DREAM OF FOOD INDEPENDENCY OF THE REGION. SHOWING THE POSSIBILITY OF THE REALIZATION THROUGH A TIMELINE. THE THESIS ALSO PROPOSES LAND USE, LANDSCAPE, URBAN AND ENVIRONMENTAL STRATEGIES FOR THE NEW PEASANT COMMUNITIES THAT WILL BE CREATED IN THE SAHARA DESERT. FINALLY SOME ARCHITECTURAL MODELS ARE DESIGNED SHOWING THE DIFFERENT BUILDING MATERIALS AND TECHNIQUES FOR THE NEW SAHARA PEASANT COMMUNITIES, AND AN IMAGINARY MASTERPLAN.



To straighten out the land | is to do justice.

THE ELOQUENT PEASANT'  
 \*A TEXT FROM THE CLASSIC PERIOD OF ANCIENT EGYPTIAN LITERATURE



EL-FALLAH EL-FASIH', SHADI ABDEL SALAM, 1970  
 \*FILM: "THE ELOQUENT PEASANT"



AL-MOHAGER', YOUSSEF CHAHINE, 1994  
 \*FILM: "THE EMIGRANT"



LATCHO DROM', TONY GATLIF, 1993  
 \*FILM



LA SOURCE DES FEMMES', RADU MIHAILEANU, 2011  
 \*FILM: "THE SOURCE"



**CHAPTER 7**

**EXPERIMENTAL PROPOSALS**

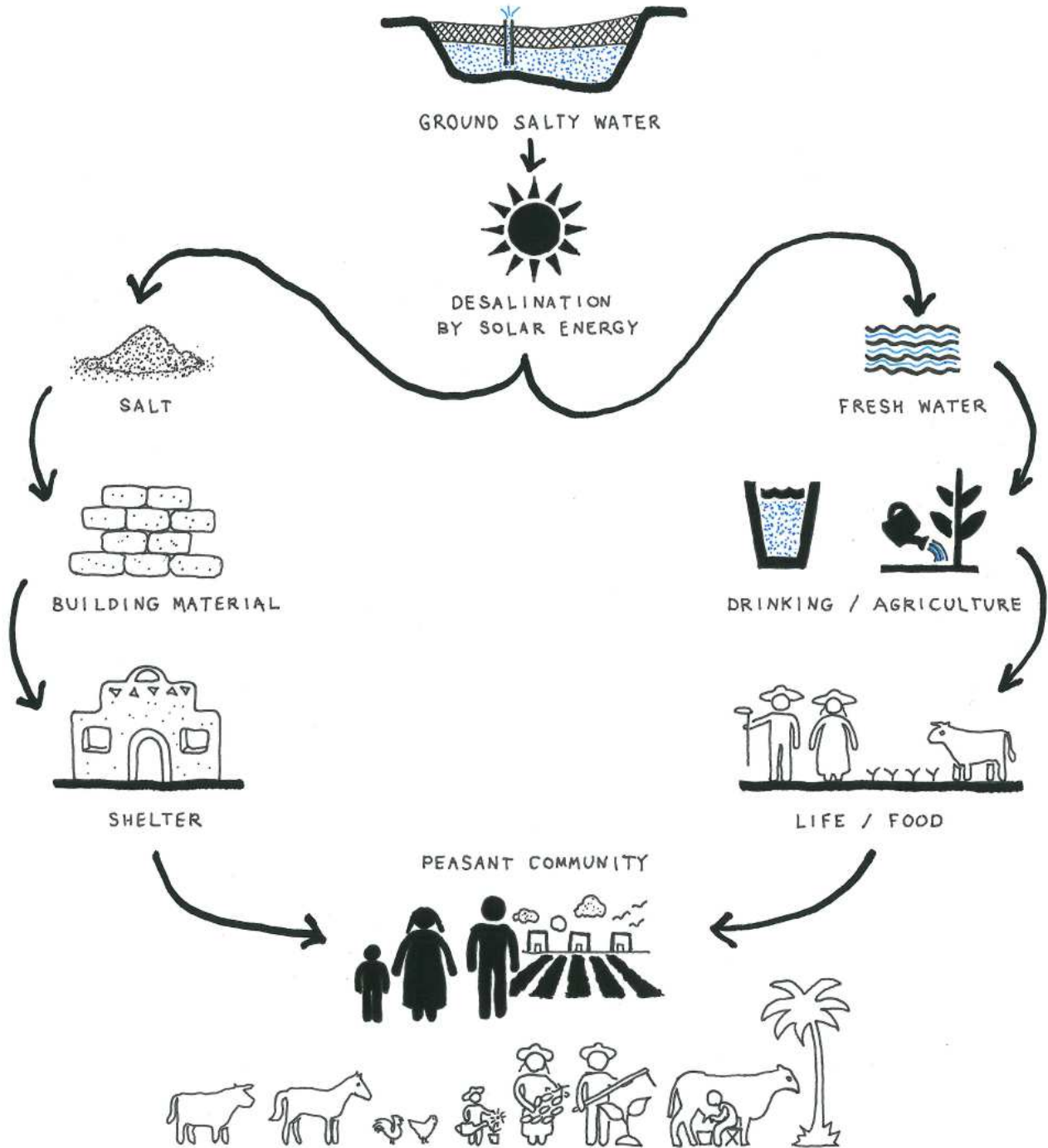
**EXPERIMENTAL PROPOSALS  
RESOURCES USAGE CONCEPT**

THE SECOND CHAPTER IS DESCRIBING THE SAHARA DESERT IN DETAIL, TWO MAIN NATURAL RESOURCES THAT HAVE HIGH POTENTIAL FOR DEVELOPMENT WERE HIGHLIGHTED AMONG THE OTHER RESOURCES; WHICH ARE GROUND WATER AND SUN LIGHT. WHEREVER THE GROUND WATER IS FOUND AND EXTRACTED, LIFE AND CREATING NEW COMMUNITIES COULD BE POSSIBLE, ONLY IF THE WATER IS FRESH AND FREE OF SALT. MOST PROBABLY THE GROUND WATER IN THE SAHARA DESERT IS SALTY WATER! THE WATER WILL BE DESALINATED BY SOLAR ENERGY WHICH IS GAINED FROM THE SUNLIGHT.

THE IDEA IS TO DESALINATE THE SALTY WATER USING SOLAR ENERGY, SO THE SALT IS SEPARATED FROM THE WATER. THE SALT WILL BE USED AS A MAIN BUILDING MATERIAL ALONG WITH THE EARTH TO BUILD HOUSES. AS FOR THE FRESH WATER, IT WILL BE USED FOR DRINKING AND ALSO FOR IMPLANTING THE LAND. IN THIS CASE OF AGRICULTURE AND BUILDING HOUSES IN PARALLEL, LIFE COULD BE POSSIBLE FOR ANIMAL MIGRATION AND PEOPLE TO MOVE FROM THEIR DENSE CITIES TO THE SAHARA AND CREATE NEW PEASANT COMMUNITIES, AND PRODUCE THEIR OWN FOOD. IN THIS CASE THE DREAM OF FOOD INDEPENDENCY WILL BE REALIZED.



PEASANT COMMUNITY



CONCEPT

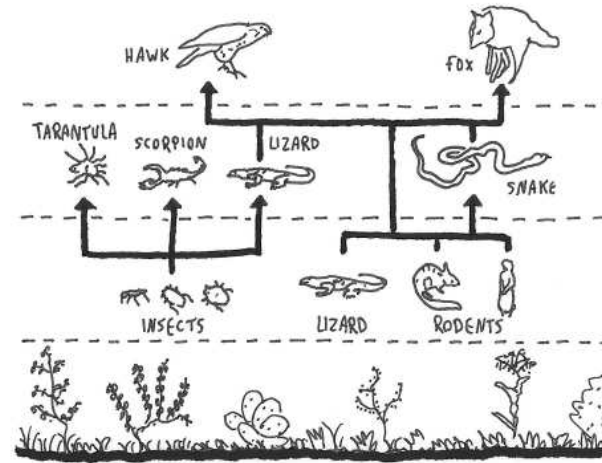


**EXPERIMENTAL PROPOSALS**  
**ECOLOGY SYSTEM**

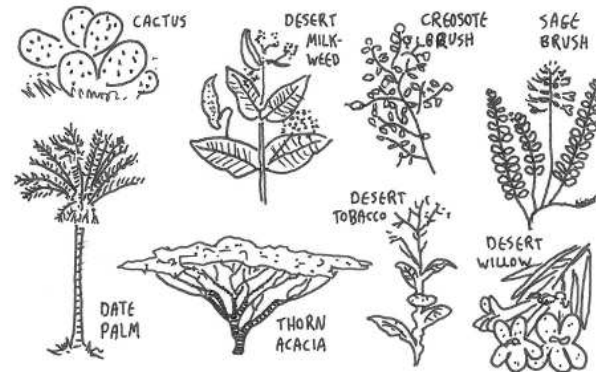
IN THE BELOW DIAGRAM: MAJOR FEEDBACK LINKAGES IN LANDSCAPE DEVELOPMENT. LARGE ARROWS INDICATE PREDOMINANT CONTROLS OR EFFECTS. EACH LOOP WHERE ONE FACTOR AFFECTS A SECOND, AND THE SECOND AFFECTS THE FIRST, IS A FEEDBACK LOOP. NOTE THE PREDOMINANT CONTROL BY CLIMATE, AND THE NATURE OF THE LINKAGE AMONG ANIMALS, VEGETATION, AND SOIL.

FOOD AND WEB CHAIN: THE SAHARA DESERT FOOD CHAIN BEGINS WITH THE PLANTS. IN SPITE OF THE EXTREME HEAT AND LESS RAINFALL THERE ARE MANY ALIVE PLANTS AND ANIMALS. THE PLANTS ARE CALLED PRODUCERS AS THEY DO PHOTOSYNTHESIS AND THUS PREPARE FOOD. IN THE SAHARA DESERT FOOD CHAIN THE NEXT LEVEL ARE THE HERBIVORES WHICH EAT ONLY PLANTS. THE PLANTS ARE EATEN BY PRIMARY CONSUMERS CALLED HERBIVORES. SOME ANIMALS EAT BOTH PLANTS AND ANIMALS. THESE ARE CALLED OMNIVORES. SOME ARE CALLED SCAVENGERS AS THEY FEED ON DEAD ANIMALS. FINALLY THERE ARE DECOMPOSERS LIKE DESERT MUSHROOMS AND BACTERIA AND WORMS WHICH DECOMPOSE THE DEAD ANIMALS AND THEIR EXCRETA AND RETURN MINERALS TO THE SOIL SO PLANTS CAN GROW.

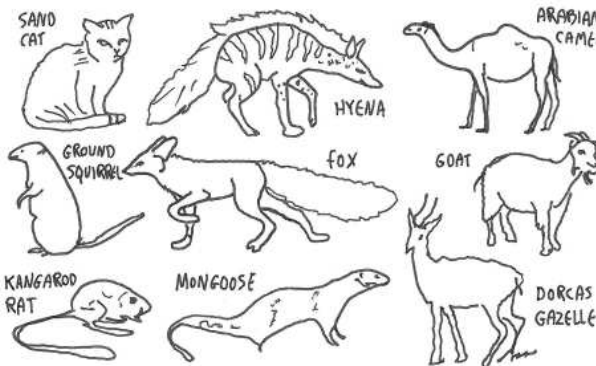
OTHER ANIMALS ARE INVITED TO MIGRATE TO HELP IN THE AGRICULTURAL WORK, AND TO JOIN THIS ECOSYSTEM.



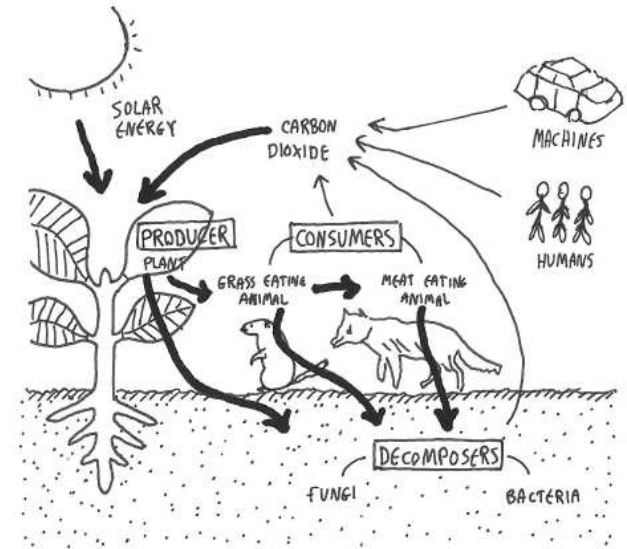
SAHARA FOOD WEB



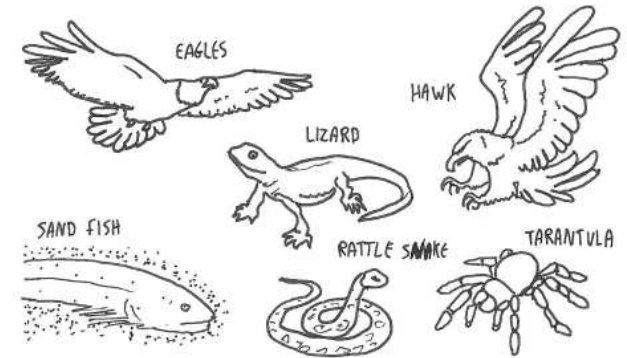
EXISTING VEGETATION



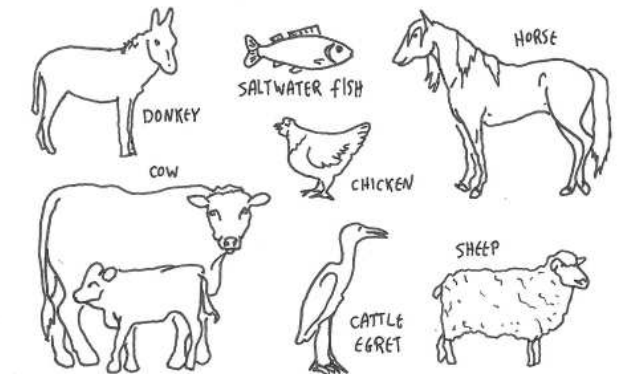
EXISTING ANIMALS



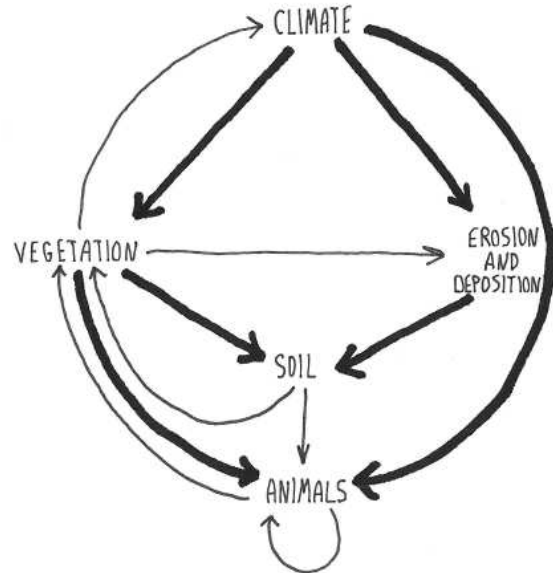
SAHARA ECOSYSTEM



EXISTING ARACHNIDS / REPTILES / BIRDS



ANIMALS INVITED TO MIGRATE

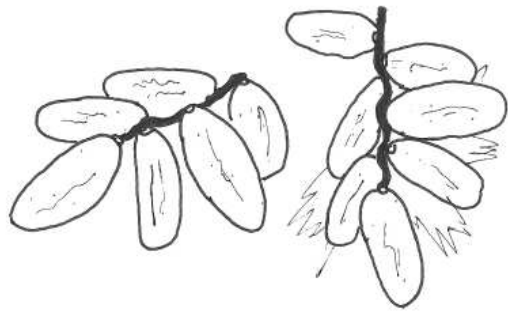


LINKAGES IN LANDSCAPE DEVELOPMENT

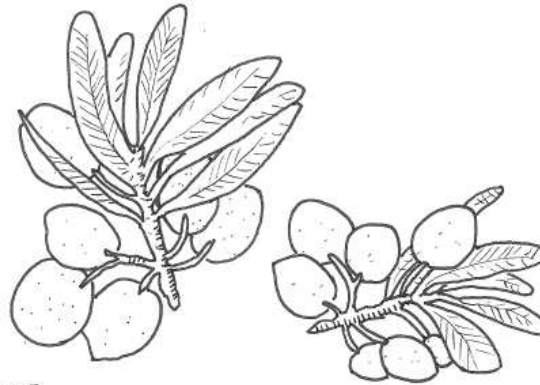
**EXPERIMENTAL PROPOSALS**

**FOOD PRODUCTION**

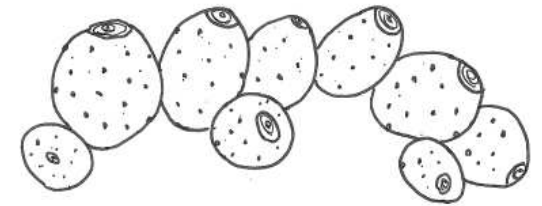
- DATE PALM
- OLIVE
- OLIVE OIL
- CACTUS FRUIT
- MELON
- ARGAN FRUIT
- ARGAN OIL



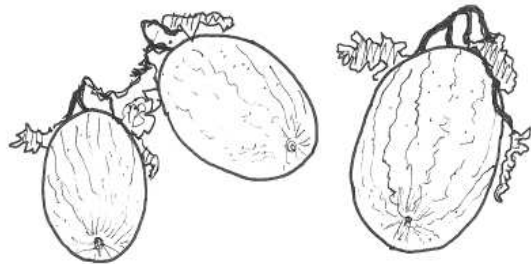
DATE PALM



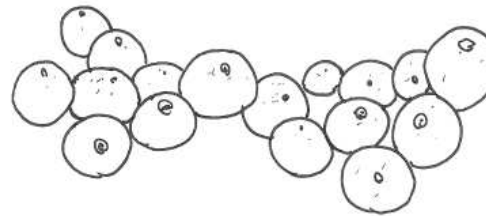
OLIVE



CACTUS FRUIT



MELON



ARGAN FRUIT



ARGAN OIL



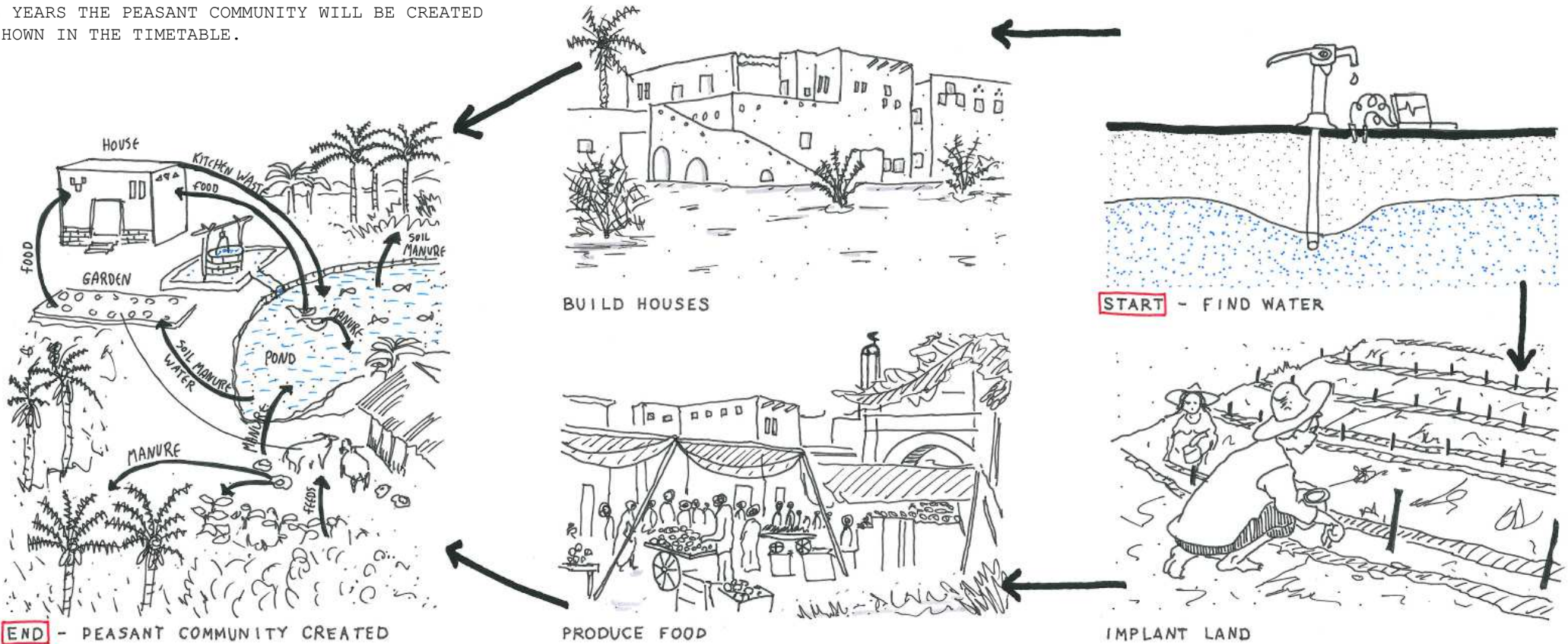
**EXPERIMENTAL PROPOSALS  
TIMELINE//STOREYBOARD**

**STEPS:**

- FIND WATER AND SET LOCATION • START WITH 20 MEN TO BUILD 50 TEMPORARY SANDBAG SHELTERS FOR THEMSELVES AND OTHER 30 FARMERS/WORKERS TO MOVE TO THE SITE • MEANWHILE DESALINATE THE WATER THROUGH SOLAR ENERGY TO FRESH WATER SEPARATED FROM SALT
- USE THE FRESH WATER TO IMPLANT THE FIRST HECTARE OF THE LAND • USE THE SALT ALONG WITH EARTH TO BUILD THE FIRST 20 HOUSES • FAMILIES OF THE FARMERS/WORKERS START TO MOVE TO THE NEW HOUSES
- MEANWHILE ELECTRICITY IS GENERATED THROUGH SOLAR ENERGY • 50 MORE WORKERS/FARMERS ARRIVE • BUILD MORE 30 EARTH HOUSES + IMPLANT 2 MORE HECTARES
- BUILD THE MARKET • FAMILIES OF THE FARMERS/WORKERS START TO MOVE TO THE NEW HOUSES • START TO SELL THE AGRICULTURAL PRODUCTS IN THE MARKET • USE THE INCOME OF THE AGRICULTURAL PRODUCTS TO BUILD THE SCHOOL • IMPLANT MORE LAND + BUILD MORE HOUSES + MORE WORKERS TO MOVE WITH THEIR FAMILIES
- IN FIVE YEARS THE PEASANT COMMUNITY WILL BE CREATED AS SHOWN IN THE TIMETABLE.

YEAR	TIME	NUMBER OF WORKERS ARRIVING	AGRICULTURE	PALM TREES	BUILDING	ACTIVITY	RESOURCE /FUND
1ST YEAR	3 MONTHS	20	LAND PREPARATION		50 TEMPORARY SANDBAG SHELTERS	DESALINATION	SOLAR ENERGY
	9 MONTHS	30	1 HECTARE	50	20 HOUSES		
2ND YEAR	1 YEAR	50	2 HECTARES	50	30 HOUSES + MARKET	ELECTRICITY GENERATION	SOLAR ENERGY + PRODUCTS INCOME
3RD YEAR	1 YEAR	50	7 HECTARES	100	50 HOUSES + SCHOOL	SELLING PRODUCTS	
4TH YEAR	1 YEAR	100	10 HECTARES	300	130 HOUSES + HOSPITAL	SCHOOL OPENING	
5TH YEAR	1 YEAR	150	50 HECTARES	500	170 HOUSES + CULTURE CENTRE		
TOTAL	5 YEARS	400 FAMILIES	70 HECTARES	1000 PALM TREES	400 HOUSES + SERVICES		SELF-SUFFICIENCY

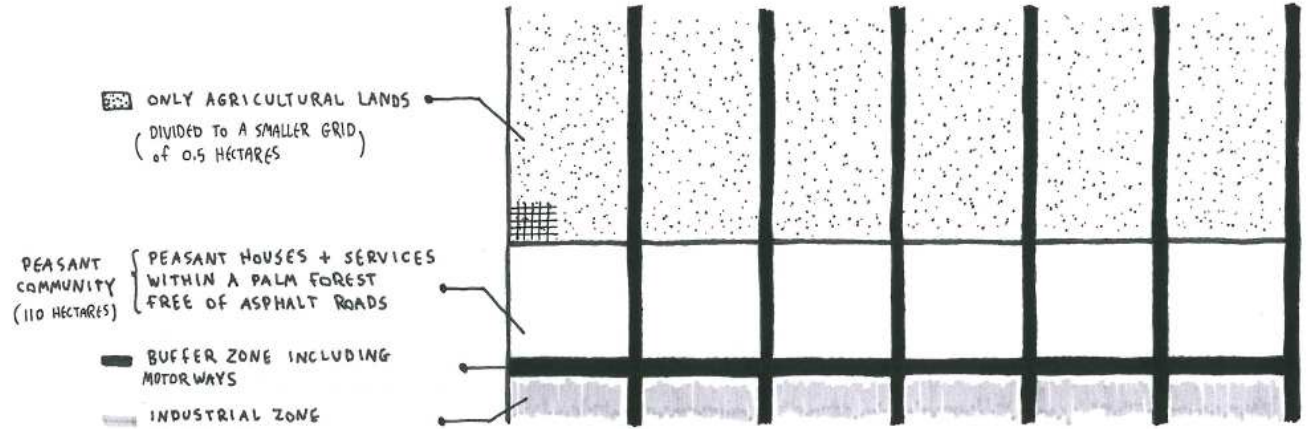
**TIMETABLE**





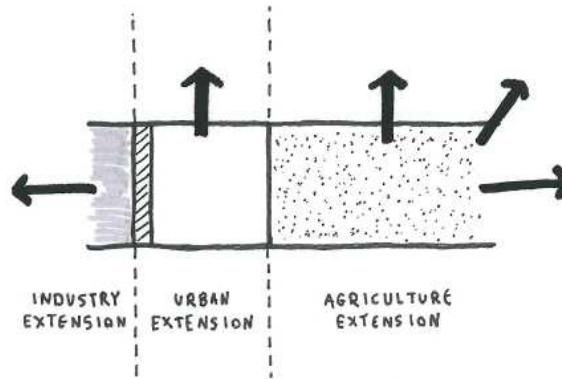
**EXPERIMENTAL PROPOSALS  
LAND USE STRATEGIES AND GUIDELINES**

- THE LAND WILL BE USED FOR AGRICULTURE AND HOUSING, IS DIVIDED AS FOLLOWS: 1) AGRICULTURAL LANDS EASILY ACCESSIBLE FROM THE PEASANT COMMUNITY. 2) PEASANT COMMUNITY CONSISTS OF PEASANT HOUSES AND SERVICES WITHIN A PALM-TREE FOREST. THE PEASANT COMMUNITY IS FREE OF ASPHALT. 3) BUFFER ZONE INCLUDING MOTOR ROADS SEPARATING THE PEASANT COMMUNITY FROM AN INDUSTRIAL ZONE
- LAND AREAS: 1) AGRICULTURAL LANDS ARE DIVIDED TO PLOTS OF 0.5 HECTARES. 2) ONE PEASANT COMMUNITY IS ABOUT 110 HECTARES.
- IN ONE PEASANT COMMUNITY THE RATIO BETWEEN BUILDINGS AND VEGETATION IS 1:5 (ABOUT 20% BUILDING).

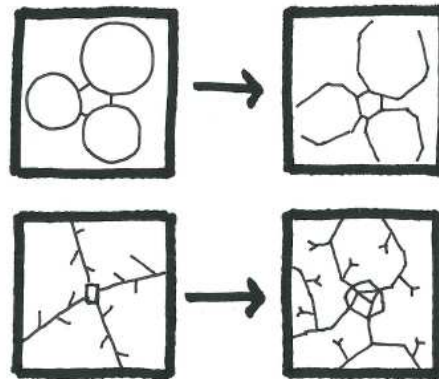


\* GRID SHAPE DEPENDS ON THE TOPOGRAPHY AND LOCATION OF THE PLACE. IT IS ASSUMED AS SQUARE

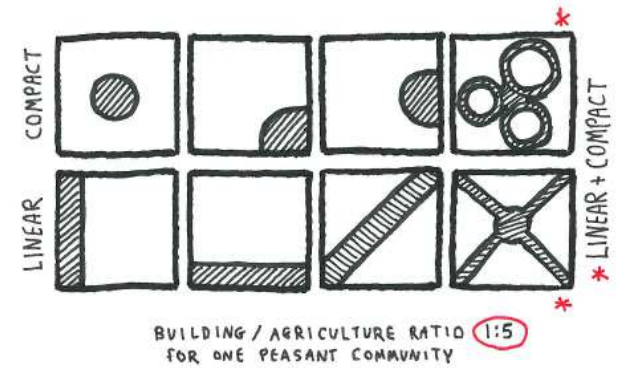
**GRID**



**FUTURE EXTENSION**

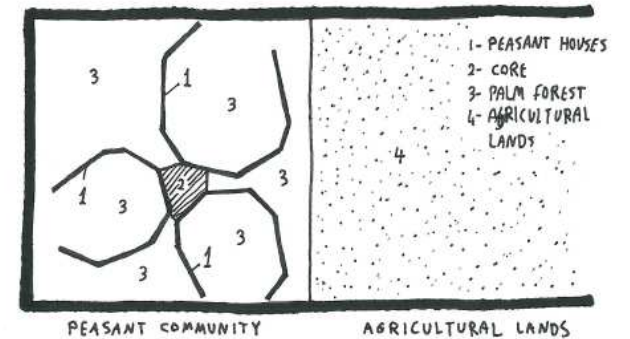


**GEOMETRY**

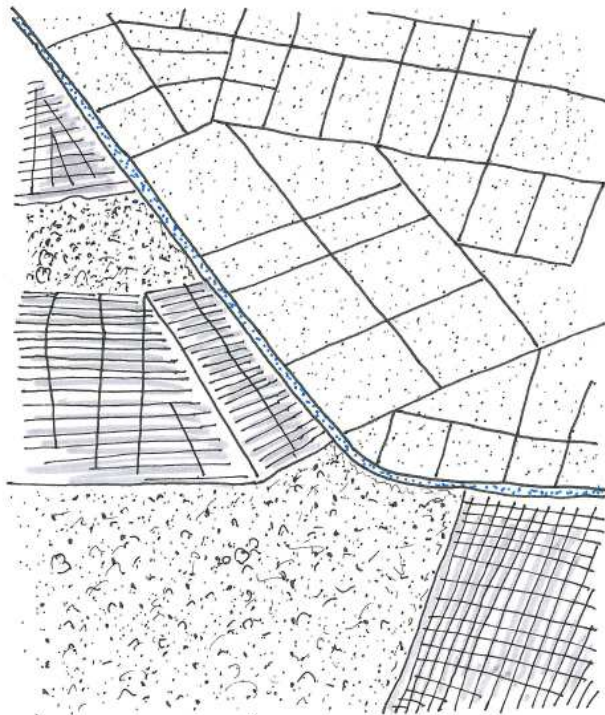


BUILDING / AGRICULTURE RATIO 1:5 FOR ONE PEASANT COMMUNITY

**RATIO/DISTRIBUTION**



**FUNCTIONS**



**IMAGINARY PERSPECTIVE**



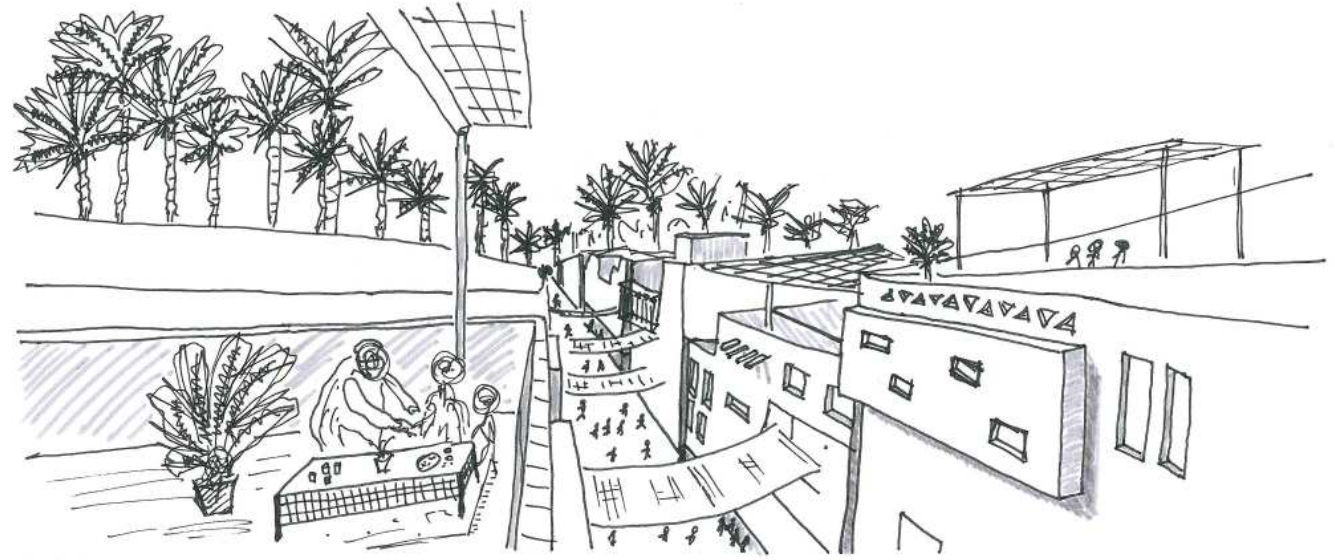
**EXPERIMENTAL PROPOSALS**  
**URBAN//ENVIRONMENTAL STRATEGIES AND GUIDELINES**

FOR PEASANT COMMUNITY

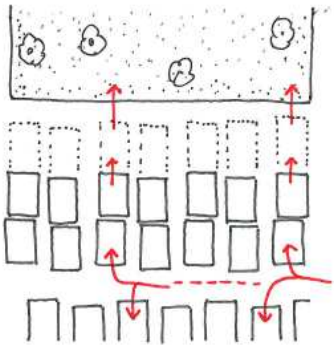


MORPHOLOGY

- DENSE SETTLEMENTS TO PRODUCE AN URBAN COOL ISLAND EFFECT
- LINEAR HOUSES FOR DIRECT ACCESS OF EACH FARMER TO AGRICULTURAL LANDS
- MAIN STREET 14M  
SIDE STREET 5M



PERSPECTIVE



DIRECT ACCESS TO  
AGRICULTURAL LANDS

↑

ANIMALS PLACE

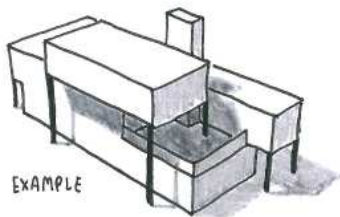
↑

HOUSE

↑

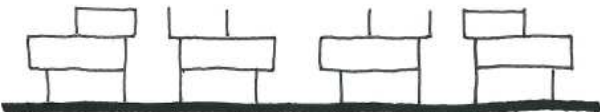
MAIN STREET

ACCESS STRATEGY

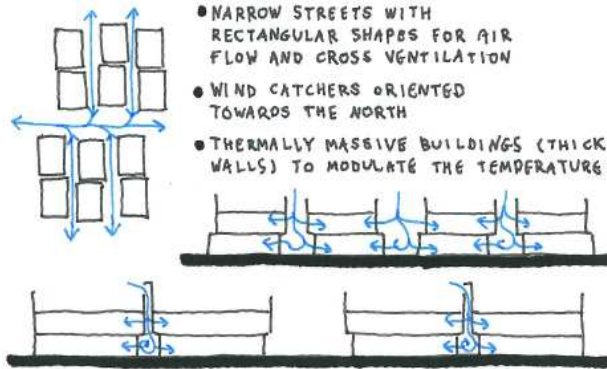


EXAMPLE

- RECESSED FORMS
- RECTANGULAR SHAPES
- MAXIMUM 2 STOREYS HOUSES

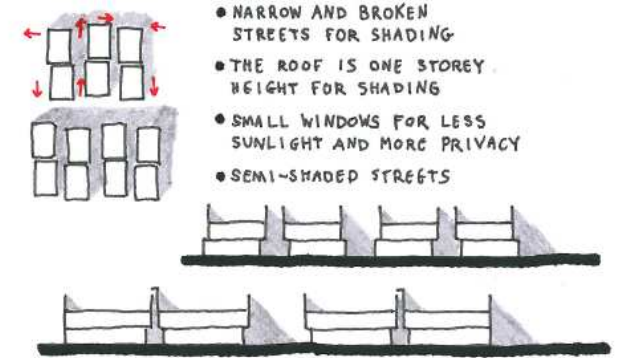


TYPOLOGY



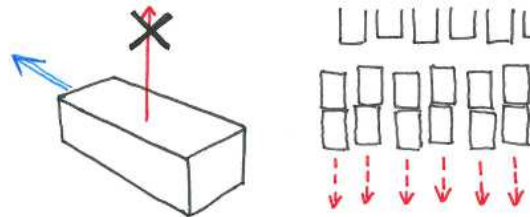
VENTILATION STRATEGY

- NARROW STREETS WITH RECTANGULAR SHAPES FOR AIR FLOW AND CROSS VENTILATION
- WIND CATCHERS ORIENTED TOWARDS THE NORTH
- THERMALLY MASSIVE BUILDINGS (THICK WALLS) TO MODULATE THE TEMPERATURE



SHADING STRATEGY

- NARROW AND BROKEN STREETS FOR SHADING
- THE ROOF IS ONE STOREY HEIGHT FOR SHADING
- SMALL WINDOWS FOR LESS SUNLIGHT AND MORE PRIVACY
- SEMI-SHADED STREETS



NO VERTICAL  
EXTENSION

HORIZONTAL  
FAMILY EXTENSION

FUTURE EXTENSION

- LOW SHRUBS PERMIT MORE AIR FLOW
- SHRUBS ARE ADJACENT TO THE BUILDING TO PRODUCE TURBULENCE BETWEEN THE SHRUBS AND THE BUILDING



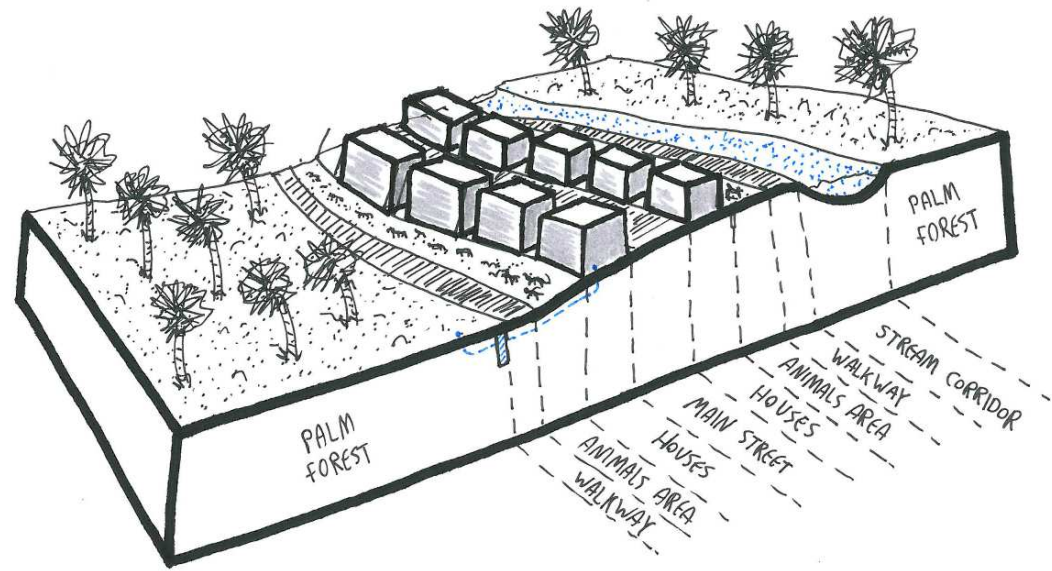
VEGETATION STRATEGY



**EXPERIMENTAL PROPOSALS  
LANDSCAPE INFRASTRUCTURE**

FOR PEASANT COMMUNITY

- THE SEMI-SHADED STREETS ARE ASPHALT FREE, IS MADE FROM RAMMED EARTH. THE STREETS INCLUDE PATHS FOR BICYCLES, ANIMALS, AND PEDESTRIAN PATHS.
- OPEN AND PUBLIC SPACES ARE ALSO ASPHALT FREE, IN THE CENTER OF THE PEASANT COMMUNITY. LIGHT STRUCTURES ARE MADE OF SOLIDIFIED SAND.
- THE PALM FOREST SURROUNDS THE URBAN AREA OF THE PEASANT HOUSES AND SERVICES.
- STREAM CORRIDORS AND WATER SOURCES ARE PRESENT FOR BOTH LAND IRRIGATION AND FOR HOUSING UTILITIES.



PEASANT COMMUNITY WITHIN THE PALM FOREST



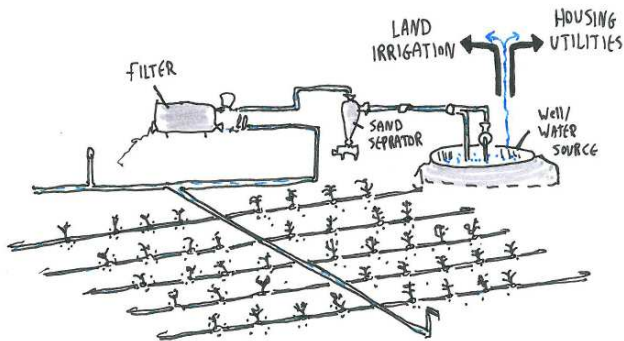
DATE PALM FOREST



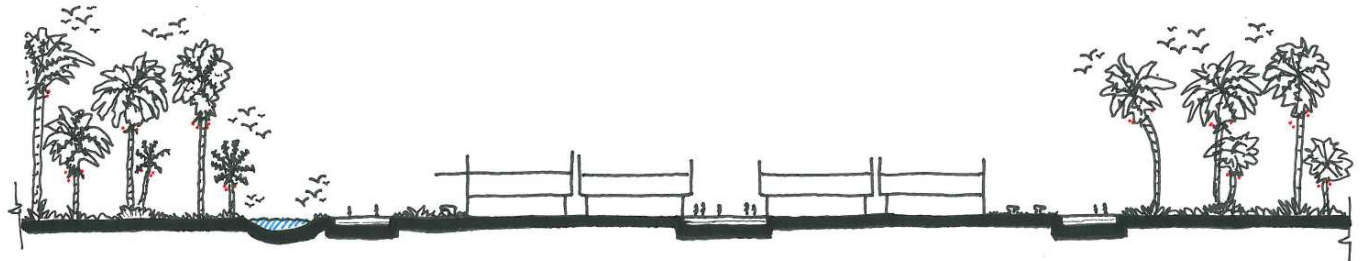
OPEN SPACES



SEMI-SHADED STREETS



IRRIGATION SYSTEM



SECTION 1:1000



**EXPERIMENTAL PROPOSALS  
ARCHITECTURAL PROPOSALS**

FOR PEASANT COMMUNITY

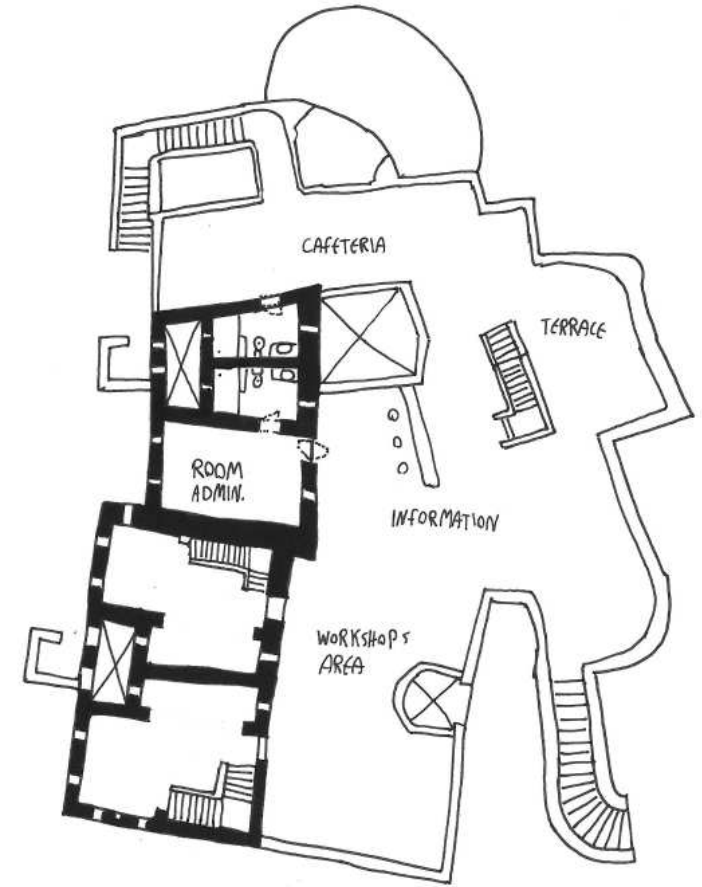
BUILDING FUNCTION:  
VISITOR CENTRE

BUILDING MATERIALS:  
SALT AND EARTH FOR WALLS  
PALM STEMS FOR STRUCTURE AND CEILINGS

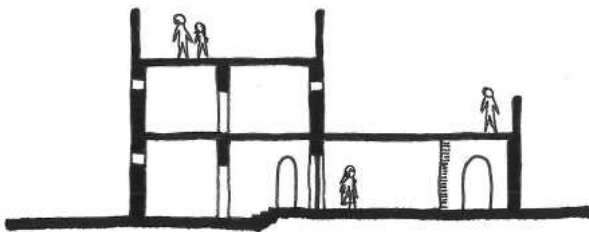
BUILDING TECHNIQUE:  
EARTHEN BLOCKS



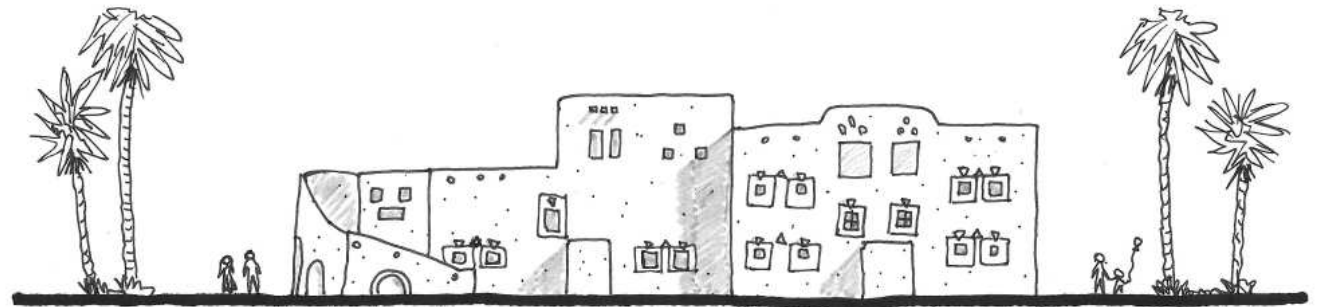
GROUND FLOOR PLAN 1:250



FIRST FLOOR PLAN 1:250



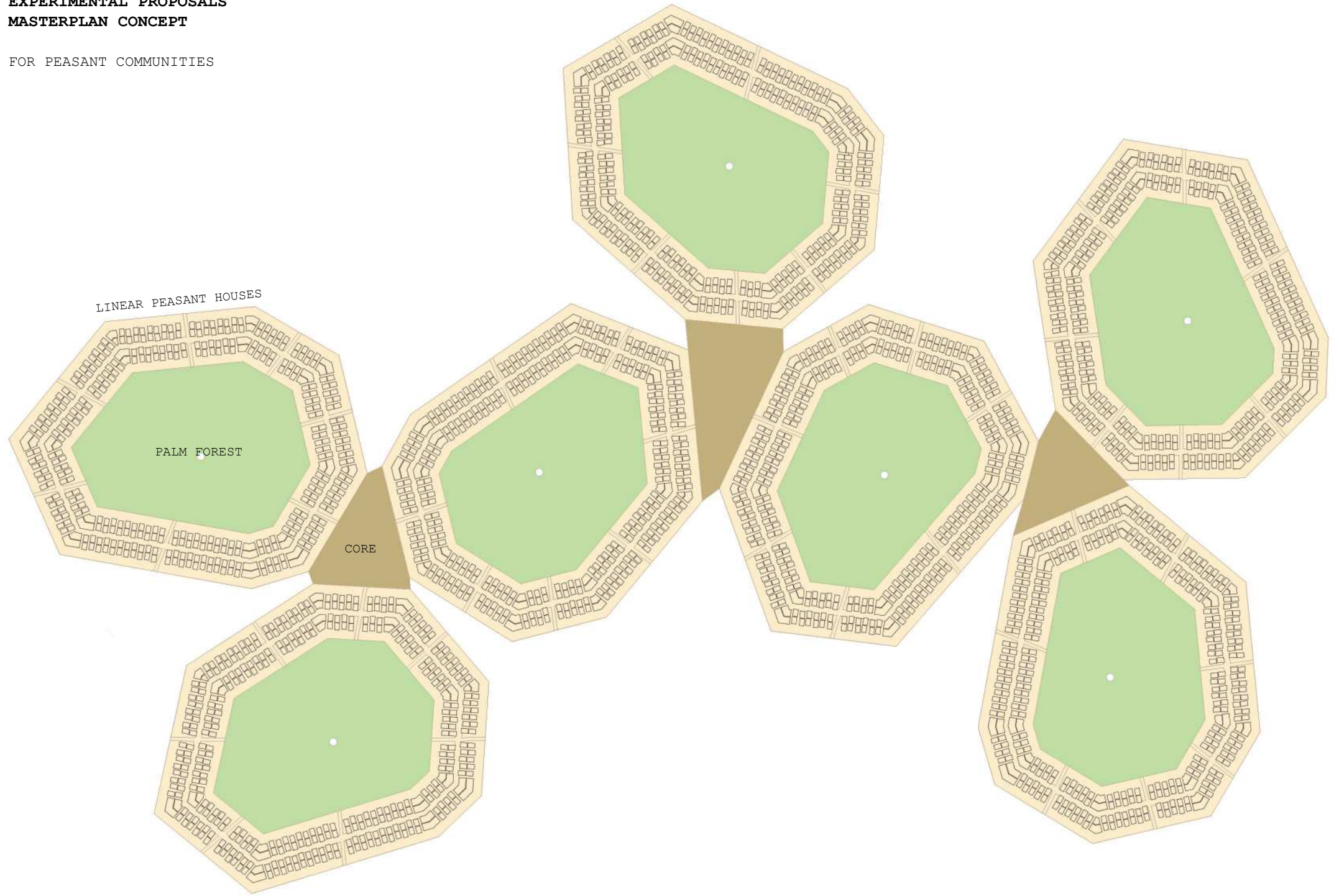
SECTION (A-A) 1:250



ELEVATION 1:250

**EXPERIMENTAL PROPOSALS  
MASTERPLAN CONCEPT**

FOR PEASANT COMMUNITIES



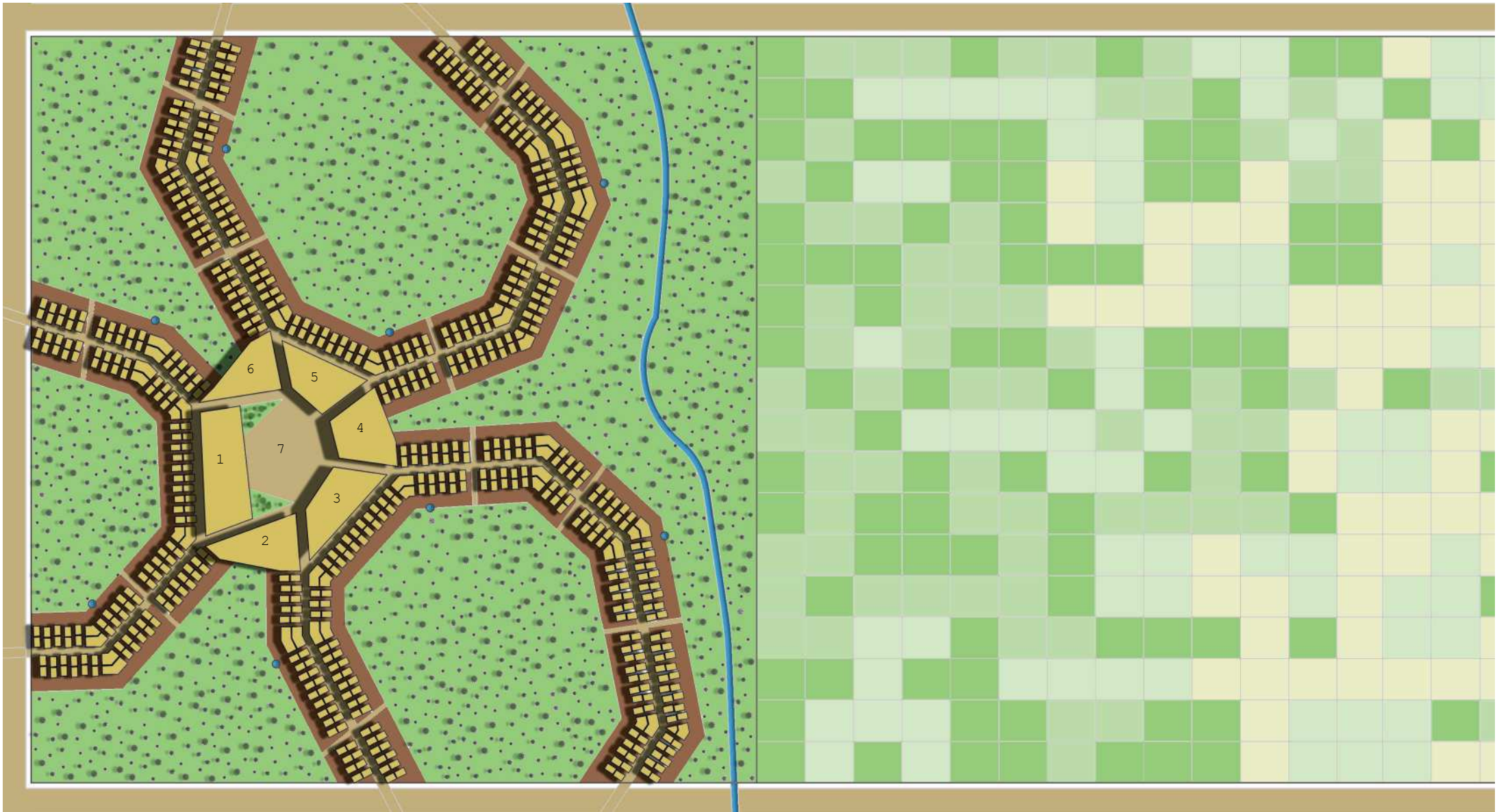
SCALE 1:10000



**EXPERIMENTAL PROPOSALS**  
**IMAGINARY MASTERPLAN**

FOR PEASANT COMMUNITY

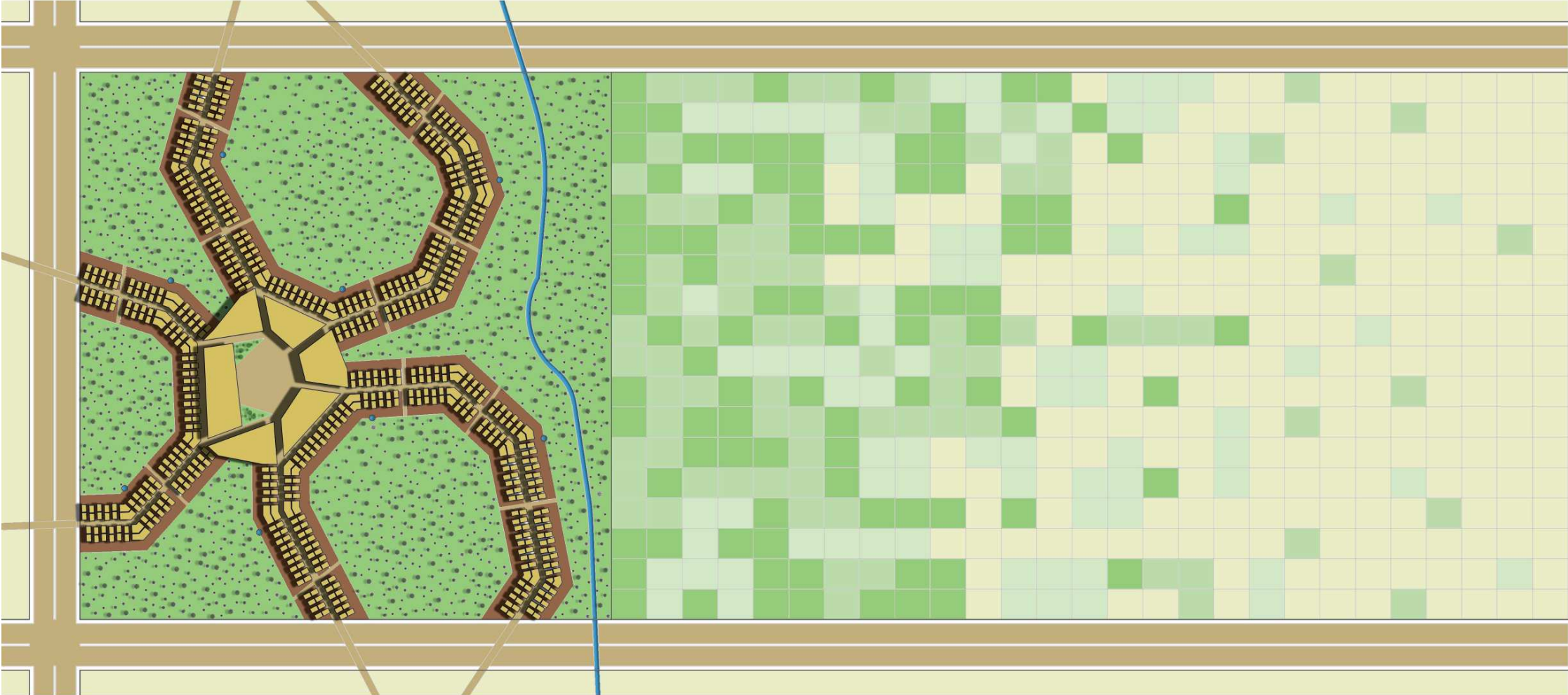
FUNCTIONS: 2- MARKET 4- CULTURAL CENTRE 6- VISITOR CENTRE  
1- SCHOOL 3- HOSPITAL 5- CRAFT WORKSHOPS 7- PLAZA



MASTERPLAN SCALE 1:7500

**EXPERIMENTAL PROPOSALS**  
**IMAGINARY MASTERPLAN**

FOR PEASANT COMMUNITY



MASTERPLAN SCALE 1:10000



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